

EVIDENCE-INFORMED CLINICAL GUIDELINES FOR NURSING
CARE PRACTICES RELATED TO THE SAFETY OF THE
MECHANICALLY VENTILATED PATIENT

BY

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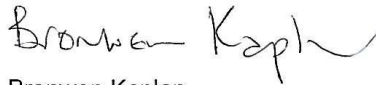
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To Whom It May Concern

EVIDENCE-INFORMED CLINICAL GUIDELINES FOR NURSING-CARE
PRACTICES RELATED TO THE SAFETY OF THE MECHANICALLY VENTILATED
PATIENT

This letter serves as certification that Mrs Portia Jordan employed me to edit the above-titled thesis, which I have done. Please note that the final responsibility for the content resides with Mrs Jordan.

Yours sincerely



Bronwen Kaplan

DEDICATION

I dedicate this study to my two wonderful children

Gabriella Cassandra Jordan

&

Joshua Romano Jordan

Dare to be what you ought to be

Dare to be what you dream to be

Dare to be the finest you can be

Tap the untapped, release the reservoir within you
and become the best you can be!

Secondly, I dedicate this study to

**all the intubated, mechanically ventilated patients in the critical
care units.**

May your psychological, emotional and physical safety, needs and preferences be
the core business of every professional nurse who cares for you while entrusted to
their care!

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“Belief at the beginning of any successful undertaking is the one ingredient that will ensure success.” Williams James

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Furthermore, I would like to acknowledge and thank the professional nurses in the critical care units in the Nelson Mandela Metropole that participated in this study. Thank you to Prof Patricia McInerney who assisted in understanding the complexity of the systematic review. The completion of the final evidence-informed clinical guidelines would not have been possible without the assistance of the expert review panel that comprise Prof Annali Botha, Dr Lizette van der Merwe, Dr Blaine Robson, Dr Guy Reed, Ms Janice Venter, Mr Xavier Demingo, Ms Jeanelle Loock, Ms Page Armstrong and Ms Janine Love.

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ABSTRACT

An evidence-based approach to clinical practice aims to deliver appropriate care in an efficient manner to individual patients. This approach entails the integration of research evidence, clinical expertise and the interpretation of patients' needs and perspectives in making decisions about the best care modalities. The increased emphasis internationally on improved patient care and cost effectiveness in health care delivery highlighted the need for quality health services that have to be built upon the use of best evidence to inform practice and patient-care decision-making (McKenna, Ashton and Keeney, 2004:178).

Critical care nursing science, a specialised branch of nursing, focusing on the care of the critically ill patient in a designated unit, is no exception to the drive to provide improved quality and cost-effective patient care. Critical care practitioners are seen to have a specialised knowledge base, specific skills in delivering advanced health care and a commitment to serve the critically ill patient. It is expected of them to be aware of new and emerging evidence about health disease processes, treatment modalities and technology used in the critical-care units. Due to the dynamic nature of a critical care unit, it is essential that every practitioner working in the unit, whether a novice professional nurse or senior unit manager, needs to be aware of the current evidence guiding their practices (Elliot, Aitken, Chaboyer, 2007:18). With reference to the critically ill patient who is connected to a mechanical ventilator, practices related to the nursing care of this group of patients, who mostly occupy the critical care units, should be based on the best evidence in order to provide cost-effective and quality care.

The research study aimed to explore and describe four identified nursing care practices related to safety of a mechanically ventilated patient as performed by professional nurses in the critical care units in the Nelson Mandela Metropole. The identified nursing-care practices include: endotracheal tube placement verification, endotracheal tube cuff pressure monitoring, endotracheal tube suctioning and mechanical ventilator settings. This objective was operationalized in Stage One of the study, by using a quantitative, explorative, descriptive and contextual approach.

A structured questionnaire was utilised to collect data from professional nurses working in critical care units. From the analysed data, it was decided to select the two nursing care practices that were done least according to the best recommended practice, namely endotracheal tube suctioning and endotracheal tube cuff pressure monitoring. Based on the results, systematic reviews were done respectively on the two nursing care practices.

On completion of Stage One of the study, evidence-informed clinical guidelines for the two identified nursing care practices were developed. The clinical guidelines were based on the evidence found in conducting the systematic reviews. The draft clinical guidelines were reviewed by an expert panel. Feedback from the reviewers was considered to prepare the final evidence-informed clinical guidelines. Based on the clinical guidelines, two clinical algorithms were developed, which might be used at the patient's bedside and can assist in quick dissemination of the recommendations for practice.

Ethical considerations were maintained throughout the study. The quality of the study was ensured in applying the principles of validity and reliability as well as performing a critical appraisal of all data collected during the systematic review. It is envisaged that the study findings be disseminated in the critical care units in the Nelson Mandela Metropole and published in peer reviewed journals.

Keywords

- Evidence-informed nursing
- Critical care nursing
- Mechanical ventilation
- Endotracheal tube suctioning
- Endotracheal tube cuff pressures
- Nursing care practices
- Clinical guidelines

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OVERVIEW OF THE STUDY

1

“The beginning of wisdom is found in doubting; by doubting we come to the question and by seeking we may come upon the truth.” Pierre Abelar

Welcome to this journey!

IN THIS CHAPTER

The aim of this chapter is to orientate the reader to the study in terms of the background of evidence-based medicine and how it evolved to evidence-informed decision-making, the critical care unit and mechanical ventilation. An overview of the research questions, objectives, research design and method will be given. Furthermore, the Joanna Briggs Institute’s model for the study’s theoretical framework will be discussed. Quality measures and ethical considerations are briefly introduced in this chapter and will be comprehensively discussed in Chapter 3.

1.1 INTRODUCTION

For over half a century, positive-pressure mechanical ventilation has saved countless lives and is the second most frequently performed therapeutic intervention after treating cardiac arrhythmias in critical care units. In a study done in critical care units in North America, South America, Spain and Portugal, it was found that 75% of patients admitted to these units required intubation and mechanical ventilation (Estaban, Anzueto, Alia, Gordo, Apezteguia, Palizas, Cide, Goldwaser, Soto, Buggedo, Rodrigo, Pimental, Raimondi and Tobin, 2000:1452). However, mechanical ventilation is not without complications as it might cause extensive physiological and psychological effects in the critically ill patient. Fenstermacher and Hong (2004:258) state that mechanical ventilation is a procedure that is associated with a greater than 30% in-hospital mortality rate. Apart from the high mortality rate, several other mechanisms of injuries and complications can occur in mechanically ventilated patients such as airway damage, tracheal stenosis, volutrauma, atelectrauma and decreased cardiac output, just to name a few (Hamed, Ibrahim, Khater and Aziz, 2006:78). It is thus important that nursing care practices, based on the best available

evidence, be implemented to reduce the risk of adverse events, mortality and complications related to mechanical ventilation in order to optimize patient safety in critical care units.

The significant variations in health care practices and the lack of implementing best care practices might be leading causes of inadequate patient care, increased health care costs and an increased risk of adverse effects to patients. The incorporation of quality improvement tools, such as evidence-informed clinical guidelines, have shown to reduce practice variations and improve the use of best practices, thus improving the processes of and outcomes for patient care (Carnett, 2002:60). Evidence-informed clinical guidelines are systematic, developed statements that are based on the best available evidence in order to inform clinical decision-making (Swinglehurst, 2005:308).

The focus of this research study will be to develop evidence-informed clinical guidelines for two nursing practices related to the safety and optimal management of patients connected to mechanical ventilators in critical care units. However, one has to be *au fait* with the principles and development of the concepts of evidence-based practice and evidence-informed care before concentrating on the critical care unit and the mechanically ventilated patient.

Over the past 15 years, developments in health care in most westernised countries have been influenced by a desire to contain costs and increase health care effectiveness. The introduction of the concept, “best practice”, relates closely to the focuses on cost effectiveness and improved quality patient care and, increasingly, is being linked to the need to base nursing care practices on the best available evidence. Worldwide, the increased emphasis on improved patient care and cost effectiveness in health care has highlighted the need for quality health services that are using best evidence to inform practice and patient care decision-making (McKenna, Ashton and Keeney, 2004:178).

As a point of departure, it is essential to describe the origin and development of care based on the best evidence. The promotion of evidence-based practice stems from

the work of A.L. Cochrane in the year 1979 when he drew attention to the lack of information about the effects of health care. However, the development of evidence-based medicine has been rapid since its emergence in the early 1990s and has primarily been led by Professor David Sackett of the University of Oxford. Evidence-based medicine has been defined by Sackett, Rosenberg, Muir Gray, Haynes and Richardson (1996:71) as the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients. Since the initial definition by Sackett *et al* (1996:71) many other definitions have been formulated. Sackett, Richardson, Richardson, Rosenberg and Haynes (2000:10) acknowledged the need to take account of patient values in defining evidence-based practice, thus stating that it is integrating the use of current best evidence and patient's preference in making clinical decisions. According to Thompson, Cullum, McCaughan, Sheldon and Raynor (2004:68), evidence-based practice involves combining knowledge arising from one's clinical expertise, patient preferences and research evidence. Nolan (2005:1274) argues that evidence-based practice should include the experiences and expertise of patients, in addition to those of professionals, and best available research. Rauen, Chulay, Bridges, Volman and Arbour (2008:98) define evidence-based practice as the integration of best research, clinical expertise and patient values or preferences in making decisions about the care of individualized patients. Reviewing the different definitions, one can conclude that practising evidence-based medicine must consider the use of current best evidence, based on research, the experiences and preferences of the patient as well as the knowledge, experience or expertise of professionals in making clinical decisions. The evidence-based approach to medicine draws on activities of numerous specialist groups from across the world, linked together to form the Cochrane Collaboration.

Secondly, it is important to understand how evidence-based nursing evolved. Although evidence-based practice began with medicine, it did not stop there as the allied health professions have systematically embraced evidence-based practice. Emerging as an offshoot of the evidence-based medicine movement, evidence-based nursing developed. Closs and Cheater (1999:11) define evidence-based nursing as nursing care based on the best available evidence, which directs the nurse to what the most successful and cost-effective approaches to patient care are.

In practising evidence-based nursing, nurse practitioners are in a position to provide the best possible care, based on the latest evidence, at the least possible cost, in an environment of limited resources. According to Mullhall (1998:969), evidence-based nursing is defined as the incorporation of evidence from research and clinical practice plus patient preferences in clinical decision-making. Ingersoll (2000:152) applied the definition of evidence-based medicine to evidence-based nursing by stating that it is the conscientious, explicit and judicious use of theory-derived, research-based information in making decisions about patient care delivery. Evidence-based nursing practice is further defined by Meijel, Gamel, Swieten-Duijfjes and Grypdonck (2004:85) as the use of empirical research findings to achieve greater reliability in successfully achieving the desired results of the intervention for clinical decision-making in patient care. Derived from these combined definitions, evidence-based nursing can be defined as rendering nursing care to patients, which is based on the best available evidence from research and clinical expertise, as well as a consideration of a patient's preferences in order to provide the most cost-effective care.

The three key components common to evidence-based medicine as well as to evidence-based nursing are thus: best research evidence, clinical expertise and patient preference. What do these terms mean?

Best research evidence refers to methodological, sound and clinically relevant research about the effectiveness and safety of nursing interventions, the accuracy and precision of assessment measures, the power of prognostic markers, the cost-effectiveness of interventions, in this case nursing interventions, and the meaning of illnesses or patient experiences. Clinical expertise refers to a practitioner's ability to first use clinical skills and past experiences to identify the health state of patients or populations, their risks, their preferences and actions and the potential benefits of interventions. Secondly, to communicate this information to patients and their families and to provide them with an environment they find comforting and supportive. Patient preferences refer to the relative value that patients place on varying health states (Di Censo, Guyatt and Ciliska, 2005:6-7).

Thirdly, we need to understand that although the principles of evidence-based medicine, as highlighted by Sackett *et al* (1996:71), extend to the allied professions, nursing science has gone beyond the primary concepts of evidence-based medicine and evidence-based nursing. Nursing science aims to create the concept of evidence-informed nursing involving interventions that draw on a wide range of research-based evidence. Evidence-informed nursing or evidence-informed decision-making means integrating the various types of evidence in making a clinical decision and this has led to its preference over the traditional evidence-based medicine approach. Winch, Henderson and Creedy (2005:22) state that evidence-informed nursing involves making decisions related to patient care by using the relevant evidence. According to McSherry, Simmons and Abbott (2002:1), nurses must be competent, active and autonomous in providing care to their patients. The term, nurses, which in this study refer to professional nurses, must also be able to justify what they do. It is no longer acceptable for them to base care on ritual and tradition. They must be able to justify the decisions they have made about appropriate care and treatment on the basis of professional expertise, which includes using evidence, not necessarily research, to inform practice. Evidence-informed care has to form the basis for justifying nursing care practices (Adam and Osborne, 2005:512). Evidence-informed practices can be utilised across the various branches of nursing science, namely primary health care, mental-health nursing, midwifery, operating theatres and critical care nursing. For the purpose of this research study, the focus will be on critical care nursing.

Fourthly, given the fundamental place of evidence in this form of clinical decision-making, the question of what constitutes appropriate evidence on which to base practice becomes important. The term “evidence” refers to data or information used to describe whether or not a claim or view should be trusted. Whenever health care professionals engage in practice, they are expected to make numerous clinical decisions. In making such decisions, the practitioners draw on a wide range of knowledge: of basic biological and behavioural sciences, the health professional’s assessment of the current context of the individual patient, their own experiences and current understanding of research reports they may have recently read. All of the knowledge that is used to make a clinical decision on patient care can be

referred to as evidence – and the validity of this evidence may be variable (Meijel *et al*, 2004:86).

Fifthly, it is important to consider the significance of evidence-informed practices in a critical care unit. Nursing is described as an art and science, directed at providing a human health care service, which is based on scientific principles. Nursing is concerned with solicitous care, where the care of people entrusted to the health care practitioners forms the fundamental aspect of this clinical human science. Critical care nurses find themselves in a unique situation. They have their feet deeply rooted in the caring art of nursing, yet their hands and minds reach for the scientific basis that the highly technical, physiological and pharmacological speciality requires (Rauen *et al*, 2008:98).

Critical care nursing science is a specialised branch of nursing focusing on the care of the critically ill patient in a designated unit. Within the critical care unit, care is provided to patients with life-threatening illnesses or injuries. Critical care nursing is a dynamic discipline, undergoing various challenges daily, and is linked to a specialised field of knowledge, advanced clinical skills and an immense amount of technology utilised in the care of the critically ill patient. Critical care nurse practitioners are seen to have a specialised knowledge base, specific clinical skills in delivering health care, a commitment to care for the critically ill patient, and a commitment to be aware of new and emerging evidence about health, disease processes, treatment modalities and technology used in the critical care units. Decision-making abilities are crucial for any practitioner rendering care to the critically ill patient. However, these decisions have to be sound, valid and reliable but, more importantly, have to be based on the best available evidence. Due to the extent and dynamics of a critical care unit, every nurse practitioner working in the unit, whether as a novice professional nurse or senior unit manager, needs to be aware of the current evidence guiding their practices (Elliot *et al*, 2007:18).

Furthermore, the critical care environment is one that is specifically staffed and equipped for continuous monitoring, observation and care of individuals with a critical illness (Elliot *et al*, 2007:129). The dynamic changes in the health care delivery

landscape, especially in the 21st century, will impact on critical care nursing, as some of the greatest changes predicted will be related to it. The technology of the 21st century will allow nurses to detect physiological changes earlier and to confront problems proactively. Non-invasive technology will become standard for many of the new diagnostic and monitoring devices. On-line analysis of electrocardiogram changes, non-invasive cardiac output monitoring, non-invasive ventilator strategies and patient-based, bedside, clinical information systems are mere examples of emerging technology that will offer unique opportunities to monitor patients in several categories. In order to keep abreast of the developments and emerging technology in critical care units, nurse practitioners need continually to update their knowledge and practices based on the best current available evidence (Elliot *et al*, 2007:47).

Admissions to the critical care environment can include any disease or condition ranging from post-operative surgical patients, those with medication conditions, polytrauma patients and many more. However, respiratory insufficiency is one of the main reasons, either as a potential or actual problem, for admission to critical care units worldwide, contributing to approximately 25% of annual admissions (Vincent, Akca and De Mendonca, 2002:1602). Patients admitted to the critical care unit with respiratory failure, or who require respiratory support, are routinely connected to a mechanical ventilator as a form of treatment. Mechanical ventilation implies that the patient is assisted by means of the use of an artificial airway connected to a mechanical ventilator to assist with the patient's breathing (Urden, Lough and Stacy, 2006:678). Considering the mortality rate, adverse effects and complications linked to mechanical ventilation as a treatment modality, the care of the mechanically ventilated patient is a fundamental component of a nurse's clinical practice in a critical care unit. It is, thus, essential that nursing care of the mechanically ventilated patient be underpinned by evidence and performed according to the best recommended practices.

Finally, it is known that evidence-based care has extended its roots to evidence-informed care to guide our clinical practice in nursing. The crucial question yet remains: Once evidence is found, how is it transferred into practice? Worldwide, various governments have introduced initiatives to support the development of

evidence-based health care systems in which decisions made by health care practitioners, managers, policy makers and patients are based on high-quality evidence. One of the initiatives includes the development of clinical guidelines, based on evidence, for an improvement in the quality of care received by patients. Practical application of rigorously reviewed evidence is thus promoted through the development and dissemination of clinical guidelines in most developed health care systems (Thompson and Dowding, 2002:149).

National clinical guidelines interpreted and implemented locally are sometimes referred to as protocols (Thompson and Dowding, 2002:149). Clinical guidelines and protocols are intended to provide information based on appraisal of the current best evidence. According to Hewitt-Taylor (2004(b):46), clinical guidelines aim to improve the quality of care received by patients and act as a mechanism for reducing inappropriate variations in clinical practice and discouraging practices that do not have convincing or sufficient evidence of effectiveness. Clinical guidelines foster an appreciation of the quality of knowledge derived by systematically reviewing available and appropriate research evidence. According to Rycroft-Malone and Duff (2000:145), these guidelines contribute to the dissemination and implementation of evidence-informed practice in three ways namely:

- To provide knowledge about care options that practitioners can draw on when making clinical decisions regarding patient care;
- To outline a course of interventions that can act as a blueprint for care;
- To provide evidence for care, against which practices can be measured.

Worldwide, health care institutions are increasingly becoming aware of the importance of developing clinical guidelines, based on the best available evidence in order to guide clinical practice. The establishment of the National Institute for Health and Clinical Excellence in England, the Scottish Intercollegiate Guidelines Network and the National Institute for Clinical Studies in Australia are but a few of the initiatives established for the development of clinical guidelines (Hewitt-Taylor, 2004(a):86; Gerrish, Ashworth, Lacey, Bailey, Cooke, Kendall and McNeily, 2007:329).

In South Africa, the concept of evidence-based, or rather, evidence-informed practice is fast emerging. A greater awareness is evolving amongst health care practitioners of an evidence-informed movement; hence, the development of local protocols and guidelines in South Africa, for instance clinical guidelines for the management of nosocomial infections in South Africa (Brink, Feldman, Duse, Gopalan, Mer, Naicker, Paget, Perovic and Richards, 2006:642-653); the Nesibopho best practice guidelines on oral care in the critically ill patient (Perrie, 2007:1) and the evidence-based clinical guideline for insulin administration in the control of blood glucose in the adult critical care unit (Turner,2007:24-30). However, clinical-guideline formulation does not yet appear to be a nationally coordinated effort in South Africa.

In critical care nursing worldwide, there is now an evolving evidence data base in the form of clinical guidelines available for specific critical care interventions: namely, close glucose control of glycaemia during critical illness, sedation protocols, weaning strategies for the mechanically ventilated patient, positioning of the mechanically ventilated patient, control and management of sepsis and septic shock, feeding protocols and a range of clinical guidelines to manage various cardiac and vascular conditions, including myocardial infarction, heart failure and cerebral vascular accidents (Elliot *et al*, 2007:34).

To date, a vast amount of literature has been published on various aspects of mechanical ventilation. A concern related to the development of ventilator-associated pneumonia (VAP) in the mechanically ventilated patient has led to the development of the evidence-based clinical practice guidelines and the ventilator-care bundle, which is a group of best practice statements that when implemented together, reduce the incidence of VAP in the mechanically ventilated patient and improve the outcome of the critically ill patient (Urden *et al*, 2006:75). The main interventions for the prevention of VAP include oral care, elevation of the head of the bed between 30 and 45 degrees, daily sedation interruption, daily assessment of the readiness to extubate the mechanically ventilated patient, stress-ulcer prophylaxis and deep-vein thrombosis prophylaxis (Grap and Munro, 2004:350). Based on the research studies linked to the development of the ventilator-care bundle, various other studies emerged. Several studies addressing the significance of oral-hygiene practices for

the mechanically ventilated patient, based on best available evidence, have been published (Deriso, Ladowski, Dillon, Justice and Peterson, 1996: 1556-1561; Fitch, Munroe, Glass and Pelegrini, 1999:314-318; McNeil, 2000:367-372; Cutler and Davis, 2005:389-394). The development of various oral-care protocols has proved effective in reducing oropharyngeal colonization and nosocomial pneumonia risks (Furr, Binkley, McCurren, Carrico, 2004:454; Perrie, 2007:1).

Despite the vast amount of research and clinical guidelines (as discussed above) available related to mechanical ventilation, limited evidence in the form of clinical guidelines is available on the following nursing care practices namely endotracheal tube verification, endotracheal tube cuff pressure monitoring, assessment and maintaining airway patency (endotracheal tube suctioning), and mechanical ventilator settings, which all form an integral part of the nursing care rendered to a patient on a mechanical ventilator in a critical care unit.

1.2 PROBLEM STATEMENT

The researcher has observed that approximately 70-80% of critically ill patients in the critical care units in the Nelson Mandela Metropolitan area are connected to mechanical ventilators. It is indisputable that in many circumstances mechanical ventilation is a life-saving therapy. However, the introduction of a machine to any clinical setting, which is a highly technical therapeutic intervention, is associated with many possible complications.

The nursing care of the mechanically ventilated patient is challenging on many levels: from the acquisition of highly technical skills, expert knowledge on invasive monitoring and the ventilator principles and the implementation of nursing interventions to care for the patient. It is thus imperative that the professional nurses rendering care to patients on mechanical ventilators are knowledgeable regarding the insertion, care and maintenance of the artificial airway, namely the endotracheal tube, the operational principles, settings and monitoring of the mechanical ventilator and the complications associated with the use of the mechanical ventilator. To improve the delivery of care to the critically ill patient, an understanding of the mechanical ventilator and the associated adverse effects and complications is

essential. This understanding and knowledge acquisition will increase the critical care nurses' confidence and allow them to focus on the patients and associated problems while rendering safe and informed care. The professional nurses must also understand how to perform a physical assessment of the mechanically ventilated patients in order to prevent any complications related to the use of the mechanical ventilator. Patient comfort, communication with the patient and ensuring psychosocial well-being are other aspects that need to be incorporated into the nursing care of mechanically ventilated patients.

All mechanically ventilated patients have an artificial airway *in situ* to enable delivery of respiratory support and clearance of airway secretions. In order to ensure the safety of the mechanically ventilated patient, continuous assessment and monitoring of the artificial airway and the mechanical ventilator is required by the nurse practitioner caring for the patient. Assessment of the critically ill patients includes a vast amount of information and integration of patient data, obtained from taking the history of the patient, as well as performing a physical examination of all the systems in their bodies. Due to the range of activities related to the nursing care of a mechanically ventilated patient, this research study will only focus on patient safety in relation to the artificial airway, namely the endotracheal tube and the mechanical ventilator settings required to ensure prevention of ventilator complications and adverse effects in the critically ill patient. The rationale for the focus of the research study is imperative because if the artificial airway is not cared for and maintained once inserted and the mechanical ventilator settings are incorrect, it will impose on the well-being or safety of the patient as further described in this section.

Firstly, it is important to know that once the artificial airway, namely the endotracheal tube, is inserted by the physician, anaesthetist or nurse practitioner, it must be verified that it is in the correct position. Incorrect **endotracheal tube placement** places the mechanically ventilated patient at significant risk from various complications, e.g., absent or ineffective ventilation, aspiration and injury to the airway resulting from oesophageal intubation or from tube placement that is too high or too low in the trachea. Frequently used strategies to verify endotracheal tube placement include lung inspection and auscultation, end-tidal carbon dioxide monitoring and

radiological examination (Pierce, 2007:71). The researcher has observed in clinical practice in the critical care units in the Nelson Mandela Metropolitan area that endotracheal tube placements in mechanically ventilated patients are often not correctly verified according to the methods stated above, or verification of the tube, if done, is not reflected in the records of the critically ill patient. An exploration and description on endotracheal tube verification as implemented by professional nurses to ensure correct placement of the endotracheal tube in the mechanically ventilated patient will thus be undertaken and compared with existing literature or recommendations.

Secondly, once the endotracheal tube has been correctly placed (as verified by the various techniques used) one needs to ensure that the **endotracheal tube cuff pressures** are monitored to avoid the possible complications associated with the tube itself that might impose on the patient's safety. Cuff pressures of the endotracheal tube must be maintained correctly in order to avoid complications, such as tracheal stenosis, tracheal, laryngeal or vocal cord mucosal injury from over-inflation, as well as complications linked to under-inflation of the cuff, such as unplanned extubations (Pierce, 2007:71). According to observations by the researcher and based on informal discussions with professional nurses within the critical care units, practice variances related to the monitoring of adequate cuff pressures appear to exist in the care of the mechanically ventilated patient. Failure to monitor endotracheal cuff pressures promptly and correctly might impose on the safety or well-being of a patient who is connected to a mechanical ventilator.

Thirdly, in ensuring the safety of a mechanically ventilated patient in a critical care unit, it is of crucial importance that the airway patency is maintained. Assessment of the airway patency encompasses the assessment of lung secretions and strategies to maintain it. **Endotracheal tube suctioning** allows the health care practitioner to assess the secretions but also support the patient by removing secretions. Endotracheal tube suctioning in itself, however, is potentially hazardous to the patient and should be performed with care and should be based on the most up-to-date evidence available (Morton and Fontaine, 2009:578).

Finally, after it has been verified that the endotracheal tube is in the correct position and the nurse practitioner has ensured the patency of the artificial airway, it is essential to connect the patient safely and competently to the mechanical ventilator. Selecting and monitoring the appropriate ventilator settings can be seen as a balance between achieving the goals of sufficient oxygenation and carbon dioxide removal, whilst minimising the risk for ventilator-induced lung injury. Inappropriate mechanical ventilator settings have been shown to increase the risk of mortality in the critically ill patient (Allerod, Rees, Rasmussen, Karbing, Kjoergaard, Thorgaard and Andreassen, 2008:205).

The study will aim to explore and describe four nursing care practices as performed by professional nurses related to the safety of the mechanically ventilated patient. The nursing care practices identified are specifically related to the artificial airway and the mechanical ventilator settings as described and illustrated in Table 1.1.

Table 1.1 Nursing care practices related to the safety of the mechanically ventilated patient	
Assessment	Nursing Care Practice
Artificial airway	<ul style="list-style-type: none"> • Endotracheal tube placement verification • Endotracheal tube cuff pressure monitoring
Airway patency	<ul style="list-style-type: none"> • Endotracheal tube suctioning
Monitoring principles	<ul style="list-style-type: none"> • Mechanical ventilator settings

The data obtained will assist in proposing clinical guidelines that is based on the best available evidence to address any identified knowledge deficits, if present. By developing evidence-informed clinical guidelines for two of the four identified nursing-care practices, it is envisaged that this research study will enhance the quality of patient care rendered and contribute to optimising the safety of the mechanically ventilated patient in a critical care unit.

1.3 RESEARCH QUESTIONS

The research questions posed are as follows:

- How are the four identified nursing care practices related to the safety of the mechanically ventilated patient, performed by professional nurses, in critical care units in the Nelson Mandela Metropolitan area?
- Which of the four identified nursing care practices are performed least according to best recommended practices?
- What is the current best evidence that should inform two of the four nursing care practices related to the safety of the mechanically ventilated patient in a critical care unit?
- What should the content be of the two evidence-informed clinical guidelines to assist professional nurses in performing nursing care practices related to the safety of the mechanically ventilated patients in a critical care unit?

1.4 RESEARCH OBJECTIVES

The objectives of the study are as follows:

- To explore and describe the four identified nursing care practices related to the safety of the mechanically ventilated patient, as performed by professional nurses, in critical care units in the Nelson Mandela Metropolitan area.
- To identify two of the four nursing care practices that are performed least according to best recommended practices.
- To explore and describe existing literature for the two identified nursing care practices related to the safety of the mechanically ventilated patient in a critical care unit.
- To formulate two evidence-informed clinical guidelines to assist professional nurses in performing nursing care practices related to the safety of the mechanically ventilated patients in a critical care unit.

1.5 PURPOSE OF THE STUDY

The overall purpose of the research study is to develop evidence-informed clinical guidelines for two of the four identified nursing care practices related to the safety of the mechanically ventilated patient in a critical care unit.

1.6 CONCEPT CLARIFICATION

The following concepts are clarified to understand how they are applied in the research study:

Evidence

Evidence refers to the available facts, data or information indicating whether a thing is true or valid (Pearson, Field and Jordan, 2007:50). According to Rycroft-Malone, Seers, Titchen, Harvey, Kitson and McCormack (2004:81) four sources of evidence can be identified, namely research, clinical experience, patient experiences and information from the local context. In this research study evidence will refer to the available facts on the four identified nursing care practices. Evidence will be drawn from various sources namely data collected from the quantitative research approach, the systematic review and the narrative literature search. In the absence of definitive evidence, clinical experience and expert opinions might be used. Due to the fact that critically ill patients are intubated, unable to communicate and often sedated and paralysed it might not be possible to include patient experiences as sources of evidence.

Evidence-based practice

Evidence-based practice has been described as “doing the right things right”. This means not only doing things more efficiently and to the best standard possible, but also ensuring that actions which are implemented are done “right” so that more good than harm results (Muir Gray, 1997:18). It is important to note that the concepts “evidence-based medicine” and “evidence-based practice” are often used interchangeably, but they might not always be correctly used within the context of nursing. This concept have been clarified in order to understand the origin of evidence-based medicine or practice, but the focus in the study will mainly be on evidence-informed nursing, rather than evidence-based medicine or practice.

Evidence-informed nursing practice

Evidence-informed nursing practice is the integration of various types of evidence in making clinical decisions (McSherry *et al*, 2002:3). In this research study, a wide range of evidence will be consulted for instance randomised control trials,

observational, descriptive, cohort, case control, qualitative, opinion or conference papers. Recommendations based on the evidence found will be made in the form of evidence-informed clinical guidelines. The aim of the clinical guidelines will be to enhance clinical decision-making in the nursing care of the adult, intubated mechanically ventilated patient.

Critical care unit

A critical care unit is a specialised unit in a hospital, which provides care for severely ill patients with potentially reversible conditions. It also provides care for patients who require close observation and/or specialised treatments that cannot be provided in a general ward (Adam and Osborne, 2005:8). In this research study, a critical care unit comprises of critically ill adult patients who have been admitted to the specialised unit with any condition or disease process that requires mechanical ventilation.

Professional nurse

A professional nurse is a person who is qualified and competent to independently practise comprehensive nursing in the manner and to the level prescribed, and who is capable of assuming responsibility and accountability for such practice (South African Nursing Council, Nursing Act, 2005, Act No 33 of 2005). The research study population will include all professional nurses who work in critical care units, who either have critical care experience or hold an additional qualification in critical care nursing science.

Nursing care practices

Nursing care practices refer to the nursing activities that are performed with the aim of promoting comfort, healing and recovery in the patient being entrusted to the nurse care practitioner (Morton and Fontaine, 2009:14). In the research study, nursing care practices will refer to the nursing care activities that are performed for the critically ill, intubated mechanically ventilated, adult patient.

Patient

A patient is described as the recipient of care from health care workers (Greig and Ricks *in* Brooker, Waugh, van Rooyen and Jordan, 2009:3). Within the research

study, a patient will refer to the adult recipient of care from a professional nurse within the critical care unit while connected to a mechanical ventilator.

Safety

Safety is defined as to be free from risk or danger or to be protected or secured from anything that wants to impose on the well-being of a being (*Oxford Dictionary*, 2004:394). Within the research study, safety will refer to the nursing care practices that are essential to ensure that the mechanically ventilated patient in the critical care unit is free from any danger that might impose on his/her well-being or recovery. A safe practitioner is able to identify and minimize hazards for patients. Furthermore, a safe practitioner is required to demonstrate adequate knowledge and clinical skill competence in order to ensure that the well-being of his/her patient is not jeopardized (Briggs and Bell *in* Brooker *et al*, 2009:289). Patient safety practices are defined as those practices that reduce the risk of adverse events related to exposure to medical care (Shojania, Duncan, McDonald, Wachter and Markowitz, 2001:668).

In this research study, the term, safety, refers to the critically ill patient on a mechanically ventilator being free from harm, risk or danger when being cared for by a professional nurse in a critical care unit. The patient will only be safe and optimally managed if the nursing care practices, as performed by the professional nurses, are based on adequate knowledge, clinical expertise and the best available evidence (with reference to what constitutes as evidence, as indicated earlier).

Mechanical ventilation

Mechanical ventilation refers to the use of an artificial device to assist a patient to breathe. A mechanical ventilator is the device or machine that is specifically designed to provide for the ventilator assistance of the patient (Urden *et al*, 2006:678). Mechanical ventilation can be categorised as invasive or non-invasive, where the ventilator support is provided without the use of an endotracheal tube. In this research study, mechanical ventilation will refer to the use of an endotracheal tube inserted into the trachea of a critically ill adult patient and connected to a mechanical ventilator.

Endotracheal tube

An endotracheal tube is an artificial airway used in a critical care setting to enable the delivery of mechanical ventilation and clearance of airway secretion (Elliot *et al*, 2007:707). In this research study specific focus will be on the endotracheal tube verification, endotracheal tube cuff pressure monitoring and patency of the endotracheal tube.

Clinical guidelines versus evidence-informed clinical guidelines

Clinical guidelines are a source of summarised information on specific practices related to patient care to guide health care professionals in their clinical decision-making (Pearson *et al*, 2007:103). Evidence-informed clinical guidelines refer to systematically developed statements that are not only based on consensus, individual opinion and/or current practice, but on the best available evidence (Craig and Smyth, 2007:238). They are systematically developed to assist clinicians, consumers and policy makers in health care decisions and to provide critical summaries of available evidence on a particular topic (Elliot *et al*, 2007:63). In this research study, evidence-informed clinical guidelines will be formulated, based on the results of the systematic review as well as from the data collected and analysed from the questionnaires. Evidence-informed clinical guidelines will be developed for the two of the four nursing care practices that is done the least according to best recommended practices.

1.7 THEORETICAL FRAMEWORK

The emergence of evidence-informed practices is patently clear and the benefits of practices according to the best available evidence are clear. However, the transition to evidence-informed principles has not always occurred smoothly as all disciplines have differences in their focus and research. Therefore, various organizations, such as the Joanna Briggs Institute (JBI) developed in Australia, were established to assist with the translation, transfer and utilisation of best available evidence into health care practice. The JBI works with researchers, clinicians and managers to identify those areas where health professions most urgently require summarised evidence on which to base their practices. The international JBI was established in Australia, Adelaide, but its links extended to most Australian states, New Zealand,

Asia, Africa, Europe and North America. Given the central role of nursing and allied health in health care delivery, and that the role of nursing and allied health professionals in evidence-based health care has been largely neglected, the JBI focuses on the need for an evidence base for nursing and the allied health sector and on assisting health consumers to make informed decisions (Pearson *et al*, 2007:7).

There are various models available on the implementation and utilisation of evidence-based practices. The JBI model was chosen as the theoretical framework for this research study as it focuses on the need for an evidence base for nursing, and it encouraged the use of a wider range of evidence other than only randomised control trials. This model recognises the three spheres of research, theory and practice as sources of evidence. Furthermore the JBI model uses an approach that links evidence from diverse sources to the core of professional practice in health care namely clinical decision-making and practice development. The results of well-designed research studies grounded in a robust methodology are seen as the most credible evidence, but in the absence of definitive evidence, other sources of evidence for instance opinion papers can be considered. The JBI model of evidence synthesis is inclusive of evidence that arises out of quantitative research, qualitative research, opinion and/or expert reports (Pearson *et al*, 2007:16). This is a clear departure from the other models for instance the model developed by the Cochrane Collaboration wherein evidence other than that generated through randomised control trials is disregarded.

According to the JBI model, evidence-informed health care could be represented as a cyclical process that begins with clinical questions, concerns or interests and then proceeds to address these questions by generating knowledge and evidence to effectively and appropriately address the questions. This evidence is then appraised and synthesized and transferred to health care delivery settings and health care professionals, who then utilise it and evaluate the impact on health outcomes, health systems and professional practice. According to Pearson *et al* (2007:17), the JBI model describes the four major components of the evidence-based health care process as:

- Health care evidence generation;
- Evidence synthesis;
- Evidence transfer;
- Evidence utilisation.

In line with the JBI model of evidence-based health care, the following stages have been applied in this research study. However, it is important to note that not all the steps in this cyclic process have been applied in the research study, as some of the steps, for instance the implementation of the evidence-informed guidelines, are beyond this study's scope.

Health care evidence generation

Evidence for health care can be generated through research, experience and formulation of opinion. Although experience and expert opinion can be regarded as sources of evidence, the results of rigorous research represents a higher level of evidence. It is essential for health care professionals to know how to locate, evaluate and even conduct research (Pearson *et al*, 2007:37). In this study, research will be conducted to explore and describe on how the four identified nursing care practices are performed by professional nurses in the critical care units in the Nelson Mandela Metropole. A positivist paradigm, utilising a quantitative methodological research approach will be used during the first stage of the study. A structured questionnaire will aim at exploring the four identified nursing care practices in ensuring the safety of mechanically ventilated patients in critical care units. Apart from conducting quantitative research, other research studies will also be located and evaluated, which will be part of the systematic review. As this study focus on an evidence-informed approach it will draw on best available evidence, which might include experience or expert opinion, if gaps in the research evidence exist.

Evidence synthesis

Evidence synthesis is the evaluation or analysis of research evidence on a specific topic to aid decision-making in health care. Evidence synthesis involves the pooling of results of research findings or other pieces of evidence in such a way to effectively determine just what interventions or activities it is that the evidence supports. The

core of evidence synthesis is the systematic review of the literature on a particular topic (Pearson *et al*, 2007:23). Within this study, systematic reviews will be conducted on two of the four identified nursing care practices. The two nursing care practices that are done least according to best recommended practices will be chosen. The process of evidence synthesis by means of conducting a systematic review will be explained in Chapter 3, while the findings of the systematic reviews will be presented in Chapter 5 of this study.

Evidence transfer

Evidence transfer is considered to be more than the dissemination or distribution of knowledge. It includes writing up of the systematic review report and developing clinical guidelines for utilisation in clinical practice (Pearson *et al*, 2007:24). Within this study, evidence-informed clinical guidelines will be formulated based on the different types of evidence found. These evidence-informed clinical guidelines will enhance nursing care practices related to the safety of the mechanically ventilated patient in a critical care unit.

Evidence utilisation

Evidence utilisation relates to the implementation of evidence in practice. The transfer of evidence into practice can be slow, and the process can be difficult for a range of complex reasons. Evidence utilisation is influenced by factors such as available resources, provider education or expertise and organisational factors; thus, a strategy requiring appropriate skill, determination, time, money and planning is prudent for the success of any programme of implementation of evidence (Pearson *et al*, 2007:25). For the scope of this research study, two evidence-informed clinical guidelines will be developed by the researcher. The two evidence-informed clinical guidelines will then be submitted to an expert panel (will be discussed later) in critical care medicine and nursing for review. The comments and recommendations from the expert panel members will be used to finalise the clinical guidelines.

1.8 STAGE ONE

The research study will be done in two different stages. Stage one will comprise of two steps as discussed.

1.8.1 STEP ONE: QUANTITATIVE RESEARCH

Stage One of the research study will comprise of a quantitative approach, which will be explorative, descriptive and contextual in nature.

1.8.1.1 Research design

A research design is the plan or blueprint for conducting a study (LoBiondo-Wood and Haber, 2010:577). The research design for the quantitative approach will be comprehensively discussed in Chapter 3.

1.8.1.1.1 Quantitative research

Quantitative research is conducted to describe new situations, events or concepts in the world, to examine relationships among concepts and ideas and to determine the effectiveness of treatments. Quantitative research is a formal, objective, systematic process in which numerical data is used to obtain information about a topic or an event (Burns and Grove, 2003:18, 27). The research study will be quantitative as it will aim, by means of a structured questionnaire, to describe the four identified nursing care practices related to patient safety as performed by professional nurses for mechanically ventilated patients in critical care units in the Nelson Mandela Metropole.

1.8.1.1.2 Exploratory Study

An exploratory study may be used to gain insight into an area for which there is little information available. An exploration is used to obtain a better understanding of the phenomenon (Babbie, 2005:89). The research study will aim to explore the four identified nursing care practices related to the safety of mechanically ventilated patients in the critical care units in the Nelson Mandela Metropole.

1.8.1.1.3 Descriptive Study

A descriptive study aims to include data, facts, empirical generalisations, narrative and stories, which provide truthful descriptions of phenomena in the world (Mouton, 1996:102). The research study will be descriptive as it will, by means of a structured questionnaire, reveal data and facts pertaining to the four identified nursing care

practices related to the safety of mechanically ventilated patients in critical care units in the Nelson Mandela Metropole.

1.8.1.1.4 Contextual Study

A contextual study aims to study the phenomena because of their intrinsic and immediate contextual significance (Mouton, 1996:133). According to Holloway and Wheeler (2002:34), the context includes the environment or conditions and the location in which the study takes place. The research study will be conducted in the critical care environment, which comprises of critically ill, intubated adult patients who are connected to mechanical ventilators. The location will be all critical care units, both in the public and private sectors, in the Nelson Mandela Metropole. Professional nurses are specific to the context as they are rendering care to mechanically ventilated patients in the critical care units.

1.8.1.2 Research method

The research method consists of the systematic, methodological and accurate execution of the research design (Babbie and Mouton 2002:74). The research method for the quantitative approach involve identifying the research population, which in this study will be the professional nurses working in the adult critical care units in the Nelson Mandela Metropole. A convenient sampling method will be used in selecting the appropriate sample for the study.

A pilot study is a trial run of an investigation, conducted on a small scale, to determine whether the research design and method are relative and effective. The pilot study will also ensure that the research instrument is adequately designed by pre-testing it. A pilot study will make it easy to correct areas of misunderstanding and improves the reliability of the study. Based on the pilot study results of the questionnaire, the researcher may delete or re-write questions, change open-ended questions to closed ones and *vice versa* and verify that all response options have been provided (Fox and Bayat, 2007:103). The pilot study will be conducted in one of the critical care units in the private health care sector.

Data will be collected by means of a structured questionnaire comprising of different sections exploring and describing the four identified nursing care practices. Data analysis will be done by means of a statistical programme and with aid of a statistician. Descriptive and inferential statistics will be used to describe and summarise data. Data will be graphically presented by mean of bar graphs and tables. Based on the results of the data analysed, the two nursing care practices that are done the least according to best recommended practices will be included in the systematic reviews.

The research method will be described comprehensively in Chapter 3 of this study.

1.8.1.3 Reliability and validity of the quantitative approach

The quality of research studies is of utmost importance in conducting research. Unless measurement tools validly and reliably reflect the concepts being tested, conclusions drawn from the empirical phase of the study will be invalid (LoBiondo-Wood and Haber, 1998:328).

Reliability refers to the fact that if a test, model or measurement is consistent, it is reliable in supplying the same answer at different times. Reliability is concerned with consistency, accuracy, precision, stability, equivalence and homogeneity. A reliable instrument is one that produces the same results if the behaviour is measured again by the same scale (Fox and Bayat, 2007:145). Validity refers to whether a measurement instrument accurately measures what it is supposed to measure. When the instrument is valid, it truly reflects the concept it is supposed to measure (Babbie and Mouton, 2002:648). The application of these concepts will be described in Chapter 3.

1.8.2 STEP TWO: SYSTEMATIC REVIEW

A systematic review is a summary of research evidence pertinent to a specified question, in which systematic and explicit methods are used to identify, select, critically appraise and synthesise the available research evidence (Craig and Smyth, 2007:344). A systematic review is a form of research and is frequently referred to as “secondary research”. “Primary research” involves the design and conduct of a

study, including the collection of primary data from participants, and its analysis and interpretation. The systematic review also collects and analyses data, but usually from published and unpublished reports of completed research (Pearson *et al*, 2007:54).

In this research study, a systematic review will be undertaken on two of the four identified nursing care practices related to the safety of a mechanically ventilated patient in a critical care unit. The nursing care practices for inclusion in the review will be determined by the findings of the data analysis as derived from the structured questionnaires. Nursing care practices that are done according to the least best recommended practices will be included in the systematic review. For the scope of this study, it was decided to perform a systematic review on two of the identified four nursing care practices as performed by professional nurses in the critical care units.

The research design and method to be used for a systematic review will be comprehensively discussed in Chapter 3 of this study.

1.8.3 ASSESSMENT OF QUALITY OF STUDIES INCLUDED FOR CRITICAL APPRAISAL IN THE SYSTEMATIC REVIEW

As part of the systematic review, all studies are assessed for methodological rigour. Critical appraisal of the studies is done to assess whether the methods and results of the research studies included in the review are sufficiently valid to be considered useful information. A great number of assessment tools and checklist have been developed to aid in the critical appraisal process (Evans, 2001:54). When assessing the quality of randomised control trials, four different types of bias: selection, performance, detection and attrition are assessed. These concepts, as well as the JBI critical appraisal tools accessed via the JBI SUMARI software package, which will be used to assess the quality of the studies to be included in the review, are discussed comprehensively in Chapter 3 of this study.

1.9 STAGE TWO: DEVELOPMENT OF EVIDENCE-INFORMED CLINICAL GUIDELINES

The purpose of Stage Two is to formulate evidence-informed clinical guidelines for the two identified nursing care practices. Derived from data found during the evidence-generation stage, which will include the systematic reviews, as well as data collected from professional nurses on current practices by means of structured questionnaires, evidence-informed clinical guidelines for two of the identified nursing care practises related to the safety of mechanically ventilated patients in critical care units will be developed. The methods and steps in formulating evidence-informed clinical guidelines will be comprehensively discussed in Chapter 3 of this study.

1.10 ETHICAL CONSIDERATIONS

Research projects are bound to raise ethical questions. The following ethical principles will be considered and will be discussed in Chapter 3 of this research study.

1.10.1 Voluntary participation requires that people are not forced to participate in research and that, if they agreed to participate, they are free to withdraw at any time they wish.

1.10.2 Informed consent means that the prospective research participants must be informed fully of the procedures and risks involved in research and must give their consent to participate. Once again, they are free to withdraw at any time they feel that they are at risk (Fox and Bayat, 2007:148).

1.10.3 Permission to conduct the research study must be obtained from the relevant authorities prior to commencement of the research study.

1.10.4 Confidentiality, where the participants will be assured that no identifying information will be made available to anyone not directly involved in the research study.

1.10.5 Anonymity, which means that participants will remain anonymous throughout the research (Fox and Bayat, 2007:148).

1.11 DELINEATION OF STUDY

The research study will be divided into the following chapters:

Chapter 1: Overview of the study

In this chapter, the reader will be orientated to the research study with specific reference to the problem statement, research design and method and the theoretical framework to be used in the study.

Chapter 2: Literature review

The focus this chapter is to discuss the literature in order to generate a picture about mechanical ventilation and the nursing care of a patient on a mechanical ventilator in a critical care unit. A literature review will also be essential in assessing the congruency of the questionnaire with the data found in the literature.

Chapter 3: Research design and method

This chapter aims to discuss the research design and method as applied to the research study. The discussion will include Stages One and Two of the research study.

Chapter 4: Data analysis and discussion of nursing care practices

In this chapter, data collected by means of a structured questionnaire are analysed, graphically presented and discussed.

Chapter 5: The systematic review reports

Data collected during performing the systematic review of the two identified nursing care practices, namely endotracheal tube suctioning and endotracheal tube cuff pressure monitoring are discussed and presented in this chapter.

Chapter 6: Evidence-informed clinical guidelines

In this chapter, the two clinical guidelines which have been developed, based on the evidence collected throughout the study are presented.

Chapter 7: Conclusions, limitations and recommendations

Concluding remarks, limitations of the research study as well as recommendations with regard to nursing practice, research and education are addressed in this chapter.

1.12 SUMMARY OF THE CHAPTER

Although the concepts of evidence-based medicine, evidence-based nursing or evidence-informed care are not new, it is reassuring that health care institutions are committed to support them. Evidence-informed practices contribute to the effectiveness and quality of patient care, as decision-making in patient care now can be based on the best available evidence. It has been proved that evidence-informed care has branched out to various disciplines within nursing science, of which critical care nursing is recognised as one.

Within critical care units, a multi-approach and multi-system disease profile can occur. However, for the purpose of this study, the focus will be on the four identified nursing care practices related to the safety of the mechanically ventilated patient. Due to the technical nature and the complications that occur during this form of treatment, mechanical ventilation poses various challenges for the practitioner caring for patients connected to these devices. It is of utmost importance that nursing care rendered to the mechanically ventilated patient uses the best available evidence. The research study will aim to generate, synthesise and transfer evidence into practice. Transfer of evidence will be in the form of clinical guidelines, which will be developed once data is collected and analysed and the systematic reviews completed. The study will thus aim to develop two evidence-informed clinical guidelines that will enhance the nursing care rendered to the mechanically ventilated patient. The next chapter will explore and describe the literature related to nursing care practices related to the safety of mechanically ventilated patients in a critical care unit.

LITERATURE REVIEW

2

“Nothing great was ever achieved without enthusiasm.”

Ralph Waldo Emerson

“A literature review is central to the research process and can refine a research question through determining inconsistencies in a body of knowledge. It inspires new research innovations and ideas while creating greater understanding about a topic.”

Patricia Cronin et al

IN THIS CHAPTER

A brief overview of the study was done in Chapter 1. The origin of evidence-based medicine, evidence-based practice, evidence-based nursing and evidence-informed nursing were explored, described and contextualized with the study. Furthermore, the significance of critical care and nursing care practices related to the safety of the mechanically ventilated patient was explained.

This chapter will discuss:

- The core concepts of evidence-informed nursing;
- An overview of mechanical ventilation;
- The four identified nursing care practices namely, endotracheal tube placement verification; endotracheal tube cuff pressure monitoring; endotracheal tube suctioning; and mechanical ventilator settings.

2.1 INTRODUCTION

A literature review is an objective, thorough summary and analysis of the relevant available research and non-research literature on the topic being investigated. In this Chapter a narrative literature review was undertaken to orientate the reader to the core concepts of the study. The narrative literature review aided in the development of the questionnaire. The differences between this literature review and the systematic review conducted in Stage One of the study are as follows:

- No clinical questions were asked,
- All pieces of evidence were used, but the choice of books was first preference in order to avoid using articles that was for possible inclusion into the systematic review. The levels of hierarchy of evidence were used as a guide in the selection of articles. Randomised control trials for instance, which is a level II evidence was carefully considered for inclusion into the literature review, as the likelihood of including it into the systematic review would be greater,
- The rigorous process of critical appraisal of evidence and data extraction was not followed as in the case of the systematic review process,
- Summaries, rather than data synthesis, as done in the systematic review process, were made of the evidence found and used in this section of the research study.

2.2 LITERATURE REVIEW PROCESS

The literature process for accessing the different pieces of evidence was as follows:

- Electronic databases were searched to identify and become familiar with relevant keywords contained in the titles, abstracts and subject descriptors;
- All databases, including electronic, hand-searched journals and books were searched using the identified key words;
- Reference lists and bibliographies of all papers were searched for additional studies.
- Various books and articles on mechanical ventilation, critical care nursing and evidence-based practice were consulted. A wide variety of electronic data bases, including MEDLINE (via PubMed), Google Scholar, Igneta, Highwire and CINAHL via EBSCO host, were searched.

Key words used for searching the electronic data bases are itemised for each section. No specific inclusion and exclusion criteria were identified in conducting the literature search, thus including all types of evidence found. A critical appraisal of the evidence was not done. Summaries of the data pertaining to the core concepts are presented in this chapter. It was aimed as far possible to exclude evidence that was for possible inclusion in the systematic reviews.

The core concepts for inclusion in this narrative literature review are illustrated in Figure 2.1.

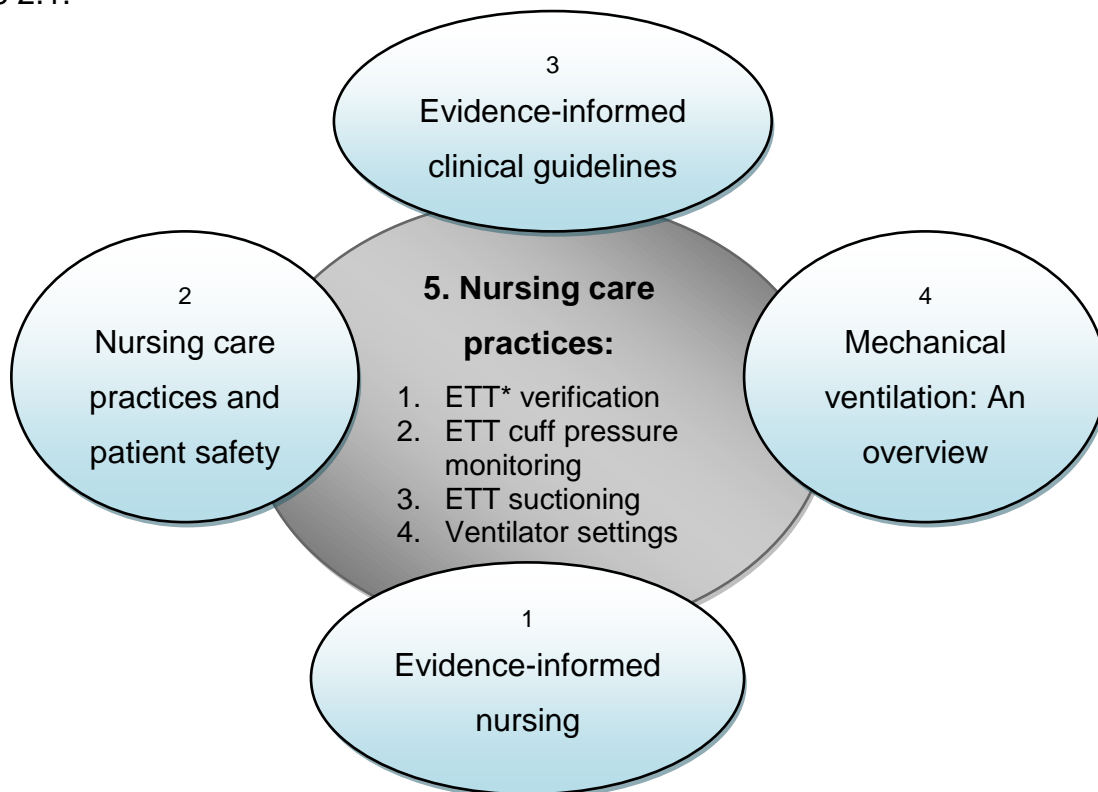


Figure 2.1 Core concepts for discussion in the narrative literature review (*ETT: endotracheal tube)

2.3 EVIDENCE-INFORMED NURSING

In Chapter 1, the background and evolution to evidence-informed nursing were given. This section of the literature review aims to give the reader an understanding of the rationale for basing nursing care practices on evidence and the impact of traditional practices on patient outcomes.

The key words that were used in searching electronic data bases for this section comprised the following: “critical care unit”; “intensive care”; “nursing”; “evidence-informed practice”; “evidence-based practice”; “evidence-based medicine”; “tradition”; “expertise”; “expert opinion” and, “barriers AND evidence-based practice”.

Evidence-informed nursing has been defined as the conscientious, explicit and judicious use of theory-derived, research-based information in making decisions about care delivery to individuals or groups of patients (Ingersoll, 2000:152).

However, in the context of this study, the definition of evidence-informed nursing as stated by Elliot *et al* (2007:58) was applied. This definition states that evidence-informed nursing refers to identifying specific nursing practices that should be improved, and then accessing and evaluating current evidence in order to make recommendations for improvement. In this research study, the four nursing care practices related to the artificial airway and the mechanical ventilator, namely endotracheal tube verification, cuff pressures, suctioning and ventilator settings have been identified for inclusion in the study (as described in the problem statement:1.2).

Many health care practitioners base their practice on what they have learned in medical, nursing or allied health schools, or on trial and error in practice, or on their own expertise, or on what they have been taught in a unit. None of these approaches to practice is appropriate in an age of rapidly changing knowledge, especially in critical care nursing. Therefore, the need and emergence of evidence-based practice in health care have become more important (Pearson *et al*, 2007:3).

Tradition is an inherited pattern of thought or action that leads to a specific practice of long standing (Pearson *et al*, 2007:33). This definition is supported by Burns and Grove (2009:8) in stating that traditions consists of truths or beliefs that are based on customs and past trends. Nursing traditions from the past have been transferred to the present by written and verbal communication and role-modelling and continue to influence the present practice of nursing. Health practitioners, whether student nurses or professional nurses enrolled in a post-basic additional qualification in critical care nursing, are required to participate in an extended period of education and training, whereby they are socialised into the traditions of their profession and of the particular school and health services where they are educated.

Furthermore, health care practitioners rely on their own expertise and on what they have been taught in the units to assist them in decision-making. Taylor-Piliae (1999:357) argues that clinical practice based on tradition or established rituals appears to be widespread amongst a variety of nurses and practice settings, including nurses working in the critical care units. However, tradition-based practice may not necessarily be based on sound scientific evidence and could be potentially

harmful to patients or result in inappropriate utilisation of resources. According to Taylor-Piliae (1998:30), tradition-based practices may result in increased costs both to the clinical setting and the patient. Clinical practice that is based on ritual or tradition may not necessarily bear any scientific merit and should thus not be encouraged amongst nurses in the health sectors. Much of the early medical and nursing practices were based on non-scientific traditions that resulted in variable and haphazard patient outcomes. These traditions and rituals, which are based on folklore, gut instinct, trial and error and personal preferences, are often passed down from one generation of practitioners to another (Ostrow, 1997:172). The use of customs, rituals or traditions should be replaced with an emphasis on identifying the best research available. It is no longer acceptable to deliver care based on tradition, personal opinions and out-dated knowledge. Nurses have a professional obligation to use the best evidence available to justify their clinical care and decision-making. Through the use of evidence-based interventions, nurses can exert a powerful, positive impact on the health care system and patient outcomes (Simko, 2005:281; Burns and Grove, 2009:9).

Even though is not encouraged to base practices on tradition, evidence-informed nursing encourages the use of various pieces of evidence, which may include expertise and personal experience. However, these terms must be explicitly defined and explored before attempting to use them as sources for basing decisions. Personal experience is the knowledge that comes from being personally involved in an event, situation or circumstance. The amount of personal experience and expertise affect the complexity of your knowledge base as a nurse. However there are different levels of experience in the development of clinical knowledge and expertise, namely novice, advanced beginner, competent, proficient and expert. The clinical expertise of the nurse is a critical component of evidence-based practice. It is the expert nurse who has the greatest skill and ability to implement the best research evidence in practice to meet the unique values and needs of patients and families (Burns and Grove, 2009:10).

Although critical care nursing is seen as a dynamic discipline, requiring decision-making based on the best available evidence in almost every patient situation,

practices based on tradition and non-research decision-making still occurs in these units. Examples of non-scientific-based critical care nursing practices include suctioning the artificial airways every 2 hours; using an iced saline injectable when measuring a cardiac output; always using lead II for cardiac monitoring and stripping chest tubes every 2 hours (Urden *et al*, 2006:5). These practices are not proven to be safe in the care of the critically patients and should thus not be done. However, they are still practiced amongst a wide range of nurses worldwide in critical care units. A study done by Estabrooks (1999:273) in the critical care units in western Canada has shown that nurses use a broad range of practice knowledge, much of which is experiential rather than research based. A Danish survey has shown similar results and suggests that critical care nurses lack fundamental knowledge of evidence-based practice (Egerod, 2004:38-42). It was established that neither critical care nurses nor nurses working in the cardiac unit regularly read scientific journals, indicating the absence of using the most recent literature in decision-making (Egerod, 2004:38; Egerod and Hansen, 2005:465).

The implementation of evidence-informed nursing care practice is the key to clinical effectiveness as it enables nurses to make sound clinical decisions about appropriate interventions. However, nurses should use the best data available, based on reliable and valid evidence, to make patient care decisions and carry out appropriate nursing interventions (Taylor-Piliae, 1999:357-362; French, 1999:72; French, 2005:242; Pearson *et al*, 2007:53; Urden *et al*, 2006:6). Practices based on tradition, rituals and own expertise should be discouraged, especially in the critical care units, where advanced levels of clinical skills and knowledge, based on the best available evidence, are required.

Part of structured questionnaire, which was part of Step One of Stage One of this research study aimed at exploring and describing if professional nurses in the critical care units in the Nelson Mandela Metropole base their practices on tradition, their own expertise or evidence.

2.4 NURSING CARE PRACTICES AND PATIENT SAFETY

The key search words used for an exploration of the literature for this section included: “mechanical ventilation”; “artificial ventilation”; “safety”; “patient safety AND critical care”; “intensive care”; “nursing care AND practices” “nursing roles AND safety”; and, “scope of practice”.

Patient safety has become a major focus of attention for health care consumers as well as providers of care and administrators of health care institutions. Patient safety and the provision of quality of care are two health service themes that have emerged since the 1990s and are strongly linked to evidence-based care (Elliot *et al*, 2007:10). Patient safety has been described as an ethical imperative and one that is implied in health care professionals’ actions and interpersonal processes. Patient safety is compromised by adverse events, which are described as unintended injuries or complications resulting in disabilities, deaths, or prolonged hospital stays and are caused by health care management (Benner, 2001:281; Elliot *et al*, 2007:10).

In a study conducted in Australia, it was established that adverse events occur in up to 16% of hospital admissions and account for about 7.1 extra days in hospital. About half of the adverse events are preventable and cost the health care system in excess of \$800 million per year in additional hospital bed-days alone (Wilson, Harrison, Gibberd and Hamilton, 1999:413). In a study done in Ottawa by Forster, Kyeremanteng, Hooper, Shojania and van Walraven (2008:1-8), it was found that 20% of patients experienced adverse events while in critical care units, while one in five of these events was considered preventable. Adverse events were independently associated with an average increase in hospital stays of 31 days. The study reaffirmed the importance of improving patient safety in the critical care units by measuring the risk of adverse events and more accurately quantifying their impact. Results from other studies (Bracco, Favre, Bissonette, Wasserfallen, Revelly, Ravussin and Chiolero, 2001:137-145; Graf, von den, Koch and Janssens, 2005:930-939; McBride, Chiang, Goldmann and Landrigan, 2005:603-608), showed that adverse events mean increased length of stay and show the need to improve patient safety in critical care units.

In the United States of America, the National Quality Forum, a non-profit organisation created to develop and implement a national strategy for health care quality measuring and reporting identified 15 consensus standards for nursing-sensitive patient outcomes (patient outcomes that may be influenced by the actions and behaviours of nurses). The patient measures that were specific to critical care included urinary catheter-associated infections, central-line catheter-associated infections and ventilator-associated pneumonia (Elliot *et al*, 2007:10). A paucity of literature exists on the specific ventilator events that compromise patient safety in critical care units. Two studies (Evans, Johnson, Flint, Kinder, Lyon, Hawley, Vawdrey and Thomsen, 2005:589-595 and Forster *et al*, 2008:1-8) were found that addressed the adverse events related to ventilator alarms, stating that enhanced ventilator alarms improve patient safety by alerting all the medical staff in a timely manner. The Joint Commission on Accreditation of Health Care Organizations (JCAHO) reviewed 23 reports of death or injury related to mechanical ventilation. Of the 23 events, 19 resulted in death and 4 resulted in coma, 65% were related to mechanical ventilator alarms, indicating the effects of mechanical ventilation on patient safety in critical care units (Korniewics, Clark and David, 2008:36-41).

Due to the busy, complex environment where the margins of error are narrow and the demands for safety are crucial, the incidence for the occurrence of errors in the critical care units are high (Benner, 2001:281). In this environment, patients are particularly vulnerable due to their compromised physiological status, multiple technologic and pharmacologic interventions and multiple care providers who frequently work at a fast pace (Urden *et al*, 2006:12). Mechanical ventilation is a common intervention used in critical care units for patients with respiratory failure or who require respiratory support. The nursing management of the mechanically ventilated patient is challenging as this form of therapeutic device has many complications, which might compromise the safety of a critically ill patient. The safety considerations in the care of the group of patients involve continuous observation and monitoring of all the systems in the body, ensuring that the artificial airway is secured, in the correct anatomical position and patent (Couchman, Wetzig, Coyer and Wheeler, 2007:4).

Nursing care practices refer to nursing activities that create a compassionate, supportive, safe and therapeutic environment for patients, with the aim of promoting comfort and healing and preventing unnecessary suffering or any compromise to patient safety (Morton and Fontaine, 2009:15). The nursing care of the mechanically ventilated patient is at the core of a nurse's clinical practice in the critical care unit. In this research study, the focus was specifically on the nursing care of the artificial airway, which included endotracheal tube verification, endotracheal cuff pressure monitoring, endotracheal tube suctioning as well as monitoring ventilator settings, all aspects that might compromised the safety of the mechanically ventilated patient if not done correctly or promptly. As the critically ill mechanically ventilated patient is often sedated, paralysed and is unable to communicate with staff and family members, it is the responsibility of the professional nurse to care for and ensure the safety of the patient while entrusted to his or her care.

However, patient safety does not only include the physical surroundings but also the staffing levels and competence of the practitioner caring for the patient. The regulation of registered nursing practices in South Africa comes under the authority of the South African Nursing Council (SANC). The SANC's Charter of Nursing Practice is supported by various acts and regulations, which include the Scope of Practice and the Acts and Omissions. These regulations guide professional nurses in terms of what is expected of them as care givers. Within the framework of the Charter of Nursing Practice, nurses are expected to provide protection, care and support for the individual patient. Furthermore, professional nurses are professionally and legally accountable for their care practices and will be held accountable for their acts and omissions (Geyer and Horsburgh *in* Brooker *et al*, 2009:129-130). Although a Scope of Practice is available for professional nurses in South Africa, there is not one for professional nurses with the additional qualification in critical care nursing. These nurses continue to function in terms of the existing Scope of Practice.

In addition to being knowledgeable, competent and skilled, a safe practitioner should be able to identify and minimise hazards for the patient. A critical-thinking approach, using reflective practice and evidence-informed method should be the cornerstone in

performing nursing care practices that are safe, compassionate and strive to ensure that the patient recovers from sickness and disease (Morton and Fontaine, 2009:13).

It can thus be concluded that in order to ensure the safety of the mechanically ventilated patient in the critical care unit, the professional nurse needs to function within the prescribed regulatory framework, have adequate knowledge, clinical skills, be competent, reflective, a critical thinker and use an evidence-informed approach to aid in decision-making in caring for patients. Shojania *et al* (2001:668) state that an evidence-approach can not only help to identify practices that are likely to improve safety but can, indeed, enhance patient safety and ultimately improve the quality of patient care.

2.5 EVIDENCE-INFORMED CLINICAL GUIDELINES

The key search words used in identifying literature for this section included: “evidence-based practice”; “nursing”; “critical care”; “intensive care”; “clinical guidelines”; “clinical practice guidelines”; “guidelines”. Please note that this section of the study only gives a brief overview, as a comprehensive discussion related to the development and process of evidence-informed guidelines follows in Chapter 3 of this study.

The SANC regulates education in critical care nursing and has a teaching guide for a course in clinical nursing leading to the registration of an additional qualification in critical care nursing. However, this teaching guide is very broad, thus allowing each school to develop its own curriculum in an area of specialisation (Regulation R.212, 1993:(i)). This implies that professional nurses who have undertaken training and education in critical care nursing as an additional qualification will conform to the teaching methodology and practices being taught in a particular school.

Furthermore, every unit manager in critical care units has the responsibility to develop unit policies and guidelines on the various nursing care practices to be performed for the critically ill patient. These policies, or guidelines, might be developed by an appointed group of people. Guidelines might also be developed by a unit manager. However, the quality of existing clinical guidelines must be assessed

prior using them in making clinical patient-care decisions. The Appraisal of Guidelines Research Evaluation (AGREE) collaboration has produced an internationally renowned instrument, which can be used in assessing the quality of clinical guidelines found on identified nursing care practices (Craig and Smyth, 2007:249).

The curriculum in critical care nursing, specific to nursing care practices related to mechanical ventilation, needs further exploration to assess if it is based on the best available evidence. It is, however, promising that the new qualification structure to be implemented in South Africa emphasis the use of evidence-based principles in the teaching programmes, and educators will thus have to incorporate the best available evidence and practice recommendations in teaching professional nurses critical care practices.

Considering the future implications for practice and education, the role of evidence-informed clinical guidelines cannot be over-emphasised. Evidence-informed clinical guidelines have been advocated to make explicit recommendations based on the best available evidence about clinical practice, reduce variations in clinical practice, determine and set standards and indicators, conduct audits and evaluations of practice and improve the quality and safety of care (Thompson and Dowding, 2002:149; Miller and Kearney, 2004:814-815; Hewitt-Taylor, 2004(b):45-52; Swinglehurst, 2005:309; Craig and Smyth, 2007:239).

However, contradictory literature was found stating that although evidence-based clinical guidelines specify good clinical practice and aim to enable appropriate decisions and improve the quality of patient care, the impact of having these available guidelines might not be optimized if they are not embraced and implemented by health care practitioners. Evidence-based clinical guidelines may even be harmful if they are partially or inappropriately implemented. Therefore, it was recommended that the impact of clinical guidelines must be increased by means of involving the relevant stakeholders in guideline production, using educational strategies to promote guideline usage, increasing the awareness amongst health care practitioners regarding the benefits of implementation as well of the variability

and gaps in their own knowledge (Burgers and van Everdingen, 2004:393; Bazian, 2005:273).

2.6 MECHANICAL VENTILATION: AN OVERVIEW

Mechanical ventilation is the process by which room air or oxygen-enriched air is moved into and out of the lungs, mechanically, by means of an artificial airway and a ventilator. Furthermore, mechanical ventilation can be viewed as a means of supporting patients until they recover the ability to breathe independently or the decision is made to withdraw ventilator support (Lewis, Heitkemper and Dirksen, 2004:1781). Mechanical ventilator support is one of the major supportive treatments used in critical care and remains one of the most challenging tasks facing health care practitioners in critical care units. Mechanical ventilation is one of the most commonly used treatment modalities in the care of the critically ill patient and up to 90% of patients world-wide require mechanical ventilation during some or most parts of their stay in critical care units (Hamed *et al*, 2006:77).

This section aims to discuss the core principles related to mechanical ventilation. Although the study focuses on mechanical ventilator settings as the core principle, an overview of mechanical ventilation is necessary to orientate the reader to this treatment modality. The key items for discussion in this section are reflected in Table 2.1.

Table 2.1 Items for discussion on mechanical ventilation
2.6.1 History of mechanical ventilation
2.6.2 Classification of ventilators
2.6.3 Indications for mechanical ventilation

2.6.1 HISTORY OF MECHANICAL VENTILATION

The first references of artificial respiration were recorded in both biblical and Egyptian history. The biblical story of Elisha, who restored the life of a young boy, recognised the principle that the respiratory function could be supported artificially. Despite such early recognition of this phenomenon, the most credible reference in

discussing artificial respiration is Galen (175 A.D.). This Greek physician experimented with the first form of artificial respiration by using a bellows to inflate the lungs of a deceased animal. Based on Galen's work, many scientists and scholars from the 14th–19th centuries experimented with artificial respiration, laying the groundwork for the use of mechanical ventilators (Baker 1971, as cited in Cawley, 2007:250).

The age of practical mechanical ventilation did not begin until the introduction of the tank respirator or the iron lung, originally developed by Dalziel in 1838 and improved by Drinker and Shaw in 1929. The device was a large, airtight metal cylinder that enclosed the patient, exposing the head and neck. Negative pressure was generated with an electric pump, causing the patient's chest to rise. This device was particularly effective as a non-invasive form of mechanical ventilation for patients with normal airways, such as those with polio. However, it was not very useful for patients with significant respiratory disorders. It was used extensively and successfully in the mid-1950s during the poliomyelitis epidemic (Baker 1971 as cited in Cawley, 2007:251). Over 20 years later, the polio epidemic led an anaesthetist in Copenhagen, Bjørn Ibsen, to recommend positive-pressure ventilation via tracheostomies, thereby reducing the mortality from 84% at the start of the polio outbreak to 26% (Hamed *et al*, 2006:78). World War II introduced several devices that were later adapted and developed for mechanical ventilation. Continuous positive-pressure breathing to increase the altitude tolerance of pilots was used during World War II and later adapted for use in intermittent positive-pressure ventilation, which then marked a new era for mechanical ventilation (Clochesy, Breu, Cardin, Whittaker and Rudy, 1996:262).

However, since the initial development, mechanical ventilators have evolved into devices that allow synchronization of a patient's ventilatory demands with the augmentation of volume and pressure waveforms. Currently, there are various types of mechanical ventilators used in hospital and home settings, long-term care facilities, critical care units, and even life-flight helicopter transport.

2.6.2 CLASSIFICATION OF MECHANICAL VENTILATORS

There are different classifications of mechanical ventilators, namely negative-pressure, positive-pressure, pressure-cycled, time-cycled and volume-cycled ventilators, which will be discussed briefly.

Negative-pressure ventilators

Negative-pressure ventilators mimic the action of the human diaphragm and respiratory muscles of the chest. They apply external negative pressure to the chest wall, causing the rib cage to expand, decreasing intra-thoracic pressure and allowing air to be drawn into the lungs. Inspiration occurs when the sub-atmospheric pressure is created around the chest and the abdomen of the patient. This type of ventilation requires the patient's upper torso and trunk to be completely enclosed by the device. Passive exhalation occurs when the negative pressure ceases. Negative-pressure ventilation is used primarily to assist patients during slowly progressive neuro-muscular diseases such as muscular dystrophies (Flynn and Bruce, 1993:73). Although negative-pressure ventilation gave way to the positive-pressure devices because of the limitations related to positioning and movement of critically ill patients and lack of adaptability to large or small body torsos, their use for specific patient types has recently been seen. Some neuro-muscular patients, especially those with residual muscular function, may benefit from nocturnal use of this type of ventilation (Morton and Fontaine, 2009:593).

Positive-pressure ventilators

Positive-pressure ventilators work on the opposite principle from negative-pressure devices. They create a positive, greater-than-atmospheric pressure in the upper airway and thus force air into the lungs. Expiration occurs when the positive pressure is removed because of the elastic recoil properties of the lungs and chest wall (Flynn and Bruce, 1993:73). Owing to the improvement of mechanical ventilators and advances in design of endotracheal and tracheostomy tubes, positive-pressure ventilators have become the mainstay of ventilator support and are used most often in hospital settings (Clochesy *et al*, 1996:263). Positive-pressure ventilators are further described as pressure-cycled, volume-cycled or time-cycled ventilators.

2.6.3 INDICATIONS FOR MECHANICAL VENTILATION

Mechanical ventilation in itself cannot cure a disease process but merely supports the patient until resolution of the underlying disease process. Mechanical ventilation is indicated for a variety of physiological and clinical reasons. Physiological objectives include supporting cardio-pulmonary gas exchange, increasing lung volume and reducing the work of breathing. Clinical objectives include reversing hypoxemia and acute respiratory acidosis, relieving respiratory distress, preventing or reversing atelectasis and respiratory muscle fatigue, permitting sedation and/or neuro-muscular blockage, decreasing oxygen consumption, reducing intra-cranial pressure and stabilising the chest wall (Urden *et al*, 2006:671; Baudouin, 2004:103). In addition to the above objectives, Hamed *et al* (2006:78) state that the main objectives of initiating mechanical ventilation are: (1) to reverse acute respiratory acidosis, intending to relieve life-threatening conditions rather than to normalize PaCO₂; and (2) to relieve respiratory distress and elevated work of breathing.

Acute respiratory failure, as manifested by either oxygenation failure or marked carbon-dioxide retention, is the primary indication for the institution of ventilator support. Respiratory failure can be categorised into various types: mechanical failure, which is the failure of the normal respiratory neuro-muscular system, often requiring immediate mechanical ventilator support. This includes neuro-muscular diseases such as Myasthenia Gravis, Guillain-Barrè syndrome and poliomyelitis. Respiratory paralysis necessitates ventilator support to maintain adequate alveolar ventilation. Musculoskeletal abnormalities, such as chest-wall trauma may impede the function of the respiratory mechanics thus requiring ventilator support (Clochesy *et al*, 1996:263).

Obstructive lung diseases in the form of asthma, chronic bronchitis, or emphysema may result in gas-exchange impairment necessitating ventilator support to oxygenate and ventilate the patient adequately. Insufficient gas exchange occurring from conditions such as pulmonary edema, atelectasis, acute respiratory distress syndrome, acute respiratory failure, respiratory muscle fatigue, apnea and coma might require mechanical ventilation (Burns *in* Lynn-McHale and Carlson, 2001:178). Clinical indicators for initiation of mechanical ventilation include the evidence of

increased work of breathing, a respiratory rate of more than 35 breaths per minute, tidal volume of less than 5ml/kg, vital capacity of less than 15ml/kg and the presence of retractions or nasal flaring (Hamed *et al*, 2006:78). Finally, patients who have received general anaesthesia, as well as post-cardiac arrest patients or patients suffering from cardiogenic shock, may require ventilator support until they have recovered from the effect of anaesthesia or the insult related to the cardiac arrest (Pierce, 2007:181).

In a study done by Estaban *et al* (2000:1450-1453) in 412 critical care units in North America, South America, Spain and Portugal, it was revealed that acute respiratory failure is the most frequent reason for the initiation of mechanical ventilation. Acute respiratory distress syndrome (ARDS) occurred in 20% of the patients who presented with acute respiratory failure, requiring mechanical ventilation. An acute exacerbation of chronic respiratory failure, which included patients with obstructive and/or restrictive lung disease, was the precipitating cause for initiation of mechanical ventilation in 36% of the patients across the critical care units used in the study. Coma, which was the indication in 15% of the total study group, was the condition with the greatest variation among countries. In most of the countries used in the study, patients with neuro-muscular disorders required mechanical ventilation in less than 10% of the total population.

Literature on the indications for mechanical ventilation in South Africa, especially at a national level, is limited. According to Engelbrecht and Tintinger (2007:118), the most common indications for intubation in South Africa are central nervous system pathology, for instance, severe head injury, drug and poisons, neuro-muscular diseases, e.g., Myasthenia Gravis or Guillain-Barrè syndrome, ARDS, pneumonia, aspiration, asthma or chronic obstructive pulmonary disease. Although no formal statistics or literature on the disease conditions necessitating mechanical ventilation in the Nelson Mandela Metropole were available, it was observed that the most common indications for mechanical ventilation included respiratory support required post-cardiac and general surgery, obstetric emergencies requiring post-operative ventilation, patients requiring ventilation for respiratory alterations following trauma, spinal-cord injuries, medical emergencies, acute respiratory failure and ARDS, drugs

and poisoning, near-drowning victims, HIV-related respiratory alterations requiring respiratory support and neuro-muscular disorders. The disease profile for patients admitted to the critical care units in the private and public sectors in the Nelson Mandela Metropole appears to be similar but needs further exploration, especially since no formal research is available on this topic.

2.7 NURSING CARE PRACTICES PERTAINING TO THE RESEARCH STUDY

The nursing care practices related to the safety of the mechanically ventilated patient in a critical care unit were identified in Chapter 1 of this study and include: endotracheal tube verification, endotracheal tube cuff pressure monitoring endotracheal tube suctioning and mechanical ventilator settings, which will be discussed in this section of the study.

2.7.1 NURSING CARE PRACTICE ONE: ENDOTRACHEAL TUBE VERIFICATION

Endotracheal tube intubation is the most reliable method for maintaining a patient's airway. However, unintentional esophageal intubation as a complication in endotracheal intubation occurs in 8% of attempts and the consequences are catastrophic if misplacement of the tube is not recognised promptly (Takeda, Tanigawa, Tanaka, Hayashi, Goto, Tanaka, 2003:154). It is thus of utmost importance that the endotracheal tube be verified promptly and correctly, using the best recommended practice.

This section of the study aims to discuss the items as reflected in Table 2.2.

Table 2.2 Items for discussion on endotracheal tube verification

2.7.1.1	Indications for endotracheal tube placement
2.7.1.2	Endotracheal tube design
2.7.1.3	Complications associated with endotracheal tube intubation
2.7.1.4	Frequency for verifying endotracheal tube placement
2.7.1.5	Methods for endotracheal tube placement verification
2.7.1.6	Inspection findings to verify endotracheal tube placement
2.7.1.7	Auscultation findings to verify endotracheal tube placement
2.7.1.8	Chest radiography findings to verify endotracheal tube placement
2.7.1.9	Methods to identify carbon dioxide in exhaled gas
2.7.1.10	Normal range for carbon-dioxide measurements
2.7.1.11	Calometric detection of carbon dioxide
2.7.1.12	Summary of the section on endotracheal tube verification

Key words that were used in searching the data bases included the following: “mechanical ventilation” ; “ventilation”; “artificial respiration”; “endotracheal tube”; “verification methods AND endotracheal tube”; “verification”; “confirmation”; “capnography”; “chest radiographs”; and “pulse oximetry”.

2.7.1.1 Indications for endotracheal tube placement

An endotracheal tube (ETT) is an artificial airway that is guided into the trachea, usually by a laryngoscope. It is placed directly into the trachea through the mouth or nose, past the vocal cords and guided 2 to 4 cm above the carina. The tube cuff lies below the vocal cords and is inflated once the tube is in place. There are two types of ET tube intubation possible, namely oral ET intubation and nasal ET intubation. However, the majority of patients in the critical care units are orally intubated. If the patient has an upper-airway obstruction, ET intubation may not be possible. In this event, an emergency tracheostomy is performed instead (Flynn and Bruce, 1993:54).

According to Pierce (2007:66), the following are indications for the use of endotracheal tube intubation:

- Airway obstruction or compromise;
- Secretion management;
- Airway protection from regurgitation or aspiration in patients with a depressed level of consciousness or ineffective airway reflexes;
- The need for high concentrations of oxygen, mechanical ventilation or general anaesthesia.

The endotracheal tube is used in situations that require controlled access to the patient's natural airway, in patients who either cannot breathe spontaneously or cannot maintain an adequate gas exchange, and for airway protection with drug-overdose, comatose patients. Furthermore, the endotracheal tube allows for positive-pressure mechanical ventilation and prevents progressive gastric distention and aspiration of the stomach contents (Elliot *et al*, 2007:707).

2.7.1.2 Endotracheal tube design

It is important to understand the design of the endotracheal tube as it influences the cuff pressure monitoring and suctioning methods and techniques. The basic design of the endotracheal tube is standardised. The connector fits into the tube at the proximal end. It has a standard 15mm outside diameter that permits universal connection to the mechanical ventilator. The tube body has a standard curvature, centimetre markings that allow for the determination of depth of insertion, and radiopaque markings, either running the length of the tube or at the distal end, so that the tube is located on chest x-ray film. The distal tip of the endotracheal tube has a bevelled edge, which allows for easier passage of the tube through the glottis slit (Pierce, 2007:67).

Adult endotracheal tubes are equipped with a cuff, which, when inflated, seals the trachea, allowing for the application of positive-pressure ventilation and minimizing aspiration. An inflating system allows for inflation of the cuff. At the proximal end of the small lumen is a spring-loaded valve that is activated by inserting a syringe. Air can then be inserted into the cuff. The valve closes when the syringe is removed,

thus preventing the escape of air from the cuff. Adjacent to this valve is the pilot balloon, a small balloon that, when felt for air pressure, indicates the general inflation status of the cuff (Pierce, 2007:67). An illustration of the basic design features of the endotracheal tube is shown in Figure 2.2.

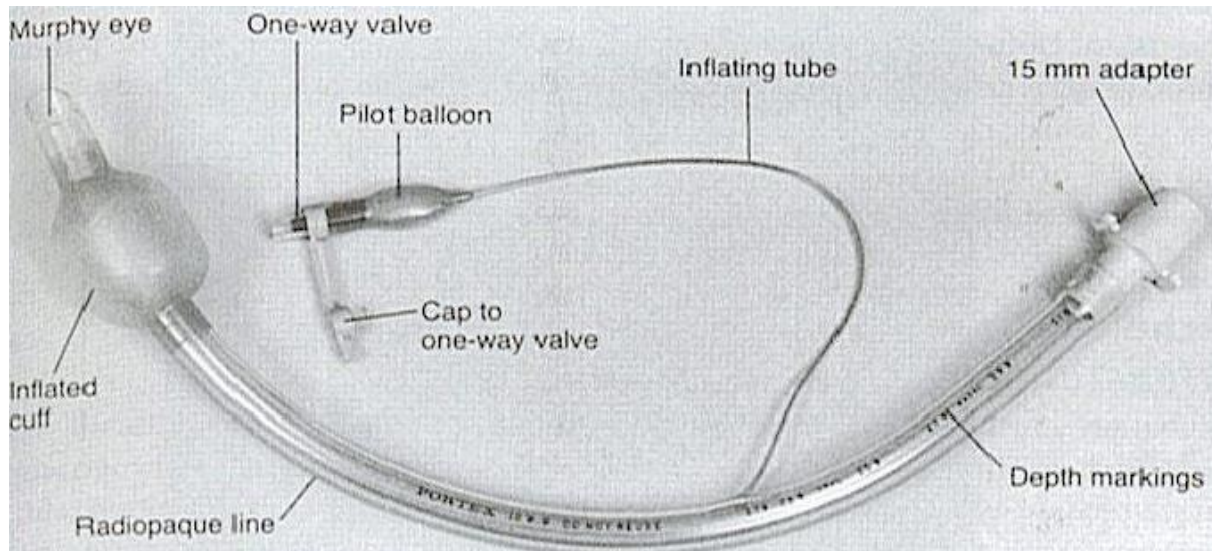


Figure 2.2 Basic design features of the endotracheal tube (Pierce, 2007:67).

2.7.1.3 Complications associated with endotracheal tube intubation

Endotracheal intubation is a highly technical clinical skill that is not without complications. The complications can occur at different stages of insertion and maintenance of the endotracheal tube.

Complications that can occur during the intubation procedure include: (1) vomiting with possible aspiration; (2) laryngeal, pharyngeal, tracheal, dental or nasal trauma; (3) bradycardia caused by vagal stimulation; (4) hypoxemia caused by delay in the procedure; (5) cardiac arrhythmias; (6) right main-stem intubation; and (7) esophageal intubation (Pierce, 2007:73).

Complications that can occur while the tube is in place include: (1) tube malpositioning; (2) laryngeal or tracheal necrosis or erosion; (3) pharyngeal edema; (4) mouth, lips or nares pressure sore development; (5) loss of cuff integrity (6) self extubation; (7) aspiration; (8) sinusitis and otitis media. After extubation complications include a sore throat, hoarseness, laryngeal edema, and vocal cord

immobility or paralysis. Late complications that can occur after extubation include tracheal stenosis, laryngeal or tracheal granuloma and laryngeal stenosis (Pierce, 2007:73).

Due to the complications related to endotracheal tube insertion, assessment and monitoring of the patient is of the utmost importance. These complications might compromise the safety of the patient and, therefore, it is essential that the endotracheal tube be verified, not only once inserted, but continuously while caring for a mechanically ventilated patient in a critical care unit. Inadequate ventilation, secondary to incorrect endotracheal tube placement and esophageal intubation, accounts for death or permanent brain damage and for most of the legal claims in America. In almost all these claims, the injuries were considered preventable with better assessment and monitoring. It is thus cardinal that nurse practitioners are knowledgeable and vigilant in ensuring correct placement and verification of endotracheal tube in mechanically ventilated patients (Salem, 2001:813).

2.7.1.4 Frequency for verifying endotracheal tube placement

Endotracheal intubation is a “potential minefield for disaster”. Errors in its performance can be associated with high morbidity and mortality for the patient and legal liability for the practitioner (Delorio, 2005:490). The properly placed endotracheal tube provides the definite protected airway and is crucial to ensuring adequate ventilation in the event of cardiac arrest, respiratory failure or significant trauma. Nevertheless, many malpractice claims have been successful because practitioners did not promptly recognize that they had improperly placed the endotracheal tubes. Therefore, it is important that nurse practitioners verify endotracheal tube placement at least once every shift, which can be either 6-or 12 hourly, to detect inadvertent position changes (Salem, 2001:813; DeBoer, 2003:444).

2.7.1.5 Methods for endotracheal tube placement verification

There are various methods used to verify endotracheal tube placement. These methods include identification of carbon dioxide in exhaled gas, the use of clinical assessment findings, palpation of the endotracheal tube cuff on each side of the

trachea, pulse oximetry, direct laryngoscopy and chest radiography (Morton and Fontaine, 2009:605). These methods will be discussed.

Identification of carbon dioxide in exhaled gas

Identification of carbon dioxide in exhaled gas has been identified as the best recommended and most accurate method to confirm endotracheal tube placement and rule out esophageal displacement (Falk and Sayre, 1994:273; Saunders, Clum, Nguyen and Balasubramaniam, 1994:774; Knapp, Kofler and Stoiser, 1999:766; Puntervoll, Søreide, Jacewicz and Bjelland, 2002:455; Cheifetz and Myers, 2007:424). Identification of carbon dioxide in exhaled gas comprises of two methods, namely capnography and calometric measurements, which will be discussed later in this section.

In a study done by Erasmus (2004:672-675) in 66 critical care units in Australia and New Zealand, it was found that end-tidal carbon-dioxide monitoring was used routinely to confirm endotracheal placement in 68% of the units. Fifty-two (83%) of the participants felt that end-tidal carbon-dioxide monitoring was superior to other methods of confirming endotracheal tube placement in the critically ill patient. Thirty-eight participants (62%) thought that end-tidal carbon-dioxide monitoring should be mandatory to confirm endotracheal intubation. Mandatory end-tidal carbon-dioxide confirmation of endotracheal tube placement was policy in 33 (54%) of the critical care units.

Although Soubani (2001:145) agrees that end-carbon-dioxide measuring helpful is in the detecting misplacement of the endotracheal tube, it is advocated that the capnographic readings be interpreted with caution in the critically ill patient with decreased perfusion and those with acute respiratory failure.

Clinical assessment findings

Nurse practitioners can use their clinical assessment skills to aid in verifying the endotracheal tube placement. These skills include inspection of symmetrical chest movements and auscultation of bilateral breath sounds (Pierce, 2007:73).

Inspection of the patient involves checking the presence or absence of several factors affecting the respiratory system and functioning. With regard to endotracheal tube verification, inspection of the chest movement can aid in noting if the endotracheal tube is in the correct position or not. Inspection of symmetric chest movements during compression of the reservoir bag can assist to distinguish between tracheal and esophageal intubations. Inspection of an asymmetric chest movement and detection of unequal bilateral breath sounds should alert the nurse to the possibility of a main-stem intubation. Absence of right apical movement or breath sounds should imply that the tube and its cuff are obstructing the right upper lobe bronchus. However, in obese patients, women with large breasts and patients with rigid chest walls, inspection findings can be misinterpreted and should thus be used with caution (Salem, 2001:816; Morton and Fontaine, 2009:544).

In chest auscultation, the diaphragm of the stethoscope is pressed firmly against the chest wall enabling the nurse to listen to the intensity or loudness of breath sounds. Normal breath sounds across the lungs bilaterally are heard on auscultation if the endotracheal tube is correctly placed (Morton and Fontaine, 2009:555-556). However, the reliability of auscultation is related to a tidal volume during the test, sites of auscultation, presence of gastric distention and the experience of the examiners (Takeda *et al*, 2003:154). Referred breath sounds can be heard throughout the chest, even with esophageal endotracheal tube placement. Breath sounds can also not be auscultated easily in a very noisy environment, thus limiting their use to verify endotracheal tube placement (DeBoer, 2003:445).

Palpation of the endotracheal tube cuff on each side of the trachea

Palpation of the cuff in the neck or on each side of the trachea between the cricoid cartilage and the suprasternal notch while moving the tube has been proposed as a method of verifying endotracheal tube placement. However, a low-pressure, large-volume, pre-stretched cuff may not be palpable despite correct placement. Conversely, an inflated cuff can be palpated in the neck in cases of esophageal intubation. This method should thus not be relied on and has not been validated by research (Salem, 2001:820). However, a single, older study done by Pollard and Lobato (1995:135-138) indicated that the palpation of the cuff in the neck on each

side of the trachea is a reliable, cost-effective and advantageous method to verify the endotracheal tube placement.

Pulse oximetry

Pulse oximetry is the continuous, non-invasive measurement of arterial oxygen saturation (SaO₂), which is the amount of oxygen carried by haemoglobin. Pulse oximetry is useful in determining a patient's oxygenation status and is an indicator and early warning sign of hypoxia, because desaturation is detected earlier by pulse oximetry than by clinical observation. It has been found that as many as 87% of nurses regularly use this technology to assess the status of the patient. However, only 36% of nursing staff felt that they had adequate knowledge in the use of the pulse oximetry (Grap, 2002:69). In a literature review comprising 14 studies done by Elliot, Taste and Page (2006:139-144), it was found that there is a significant knowledge deficit regarding the accurate use and interpretation of pulse oximetry. There is a concern that if the practitioners' understanding of oximetry is poor, they may be unable to determine false high or low oxygen saturation readings.

Although pulse oximetry will indicate the oxygenation status, unrecognised esophageal intubation, ultimately leading to a severe decrease in arterial oxygen saturation, might only be detected minutes after this has happened. Various factors, for instance, pre-oxygenating the patient, changes in the oxygen consumption and cardiac output, and underlying respiratory alterations can influence the pulse oximetry readings. Misplacements of the ET tube might thus not be immediately detected through the use of pulse oximetry and it is, therefore, not a reliable indicator of ET tube verification (Schell and Puntillo, 2001:122; Pierce, 2007:332). A single-blinded, cohort study done by Hale, Jewett and Harris (1999:s14) revealed that pulse oximetry findings is an unreliable method to confirm the endotracheal tube placement. Although the pulse oximetry reading was up to 98% in the patients in this study, it was found that the endotracheal tube was placed in the right or left main-stem bronchus or was too deep or too shallow. Therefore, it is not recommended to use pulse oximetry as a method to verify endotracheal tube placement.

Direct laryngoscopy

Viewing the tube passage through the larynx during or after intubation is a reliable and direct method to ensure tracheal tube placement. Direct laryngoscopy is considered the primary method of verification. Viewing of the ET tube entering the larynx, however, cannot be performed in all cases of direct laryngoscopy, especially if the intubation is difficult (Salem, 2001:815). Copious amounts of blood or secretions in the line of sight can make direct visualization quite difficult. Anatomic irregularities, such as a large tongue, prominent teeth, or a short thick neck, can further interfere with direct visualization, especially when cervical stabilization must be maintained. Because of these problems and the fact that the tube may become dislodged before or after it has been secured, there is an absolute need for secondary methods of verification. Furthermore, direct laryngoscopy must be performed by the practitioner who is competent and skilled in managing intubations and an artificial airway (DeBoer, 2003:445).

Chest radiographs

Chest radiographs are routinely performed on the majority of mechanically ventilated patients to verify the correct position of the endotracheal tube placement or other invasive lines and to diagnose complications such as VAP, pulmonary edema and pneumothorax. A chest radiograph is always requested following endotracheal tube intubation. This is because physical examination is not sufficiently sensitive to determine the endotracheal tube mal-position. Although clinical physical assessment can recognize a misplaced endotracheal tube 2-5% of the time, suboptimal positioning is identified in 20-25% of cases by chest x-rays (Trotman-Dickenson, 2003:198). However, Krivopal, Oksana, Shlobin and Schwartztein (2003:1612) indicate that endotracheal tube mal-positioning is common enough to warrant a portable chest radiograph after an intubation. But once the endotracheal tube is in place and secured, there should not be any reason to perform routine chest radiographs to confirm the endotracheal tube placement.

Although chest radiographs have been used for many years in the critical care units as a diagnostic tool, there have been various debates on the topic. Clec'h, Simon, Hamdi, Karoubi, Fosse, Gonzalez, Vincent and Cohen (2008:270) recommend

restrictive use of chest x-rays in the mechanically ventilated patient in the critical care unit as their study revealed better prognostic and therapeutic efficacy when restrictive uses of chest x-ray were implemented compared to daily radiographs. Their study lends support to protocols advocating clinically indicated, rather than daily routine chest x-rays, until digital radiographs are more widely available. Krivopal *et al* (2003:1614) performed a randomised controlled trial and found that there were no additional benefits from a strategy that required daily chest x-rays in comparison to one that mandated only clinically indicated chest x-rays.

Chest radiographs based on clinical indications yielded better diagnostic and therapeutic efficacy at lower cumulative radiation exposure and decreased cost, with no difference in the duration of critical care and hospital stay and no increase in mortality. It can thus be concluded that chest radiographs can be used to verify the endotracheal tube placement initially. Thereafter, the use of radiographs are not essential, unless abnormalities are expected, or cost-effective to use as a method to verify endotracheal tube placement (Graat, Stoker and Vroom, 2005:240; Graat, Kröner, Spronk, Koerevaar, Stoker, Vroom and Schultz, 2007:639-644). According to the American College of Emergency Physicians (ACEP, 2009:141), chest radiographs are not reliable as sole techniques to determine endotracheal tube location.

2.7.1.6 Inspection findings to verify endotracheal tube placement

When using inspection as a method to verify endotracheal tube placement, the chest wall should be observed for equal, symmetrical and bilateral chest movement. Observation for the absence of abdominal distention, cyanosis and hypoxia helps to confirm the endotracheal tube placement (Liang, 2008:153).

2.7.1.7 Auscultation findings to verify endotracheal tube placement

Auscultation of the patient should focus on evaluation of normal breath sounds, identification of abnormal sounds and the assessment of voice sounds. Auscultation of breath sounds must be done in each axilla, over both lungs fields, to decrease the chance of being misled by breath sounds from the opposite lung. Breath sounds heard near the mid-axillary lines confirm that the tube is properly placed (Pierce,

2007:71). Absence of breath sounds is indicative of an esophageal intubation, whereas breath sounds heard on only one side is indicative of a main-stem intubation (Urden *et al*, 2006:662). Diminished breath sounds on one side necessitate the immediate withdrawal of the endotracheal tube until breath sounds become equal (Pollard and Lobato, 1995:136). In order to aid in correct verification of the endotracheal tube, bilateral breath sounds must be auscultated (Morton and Fontaine, 2009:557).

2.7.1.8 Chest radiography findings to verify endotracheal tube placement

When using chest radiographs to verify the endotracheal tube placement, the correct findings must be noted. The tip of endotracheal tube should be approximately 2-3 cm above the carina when the patient's head is in the neutral position. Once final adjustment of the position is complete, the level of insertion at the teeth is noted (Urden *et al*, 2006:662).

Esophageal intubation should be suspected if any part of the border of the tube is seen outside or lateral to the air column of the trachea-bronchial tree and when there is noticeable deviation of the trachea caused by an over-inflated cuff (Salem, 2001:830).

2.7.1.9 Methods to identify carbon dioxide in exhaled gas

Carbon dioxide is a by-product of cellular metabolism and is transported in the venous blood to the lungs, where it is eliminated during the expiratory phase of breathing. Identification of carbon dioxide in exhaled gas has emerged as the standard for verification of proper endotracheal tube placement and includes the use of two methods, namely capnography and calorimetric detection of carbon dioxide, which will be briefly discussed (DeBoer, 2003:446).

Capnography

Various principles are used to measure carbon-dioxide/end-tidal carbon-dioxide levels in the inspired and exhaled gases on a breath-to breath basis and are then displayed on a carbon-dioxide waveform. Capnography is defined as the numerical and graphical representation of carbon-dioxide concentration during the respiratory

cycle, whereas capnometry is the digital display of carbon-dioxide measurement. The capnometer sensor device is placed near the patient's mouth or in-line with the exhaled circuit of the ventilator. The numerical value that is displayed is termed the end-tidal carbon dioxide (ETCO₂), which reflects the peak amount of CO₂ during exhalation. This exhaled measurement closely reflects the PaCO₂ (Martin and Wilson, 2002:10).

Capnography used to confirm the initial ETT placement has also proved to be invaluable in detecting a dislodged or occluded ET tube. Esophageal intubation can be detected using capnography. If the tube is in the trachea, the capnography carbon-dioxide level will rapidly rise. Other indications include assessment of the pulmonary circulation and monitoring of ventilation in both mechanically ventilated and non-intubated patients (Schell and Puntillo, 2001:287). According to Lynn-McHale and Carlson (2001:11), continuous end-tidal CO₂ monitoring can be used to determine a baseline CO₂ waveform, continuously monitor the patency of the airway and the presence of breathing, provide a mechanism for early detection of changes in the waveform pattern value and assist in evaluating the patient's response to activities that may positively or negatively affect ventilation, e.g., suctioning or repositioning of a patient.

It is, however, important that the nurse practitioner be able to recognize and interpret changes in the shape of the capnogram to assess the ventilator status adequately. In a normal capnogram, at the beginning of exhalation, the carbon-dioxide value is zero as gas from the anatomic dead space leaves the airway (Figure 2.3:A-B). A sharp rise in the waveform (and thus in carbon-dioxide elimination) occurs as alveolar air mixes with dead-space gas (Figure 2.3:B-C). Most of exhalation is represented by a levelling of the curve known as the alveolar plateau, which represents gas flow from the alveoli (Figure 2.3:C-D). The PCO₂ at the end of the plateau (Figure 2.3:D) is the ETCO₂, which is the highest concentration of exhaled alveolar carbon dioxide. The curve then takes a rapid, sharp down stroke as inspiration of carbon-dioxide free gas occurs (Figure 2.3:D-E). Figure 2.3 illustrates a normal capnogram (Pierce, 2007:344).

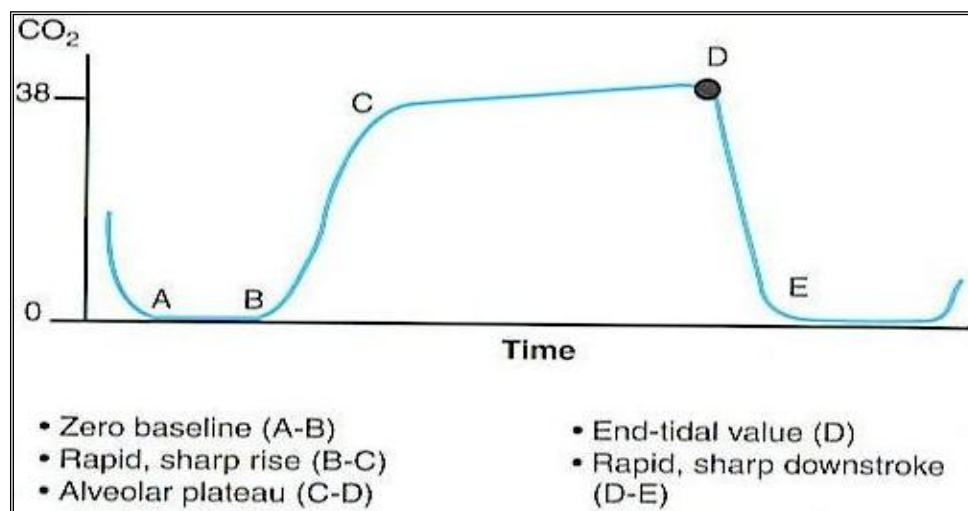


Figure 2.3 Normal capnogram (Pierce, 2007:344)

2.7.1.10 Normal range for carbon-dioxide measurements

The normal range for carbon dioxide measurement must be between 35 to 45 mmHg to indicate correct placement of the endotracheal tube (Pierce 2007:72). Patients with normal lung function will have an end-tidal carbon-dioxide value of 35-45 mmHg and a narrow ETCO₂-PaCO₂ gradient (0-5 mmHg). The amplitude of a capnogram is determined by the end-tidal carbon-dioxide value and the width is determined by the expiratory time. Hyperventilation results in a low amplitude and narrow capnogram, whereas hypoventilation results in a high amplitude and wide waveform. In the normal state, the ETCO₂ is slightly lower than the PaCO₂ because of alveolar dead space. Increased ETCO₂ readings equate with increased PaCO₂; therefore, in patients without chronic hypoventilation, ETCO₂ greater than 70 mmHg indicates respiratory failure (Nagler and Krauss, 2009:83).

2.7.1.11 Calometric detection of carbon-dioxide measurement

Calometric carbon-dioxide analysis is considered by many the standard for detection of esophageal intubation. The device is placed on the end of the ET tube and the patient is given six full breaths. At end-expiration on the sixth breath, the colour is read. The indicator paper changes colour if carbon dioxide is detected. If the indicator remains purple, the carbon-dioxide level is low and represents esophageal intubation. If it turns yellow, the carbon-dioxide level is high, indicating a tracheal

intubation. Beige indicates an intermediate carbon-dioxide level, with an indeterminate result (Mims, Roberts, Toto, Brock, Leucke and Tyner, 2004:28).

Calometric devices are reliable as long as the patient is alive, has a perfusing cardiac rhythm and the device remains uncontaminated. In a case of limited pulmonary perfusion, very little carbon dioxide gets to the lungs to be exhaled and the adapter may not change colour quickly if at all. Fluids that may be found in and around the respiratory tract can affect the reliability of these devices. To ensure reliability of the device, manufacturers recommend examining the detector after 6 breaths for true verification of endotracheal tube placement (DeBoer, 2003:448).

Calometric devices are less expensive than capnography, are portable and are single-use disposable items. They are safe, reliable and provide early confirmation of tracheal intubation and early detection of esophageal intubation. Calometric monitoring confirms endotracheal tube placement more rapidly than chest auscultation. However, calometric monitoring is only recommended as a method to verify endotracheal tube placement when capnography is not available in patients who are hemodynamically stable (Goldberg, Rawle, Zehnder and Sladen, 1990:191).

2.7.1.12 Summary of the section on endotracheal tube verification

As illustrated by the literature, there are various complications related to incorrect placement of the endotracheal tube in the critically ill, mechanically ventilated patient. Although considered a simple manoeuvre, intubation of the trachea can produce grave consequences if the endotracheal tube is misplaced in the esophagus, or in the main stem bronchus, or if inadvertent extubation occurs. Mal-positioning of the endotracheal tube may jeopardise the safety of the patient. Therefore, it is important to verify endotracheal tube placement according to the best recommended method. Endotracheal tube verification should thus become an integral part of patient monitoring in a critical care unit.

2.7.2 NURSING CARE PRACTICE TWO: ENDOTRACHEAL TUBE CUFF PRESSURE MONITORING

Endotracheal intubation is a life-saving procedure that enables the application of mechanical ventilation. In adults, endotracheal tubes have a balloon-like cuff that when inflated seals the airway, enabling delivery of positive-pressure ventilation without the loss of volume or aspiration of pharyngeal contents. Intra-cuff pressure provides an approximation of cuff tube pressure. The measurement of cuff pressures is, therefore, one mechanism advocated to prevent complications related to excessive or inadequate cuff pressures (Pierce, 2007:93).

The key words that were used in searching electronic data bases for this section included the following: “critical care unit”; “intensive care”; “nursing”; “endotracheal tube”; “tracheal tube”; “cuff pressures”; “cuff pressure AND monitoring”; “over-inflation AND cuff pressures ”; “under-inflation AND cuff pressures”.

This section aims to discuss cuff management practices necessary to ensure the safety of the mechanically ventilated patient. A summary of the items for discussion is illustrated in Table 2.3.

Table 2.3 Items for discussion on endotracheal tube cuff pressure monitoring	
2.7.2.1	Functions of the endotracheal cuff
2.7.2.2	Frequency for measuring endotracheal tube cuff pressure
2.7.2.3	Positioning of the patient in monitoring endotracheal tube cuff pressure
2.7.2.4	Methods to check endotracheal tube pressures
2.7.2.5	Normal range for endotracheal tube cuff pressures
2.7.2.6	Deflation and re-inflation of endotracheal tube cuffs
2.7.2.7	Cuff leaks
2.7.2.8	Consequences of under-inflation of the endotracheal tube cuff
2.7.2.9	Consequences of over-inflation of the endotracheal tube cuff
2.7.2.10	Summary of the section on endotracheal tube cuff pressure monitoring

2.7.2.1 Functions of the endotracheal cuff

The endotracheal tube comprises a cuff, which is illustrated in Figure 2.1. The purpose of the cuff on airways is twofold: to allow for the application of positive-pressure ventilation without a loss of tidal volume and to prevent aspiration of oral and gastric secretions. For the cuff to perform these two functions, it must exert some pressure against the tracheal wall. The pressure between the cuff and the tracheal wall is appropriately termed the cuff-to-tracheal wall pressure or the cuff pressure. The cuff pressure should be as low as possible so that the cuff may perform its functions while complications of excessive pressures are prevented (Pierce, 2007:91).

2.7.2.2 Frequency for measuring endotracheal tube cuff pressure

Endotracheal tube pressures should be monitored at least once per shift, which can be 6- or 12 hourly to prevent overdistention and excess pressure on the tracheal wall mucosa, which can cause complications such as tracheal stenosis. However, if any adjustments are made to the ventilator or if the patient is re-positioned, the cuff pressures should be checked (Urden *et al*, 2006:667; Pierce, 2007:93 and Morton and Fontaine, 2009:609).

2.7.2.3 Positioning of the patient in monitoring endotracheal tube cuff pressure

Cuff pressure monitoring procedures should be performed in the semi-recumbent position, which is 30-45 degrees. It is known that this recommended practice reduces stimulation of the gag reflex and the risk for aspiration, which might contribute to the development of ventilator-associated pneumonia (VAP) in the mechanically ventilated patient. VAP in the critically ill patient may increase hospital stay, increase cost, morbidity and mortality and it is, therefore, important to avoid factors which might contribute to its development. Supine positioning has been associated with a higher incidence of significant aspiration. (Metheny, Clouse, Chang, Stewart, Oliver and Kollef, 2006:1010).

2.7.2.4 Methods to monitor endotracheal tube pressures

Four methods for measuring and monitoring cuff pressures are described. These are the minimal occlusive volume technique (MOV), the minimal leak technique (MLT), the cuff pressure measurement (CPM) and the palpation method (Pierce, 2007:93).

The MOV describes the method used when there is sufficient air in the cuff to abolish air leaks on inspiration. During auscultation over the trachea, air is injected into the cuff until no leak is heard. Then 0.5 ml air is removed until a small leak is heard. Air is then re-installed until no leak is auscultated on inspiration. MOV offers less potential for aspiration because the trachea is sealed and there is no loss of tidal volume. However, it has a greater potential for injury to the trachea wall than MLT (Mims *et al*, 2004:29).

The MLT describes the method used when there is sufficient air in the cuff to allow a small leak on inspiration. During auscultation over the trachea, air is injected into the cuff until no leak is heard. The air is then removed in 0.1 ml increments until a small air leak is heard. The MLT is advantageous as it avoids the pooling of secretions above the cuff because they will either be forced up by air passing around the cuff or will drain into the lung to be coughed up. It is potentially less harmful to the trachea because it uses a lower cuff pressure and is, therefore, likely to be associated with less tracheal damage than the MOV. However, the MLT can cause aspiration caused by secretions filtering around the cuff into the lungs and also cause a loss of tidal volume (Mims *et al*, 2004:29).

The CPM is performed with an aneroid manometer during the inspiratory phase, provides objective measurement of the cuff pressure and does not involve cuff deflation. Sphygmomanometers have been used in the past but due to removal of mercury from hospitals and the use of automatic blood pressure cuffs, this practice is not as common. CPM is done by using a Cufflator or similar aneroid cuff pressure manometer. These devices vary according to manufacturer and guidelines should be considered when using them. Furthermore, pressure readings might be influenced by a patient's body position and head alignment, tube migration, coughing, lung compliance, and airway and intra-thoracic pressures. (Pierce, 2007:95). Figure 2.4

shows an example of an aneroid manometer that can be used in cuff pressure monitoring.

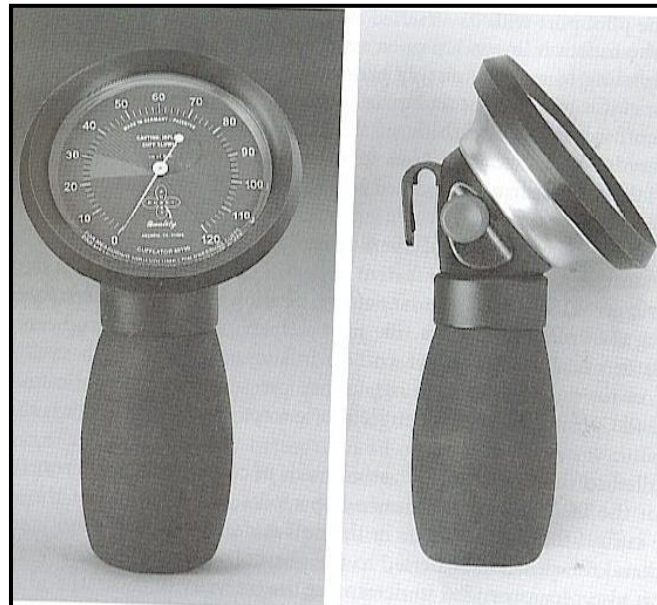


Figure 2.4 Aneroid pressure manometer (Pierce, 2007:95)

The fourth method, palpation, involves the subjective estimation of cuff inflation based on gentle palpation of the pilot balloon. This method is subjective and its use has resulted in excessive pressures in numerous studies, with cuff pressures as high as 100 cmH₂O identified when estimation techniques were used exclusively (Morton and Fontaine, 2009:610; Mims *et al*, 2004:29). This method is thus not recommended in ensuring adequate cuff pressures.

2.7.2.5 Normal range for endotracheal tube cuff pressures

Most tracheal injury from endotracheal intubation is cuff site ulceration from lateral tracheal wall pressures exerted by the inflated cuff. Tracheal capillary arterial perfusion pressure is estimated to be approximately 22 mmHg, and lymphatic flow occurs at 5 mmHg. The pathogenesis of tracheal injury begins when cuff pressure exceeds tracheal perfusion pressure. Ischemia and inflammation result and may progress to mucosal necrosis, ulceration and haemorrhage. Mucosal injury through the healing process may result in granuloma and scar formation. After extubation or decannulation, these areas may cause stenosis or obstruction (Pierce, 2007:93).

The cuff pressure should thus be maintained at 25-30 cmH₂O (18-22 mmHg). Cuff pressures less than 18 mmHg are associated with an increased risk of aspiration and a 2.5 fold increase in VAP, whereas pressures greater than 22 mmHg (30 cmH₂O) may impede capillary blood flow to the area of the tracheal wall in contact with the cuff, resulting in damage of the tracheal wall mucosa. Total obstruction of tracheal blood flow occurs at pressures greater than 50 cmH₂O. In patients with hypotension, cuff pressures of more than 34 cmH₂O may exceed the perfusion pressure of the trachea, resulting in significant tracheal damage (Rose and Redl, 2008(b):433).

2.7.2.6 Deflation and re-inflation of endotracheal tube cuffs

Routine deflation of endotracheal tube cuffs is no longer indicated because it does not significantly affect lateral tracheal wall pressure and may, in fact, increase the risk of aspiration and pneumonia (Urden *et al*, 2006:667).

2.7.2.7 Cuff leaks

Possible sources of air loss might be from around the cuff as result of patient position changes, from the cuff itself, from a faulty one-way valve on the pilot balloon or from a cracked or broken inflation line. If it is determined that the leak is caused by position changes, repositioning the patient's head should correct the problem. If the leak is from the cuff or from a cracked or broken inflation line, then the patient should be re-intubated. Air leaks may also be caused by an endotracheal tube being misplaced too high in the trachea. The cuff should be deflated, followed by repositioning and stabilizing the tube (Pierce, 2007:98).

Whenever a leak is noted, continued cuff inflation should be attempted to obtain a seal, irrespective of volume of air inserted. However, if more than 10 ml of air is inflated, the physician should be notified as the patient might require re-intubation (Morton and Fontaine, 2009:609).

2.7.2.8 Consequences of under-inflation of the endotracheal tube cuff

The presence of an artificial airway in the trachea is associated with a number of potential problems and complications. Some of these problems are immediately

apparent but many will not become apparent until later in the patient's recovery period when decannulation highlights them (Adam and Osborne, 2005:87).

Under-inflation of the endotracheal tube cuff is associated with inadequate delivery of prescribed tidal volume and aspiration of secretions. The goal is to keep cuff pressures below the capillary perfusion pressures. However, lower cuff pressures, <20 mmHg or <15 mmHg, are associated with silent micro-aspiration or subglottic secretions through folds in the cuff wall. Therefore, it is recommended that cuff pressure be maintained at 18 to 22 mmHg (25 to 30 cmH₂O) to compromise between the risk of aspiration and the risk of ischemia (Adam and Osborne, 2005:88).

2.7.2.9 Consequences of over-inflation of the endotracheal tube cuff

Pressure from the cuff of the endotracheal tube or from the tube itself on the pharyngeal, laryngeal and tracheal mucosa can result in long-term damage. Edema and ulceration in the upper airway, caused by pressure from the endotracheal tube, can be observed after several days of intubation. Most of the injury from pressure of the tube occurs in the posterior commissure and posterior portion of the pharynx (Beebe, 2001:170 Sierra, Benitez, Leon and Rello, 2005(b):460).

Over-inflation of a cuff creates excessive pressure on the trachea wall. This constant pressure can lead to weakening of the tracheal muscles or softening of cartilage. The area of contacts dilates and volume must be added to the cuff to achieve an effective seal. The trachea may then further dilate, requiring more volume in the cuff and a dangerous cycle is set up. Erosion into adjacent structures may present as tracheoesophageal or tracheovascular fistula (Pierce, 2007:91).

Complications related to over-inflation of the endotracheal tube cuff include tracheal erosion, tracheal stenosis, tracheal rupture or tracheal innominate artery fistulas. Tracheal stenosis, an abnormal narrowing of the tracheal lumen, most commonly occurs at the level of the stoma or above the stoma, but below the vocal cords. Tracheal stenosis may also occur at the site of the endotracheal tube cuff or at the site of the tube's distal tip, where cuff pressure exceeds the perfusion pressure of the capillaries of the tracheal wall. Shearing forces from the tube or the cuff may further

aggravate injury to the airway. With prolonged ischemia, mucosal ulceration, chondritis and cartilaginous necrosis may ensue, leading to the formation of granulation tissue. The process is exacerbated by the presence of pooled secretions or gastro-esophageal reflux disease. Tracheal stenosis may present while the patient is still undergoing mechanical ventilation, the presentation may be that of a patient who cannot wean from mechanical ventilation or who cannot be decannulated. Alternatively, tracheal stenosis may present as unexplained dyspnea weeks to months after decannulation (Epstein, 2005:544).

Tracheomalacia or weakening of the tracheal wall results from ischemic injury to the trachea, followed by chondritis and subsequent destruction and necrosis of supporting tracheal cartilage. Tracheomalacia may present as failure to wean from mechanical ventilation. Tracheoinnominate artery fistula occurs in less than 1% of all patients who are intubated, but have a 100% mortality rate if it occurs. Risk factors for the development of tracheoinnominate artery fistula include excessive movement of the tube, over-inflated cuff or a tube that has been placed too low. The over-inflated cuff balloon can severely damage the tracheal mucosa leading to necrosis and eventual erosion into the innominate artery. Excessive cuff pressure can cause posterior tracheal injury leading to the development of a tracheoesophageal fistula. The presence of a nasogastric tube and resulting esophageal injury may also contribute to the development of this complication. It may manifest as the copious production of secretions (Darteville and Macchiarini, 1996:822).

Due to the complications related to under-inflation and over-inflation of the endotracheal tube cuff, it is thus of utmost importance that nurse practitioners are aware of these complications and should maintain the correct cuff pressures to ensure the safety of the mechanically ventilated patient in a critical care unit.

2.7.2.10 Summary of the section on endotracheal tube cuff pressure monitoring

This section illustrated the importance of implementing meticulous cuff management practices when caring for the mechanically ventilated patient. Meticulous care of the airway may reduce the complications associated with incorrect cuff pressure

measurement and monitoring. It is, therefore, imperative that nurse practitioners caring for the critically ill patient ensure that cuff pressures are monitored correctly and consistently in order to ensure the patient safety while connected to the mechanical ventilator.

2.7.3 NURSING CARE PRACTICE THREE: ENDOTRACHEAL TUBE SUCTIONING

Endotracheal and tracheostomy tubes are used to maintain a patent airway and to facilitate mechanical ventilation. The presence of these artificial airways, especially endotracheal tubes, prevents glottic closure. As a result, the patient is unable to use the normal clearing mechanism, namely to effectively cough up secretions, thus requiring periodic removal of pulmonary secretions with suctioning. Endotracheal tube suctioning is defined as a component of bronchial hygiene therapy and mechanical ventilation and involves the removal of secretions using a suction catheter placed in the trachea. Endotracheal tube suctioning is an important activity in reducing the risk of consolidation and atelectasis that may lead to inadequate ventilation and is essential for maintaining airway patency (Adam and Osborne, 2005:103; Urden *et al*, 2006:668; Morton and Fontaine, 2009:578).

A summary of the items for discussion in this section is illustrated in Table 2.4.

Table 2.4 Items for discussion on endotracheal tube suctioning	
2.7.3.1	Frequency for performing endotracheal tube suctioning
2.7.3.2	Indications for endotracheal tube suctioning
2.7.3.3	External diameter of suction catheter
2.7.3.4	Patient assessment prior to suctioning
2.7.3.5	Positioning of the patient when performing suctioning
2.7.3.6	Suction pressures
2.7.3.7	Hyper-oxygenation
2.7.3.8	Hyperinflation
2.7.3.9	Normal saline instillation
2.7.3.10	Hand hygiene
2.7.3.11	Duration of suction procedure
2.7.3.12	Depth of catheter insertion
2.7.3.13	Complications of endotracheal tube suctioning
2.7.3.14	Respiratory assessment post suctioning
2.7.3.15	Endotracheal tube suctioning technique
2.7.3.16	Summary of the section on endotracheal tube suctioning

The key words that were used in searching electronic data bases for this section included the following: “critical care unit”; “intensive care”; “endotracheal tube”; “tracheal tube”; “suctioning”; “airway clearance”; “tracheal suctioning”; “normal saline AND suctioning”; “hyperoxygenation AND suctioning”; and, “hyperinflation”.

2.7.3.1 Frequency of endotracheal tube suctioning

Based on the results from the narrative literature review, it is recommended that endotracheal suctioning be performed intermittently when evidence of secretions in large airways is heard as crackles or wheezes (Adam and Osborne, 2005:103). It is, furthermore, argued that suctioning is a necessary frequent intervention in an intubated patient. Careful physical assessment of the patient is, however, essential to provide effective and timely removal of secretions, particularly in the presence of a weak or absent cough (Elliot *et al*, 2007:280). This argument is supported by Day, Wainwright and Wilson-Barnett (2001:682), who state that endotracheal tube suctioning should be performed when clinical judgment indicates it and not on a

routine basis. The need for endotracheal tube suctioning should be determined by auscultation of adventitious breath sounds over the trachea and main-stem bronchi and the patient's lungs. Morton and Fontaine (2009:578) support this by stating that endotracheal tube suctioning is not without risks and should only be done when needed. According to Day *et al* (2001:685), endotracheal suctioning that is not clinically indicated may cause unnecessary anxiety and stress and provoke life-threatening suction-related complications. Therefore it is recommended that endotracheal tube suctioning be done only when required and not routinely.

2.7.3.2 Indications for endotracheal tube suctioning

Endotracheal tube suctioning is indicated whenever a patient is unable to clear secretions independently. It is recommended that the frequency of suctioning should not be based on a routine schedule but on clinical signs and symptoms. Other indications for suctioning include preparation for extubation, assessment of airway patency, cough reflex stimulation and sputum specimen collection. Suctioning should not be indicated for peripheral crackles, which are either far beyond the large central airways or caused by interstitial processes not associated with secretions. The nurse practitioner should also be aware of the signs and symptoms of excessive secretions, which might include adventitious breath sounds on auscultation, ineffective cough, increased work of breathing, increased peak pressures as reflected on the mechanical ventilator and decreasing oxygen saturation (Schell and Puntillo, 2001:333).

2.7.3.3 Suction catheter size

Suction catheters should be as small as possible, yet large enough to facilitate secretion removal. When the catheter size is small, air may enter the lungs around the catheter during suctioning. This prevents a sudden drop in functional residual capacity and thus reduces the risk of atelectasis. It is recommended that the external diameter of the suction catheter be less than half of the internal diameter of the endotracheal tube to allow gases to flow around the catheter during suctioning. A catheter that is too small makes secretion removal difficult especially if secretions are thick (Adam and Osborne, 2005:104; Pierce, 2007:160).

2.7.3.4 Patient assessment prior to suctioning

As previously indicated, endotracheal tube suctioning should only be performed when necessary and not as part of the routine procedures in caring for the mechanically ventilated patient. Therefore, suctioning should be performed following a comprehensive assessment of the patient's respiratory status, which should include chest auscultation (Day *et al*, 2001:680). Chest auscultation findings such as rhonchi and crackles would be indicative of the need to perform suctioning (Pierce, 2007:163).

2.7.3.5 Positioning of the patient when performing suctioning

According to Day *et al* (2001:681) and Pierce (2007:160), the patient should be positioned in a semi-fowlers position, unless the patient's condition otherwise contraindicates this position. The semi-fowlers position is beneficial in performing endotracheal tube suctioning, as it promotes gas exchange. The supine position should be avoided as it increases the risk for aspiration and the development of ventilator-associated pneumonia in the critically ill patient.

2.7.3.6 Suction pressures

The amount of negative pressure produced by the suction source should be adjusted between 80 and 120 mmHg. In order to adjust the suction level, the suction source should be turned on, the end of the suction tubing must be occluded and the vacuum regulator should be adjusted until the dials read between 80 and 120 mmHg (Pierce, 2007:163). The use of a suction pressure of 80-120 mmHg was used in more than 50% of the studies of endotracheal suctioning examined by Oh and Seo (2003:912). However, patients on high levels of positive pressure ventilation may require slightly elevated suctioning pressures to aid in secretion clearance when using the closed suction system. Suction pressure may be increased to 150 mmHg only when deemed necessary, but should not exceed this pressure.

2.7.3.7 Hyperoxygenation

Suctioning may frequently lead to hypoxia, which can cause cardiac arrhythmias, hypotension and even cardiac arrest and death. A strategy to minimize these effects includes hyperoxygenation. Hyperoxygenation involves the administration of oxygen

at a greater percentage or fraction of inspired oxygen than the patient has been currently receiving. Hyperoxygenation before and after suctioning is the most critical variable in determining the post-suction PaO₂ and preventing hypoxemia during endotracheal suctioning (Pierce, 2007:164).

It is concluded in a study done by (Oh and Seo, 2003:915) that hyperoxygenation with 100% oxygen reduces the occurrence of suction-induced hypoxemia by 32%. Combining pre- and post- oxygenation reduces the incidence of hypoxia by 49%. Bourgault, Brown, Hains and Parlow (2006:268-278) examined the effect of endotracheal tube suctioning on arterial oxygen tension in a controlled trial comprising of 18 patients. Arterial oxygen tension was measured 30 seconds prior to hyperoxygenation and at 30 seconds and 5 minutes after the second suction pass. The study results showed a change in arterial oxygen tension from 30 seconds prior to hyperoxygenation to 5 minutes following suctioning, $p < .01$. In addition, after 5 minutes the arterial oxygen tension levels remained elevated above pre-suctioning levels, $p < .05$. The study concluded that hyperoxygenation with 100% oxygen for a minimum of 1 minute should be used in suctioning procedures to avoid a decrease in arterial oxygen tension following endotracheal tube suctioning.

2.7.3.8 Hyperinflation

Hyperinflation is performed by inflating the patient's lungs and may be performed with a manual bag or the ventilator. However, when a manual bag is used, the patient must be disconnected from the ventilator, which results in the loss of positive-pressure ventilation and positive-pressure end pressure (PEEP). The volumes delivered with a manual vary among individuals because of hand size and use of a one- versus two-handed techniques. Rarely can an individual deliver hyperinflation volumes with a manual bag when performing the procedure without an assistant. Use of one hand may result in volumes that are smaller than ventilator volumes. The use of ventilator hyperinflation may be superior because delivered volume and flow are precisely controlled and PEEP is maintained (Pierce, 2007:165).

It was found that the combination of hyperoxygenation and hyperinflation reduced the occurrence of hypoxemia by 55% compared to no intervention (Oh and Seo, 2003:915).

2.7.3.9 Normal saline instillation

The introduction of small amounts of sterile normal saline solution, usually 10 ml or less, is referred to as endotracheal instillation or lavage and is a highly controversial practice. Instillation of normal saline into the endotracheal tube, which used to be performed with suctioning, is an attempt to thin tenacious secretions. However, normal saline instillation may have significant adverse effects for the mechanically ventilated patient. These adverse effects include bronchoconstriction, decreased levels of SaO₂ and paroxysms of coughing resulting in increased intra-cranial pressure and arterial pressure, anxiety, nosocomial pneumonia and absorption of normal saline into the systemic circulation, contributing to fluid volume excess. It is thus recommended that the instillation of normal saline should not be part of the suctioning procedure (Mims *et al*, 2004:39).

2.7.3.10 Hand hygiene

Suctioning is an invasive procedure associated with an increased risk of infection. Aseptic technique is imperative during endotracheal tube suctioning. The hands should be washed before and after the procedure, and sterile gloves and a sterile suction catheter must be used. It is advisable that eye protection for the health care practitioner be routine. Universal precautions should be adhered to during endotracheal tube suctioning. It is recommended that nurse practitioners wear gloves with open, as well as closed, suction systems (Pierce, 2007:63; Morton and Fontaine, 2009:578).

2.7.3.11 Duration of suction procedure

The duration of the suctioning procedure affects the severity of adverse effect. A number of papers recommend a maximum of 10 seconds. Longer durations are associated with an increased risk of mucosal damage and hypoxemia (Morton and Fontaine, 2009:576; Pierce, 2007:64; Day *et al*, 2001:685).

2.7.3.12 Depth of suction catheter insertion

Stimulation of the vagus nerve may result in alterations in heart rate and blood pressure. Prolonged paroxysmal coughing will result in increased intra-thoracic pressure, decreased venous return and transient hypotension. The suction catheter should be inserted to the carina, which is either felt by resistance or on stimulation of a cough, and retracted 1-2 cm before applying suction (Pierce, 2007:63).

2.7.3.13 Complications of suctioning

Potential complications of the endotracheal suctioning procedure include cardiac arrhythmias, hypoxemia, cardiac arrest, vagal stimulation, mucosal trauma, atelectasis, contamination of the lower airway and the development of pneumonia, bronchospasm, pulmonary or tracheal bleeding and increased intra-cranial pressure. The cardiac complications may stem from procedure-induced hypoxemia or from tracheal stimulation. The nurse practitioner caring for the mechanically ventilated patient should be aware of these complications when suctioning the patient (Pierce, 2007:159). Infection is a major complication secondary to endotracheal tube suctioning and will be discussed briefly.

Infection

Intubated and mechanical ventilated patients are at significant risk from developing nosocomial infections because of suppressed immune function and invasive procedures (Robb, 1997:360). Although patients undergoing positive pressure mechanical ventilation may have impaired lung function and possible impaired systematic immune defences by virtue of their underlying lung pathology, further dysregulation of natural defences occur in these patients. The presence of an endotracheal tube bypassing natural upper airway defences, decrease or loss of coughing, paralysis of bronchial cilia, alterations in surfactant and phagocyte and epithelial defences (a critical first-line anti-bacterial defence mechanism) all contribute to impairment in host defence (Baker, Evans, Randle and Haslam, 1999:1232). Mechanical ventilation may not only enhance the local and systematic dissemination and, perhaps, the growth of pathogenic bacteria, but it may also increase susceptibility to the development of systematic bacteremia. The risk of

developing infection in the mechanically ventilated patient is thus increased (Dos Santos, Zhang, Liu and Slutsky, 2005:283).

Ventilator-associated pneumonia (VAP) is the second-most common hospital acquired infection and the leading cause of death from nosocomial infections. The incidence of nosocomial pneumonia is increased 10 fold in intubated patients, and the risk for developing VAP is especially great in the critically ill patient (Kollef, 2004:1400; ACCN, 2005:105; Cason, Tyner, Saunders and Broome, 2007:28-38). Morbidity and mortality associated with the development of VAP is high, with mortality rates ranging from 20 to 41%. The development of VAP increases ventilator days, critical care length of stay, hospital stay and additional cost to the patient and health care institutions (Bercault and Boulain, 2001:2303; Sierra, Benitez, Leon and Rello, 2005(a):170).

VAP is defined as pneumonia occurring in the mechanically ventilated patient that is neither present nor developing at the time of intubation and presents 48 hours after intubation (Grap and Munro, 2004:350). There is a great potential for the development of pneumonia after the placement of an artificial airway because the tube bypasses or impairs many of the lungs' normal defence mechanisms. Once an artificial airway is placed, contamination of the lower airways can develop within 24 hours. This results from a number of factors that can directly and indirectly promote airway colonization, and can include the use of ventilators, severity of patient's illness, malnutrition and the placement of nasogastric tubes (Urden *et al*, 2006:674).

Furthermore, factors contributing to infection and the development of VAP in the patient supported by mechanical ventilation include poor oral hygiene, aspiration, contaminated respiratory equipment, poor hand washing by care givers, breach of aseptic techniques during suctioning or handling of respiratory equipment, impairment of the muco-ciliary system because of oxygen toxicity, inadequate hydration, suboptimal humidification, trauma during suctioning, the decreased ability of the patient to produce effective coughing and removing of secretions and diminished airway reflexes (Pierce, 2007:300; Morton and Fontaine, 2009:602).

Implications for practice

In order to prevent the development and/or reduce the incidence of VAP in the mechanically ventilated patient, the health care practitioner needs to apply the following strategies:

- Elevate the head of the bed 30 to 45 degrees, if not medically contraindicated;
- Change the ventilator circuits only when soiled or malfunctioning;
- Use only sterile fluid for humidification or nebulisation;
- Practice proper hand hygiene before and after patient contact;
- Wear gloves for handling respiratory secretions or objects;
- Use the oral route for insertion of tubes;
- Exercise meticulous oral care using a well-defined oral hygiene programme;
- Use non-invasive ventilation whenever feasible (Pierce, 2007:301).

The advent of the ventilator bundle, which incorporates the above pointers, has reduced the incidence of VAP in many institutions. These procedures should be included as an integral part of the care of ventilated patients (Morton and Fontaine, 2009:602). There has been extensive literature published on VAP and the ventilator care bundle, but is beyond the scope of this study.

2.7.3.14 Respiratory assessment post-suctioning

To determine the effectiveness of the suctioning procedure, a thorough assessment of the patient should be made post-suctioning. This should include chest auscultation. The following would be indicative of the effectiveness of the suctioning procedure: increased oxygen saturation, decreased rhonchi on auscultation, decreased peak inspiratory pressure and decreased secretions (Day, 2000:13).

2.7.3.15 Endotracheal tube suctioning technique

Suctioning is performed using one of two basic methods, namely open and closed suctioning. The *open-suction technique*, which is regarded as the conventional technique, involves the use of a sterile, single-use suction catheter. It requires the health care practitioner to disconnect the patient's ventilator circuit from the endotracheal tube, insert the catheter into the patient's trachea, apply suction, withdraw the catheter and reconnect the ventilator circuit (Pierce, 2007:63).

In *closed-suction technique*, a multi-use suction catheter inside a sterile plastic sleeve is inserted through a special diaphragm attached to the end of the artificial airway (Lynne-McHale and Carlson, 2001:41). A closed-suction system consists of a suction catheter housed in a plastic sheath, an adapter that attaches to the ventilator circuitry and allows the system to remain continuously attached, an irrigation port for tracheal lavage solution instillation and for rinsing the catheter after use and a thumb-activated suction-control valve (Figure 2.5). After insertion of the catheter into the endotracheal tube and the performance of suctioning, the catheter is withdrawn into the plastic sleeve. Advantages of maintaining a closed-suction system include the reduction in the potential for contamination to personnel and the environment, maintenance of positive-pressure ventilation, less loss of PEEP and functional residual capacity and, therefore, less de-recruitment and hypoxemia, continuation of oxygen supply and the ability to suction the patient safely (Lynne-McHale and Carlson, 2001:41).

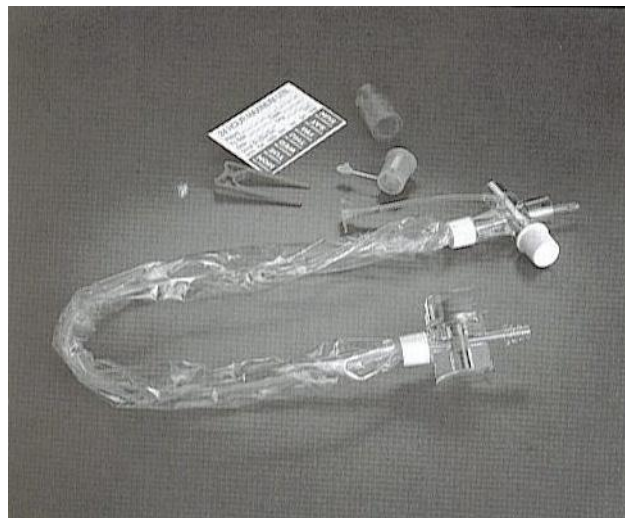


Figure 2.5 Closed-suction system (Pierce, 2007:161)

Closed-suction systems have become increasingly popular in the past decade. In the United States, 58% of the intensive care units use the closed-suction system, while only 4% use the open-suction system. Preferences for the closed-suction system were mainly based on the assumed advantages, like the lower incidence of VAP, fewer physiological disturbances, decreased microbial contamination, and thus the lower risk for cross infections (Paul-Allen and Ostrow, 2000:10). No literature was

found related to the use and/or preference of the closed versus open-suction systems in South Africa.

A systematic review on closed tracheal suction systems versus open-suction systems has been undertaken by Subrina, Sola, and Benito (2009) and is published by the Cochrane Library (<http://www.thecochranelibrary.com>). This review included 16 trials that evaluated the effects of a closed-suction system versus an open one. The review results showed that suctioning with either closed or open-suction systems had no effect on the risk of ventilator-associated pneumonia, mortality, cost or length of stay in a critical care unit. Another systematic review, comprising of eight randomised controlled trials conducted by Niel-Weise, Snoeren and van Broek (2007:531-536), confirms the findings in stating that the type of suction system did not make any difference in the incidence of VAP in the mechanically ventilated patient. In using a meta-analytic technique in comparing the use of closed versus open-suction systems in the development of VAP, Peter, Chacko and Moran (2007:201-211) as well as Jongerden, Maroeska, Grypdonck and Bonten (2007:260-269) and Zeitoun, Leite de Barros and Diccini (2003:484-489) confirm the findings that no differences were noted in the type of suction system used in the development of VAP.

The principles of endotracheal tube suctioning remain the same, whether using an open or closed suction system. The study will thus address the overall principles of endotracheal tube suctioning.

2.7.3.16 Summary of the section on endotracheal tube suctioning

Endotracheal tube suctioning is probably one of the most common respiratory procedures performed in the critical care settings by nurses and respiratory therapists. The goal of suctioning, namely secretion removal, should be obtained while patient discomfort and adverse hemodynamic effects are minimized and hypoxemia related to suctioning is prevented. Nurses should be aware of the best recommended practice in performing endotracheal tube suctioning. In adhering to this, the safety of the mechanically ventilated patient in the critical care unit will be ensured.

2.7.4 NURSING CARE PRACTICE FOUR: MECHANICAL VENTILATOR SETTINGS

Mechanical ventilator settings regulate the rate, depth and other characteristics of artificial ventilation in the patient requiring ventilatory assistance. Settings are based on the patient's status, including the arterial blood gases, body weight, level of consciousness and muscle strength (Lewis *et al*, 2004:1783). A variety of settings on the ventilator will allow ventilator parameters to be individualized to the patient and also allow selection of the desired ventilation mode. In addition, each ventilator has a patient-monitoring system that allows all aspects of the patient's ventilator pattern to be assessed, monitored and displayed (Urden *et al*, 2006:671).

Over the last decade, it has become clear that inappropriate application of mechanical ventilation can result in injury to the lung, which is referred to as ventilator-induced lung injury. Setting the correct and appropriate mechanical ventilator settings, which include the tidal volume, peak airway pressure, positive end expiratory pressure (PEEP), fraction of inspired oxygen concentration (FiO₂), respiratory rate and flow rate are important during the initial and continuous care of the mechanically ventilated patient (Pierce, 2007:288). For the purpose of this study, ventilator modes will also be considered as part of mechanical ventilator settings.

Setting and monitoring the correct mechanical ventilator settings will minimise the incidence of ventilator-induced lung injury and other complications related to mechanical ventilation, which is ultimately necessary to optimize the safety of the patients in critical care units. Therefore, it is cardinal to understand the complications related to incorrect mechanical ventilator settings. Furthermore, in order to ensure the safety of the critically ill patient, it is important to ensure that the alarms are correctly set as they warn the nurse practitioner of any troubleshooting, thus minimizing complications. For the purpose of this study, the complications of mechanical ventilation as well as a discussion on the alarms used in setting the mechanical ventilator were included.

Key words that were used in searching the data bases included the following: "mechanical ventilation" ; "ventilation"; "artificial respiration"; "ventilator-induced lung

injury”; “acute lung injury”; “lung protective strategies”; “PEEP”; “positive end expiratory pressure”; “tidal volume”; “reduced tidal volume”; “oxygen toxicity”; “oxygen administration”; “barotrauma”; “volutrauma”; “atelectrauma”; “biotrauma”; “respiratory rate”; “frequency”; “acidosis”; “alkalosis”; “hypoventilation”; “hyperventilation”; “complications AND mechanical ventilation”; and “troubleshooting AND mechanical ventilation”.

A summary of the mechanical ventilator settings discussed in this section is reflected in Table 2.5.

Table 2.5 Items for discussion on mechanical ventilator settings
2.7.4.1. Ventilator modes
2.7.4.2 Tidal volume
2.7.4.3 Peak airway pressure
2.7.4.4 PEEP
2.7.4.5 Fraction of inspired oxygen (FiO ₂)
2.7.4.6 Respiratory rate
2.7.4.7 Flow rate
2.7.4.8 Complications of mechanical ventilation
2.7.4.9 Alarms
2.7.4.10 Summary of mechanical ventilator settings

2.7.4.1 Ventilator modes

The variable methods by which the patient and the ventilator interact to deliver effective ventilation are called modes (Lewis *et al*, 2004:1783). According to Urden *et al*, (2006:671), ventilator modes refer to how the machine will ventilate the patient. In other words, selection of a particular mode of ventilation determines how much the patient will participate in his/her ventilatory pattern. The ventilator mode selected is based on how much work of breathing the patient ought to or can perform and is determined by the patient’s ventilator status, respiratory drive and arterial blood gases. Generally, ventilator modes are controlled or assisted. With controlled

ventilator support, the ventilator does all the work and with assisted ventilator support, the patient and the ventilator share the work of breathing (Pierce, 2002:56).

Modes are further categorised as volume modes and pressure modes, non-conventional and newer modes. Many of these modes may be used in conjunction with each other. However, in the midst of all the wide variety and availability, the modes of ventilator operation constitute one of the most essential and challenging areas of requisite knowledge for the nurse caring for patients undergoing mechanical ventilation (Mims *et al*, 2004:50). This is because the mode essentially determines the level of ventilator support offered and the way the machine (ventilator) is functioning at a given time. Therefore, to confidently and competently manage a patient-ventilator system and to ensure patient safety, familiarity with ventilator modes is fundamental to the professional nurses working in the critical care unit. For the purpose of this study, only volume and pressure modes and their effect in ensuring the safety of the critically ill patient while connected to the mechanical ventilator will be discussed.

Volume modes

Volume modes refer to the ventilator modes that are dependent on a preset volume of air in the ventilator. Volume modes include continuous mandatory ventilation, assist-control and synchronised, intermittent mandatory ventilation mode (Morton and Fontaine, 2009:594). These modes can be referred to as common modes of ventilation as they are frequently used in the critical care units and have been utilised traditionally in the majority of critically ill patients (Hamed *et al*, 2006:78). A brief description of the volume modes and the complications related to their use is given below.

Continuous Mandatory Ventilation (CMV)

With CMV, the patient receives a pre-set number of breaths per minute with a pre-set tidal volume at regular intervals. Patient effort does not trigger a mechanical breath and the ventilator performs all the work of breathing. This has led to the recommendation that this mode should be best reserved for patients with no respiratory effort because of the dysfunction of the central nervous system, for

instance, Guillain-Barrè syndrome or high-level spinal cord lesions, patients with apnea, respiratory arrest or those whose clinical condition requires sedation or paralysis or anaesthesia (Hamed *et al*, 2006:78; Pierce, 2007:214; Elliot *et al*, 2007:284).

CMV was used widely before the advent of assist-control ventilation and some manufacturers might even use the term CMV to refer to the assist-control mode. Many ventilator brands available might have a true CMV modes and assist-control would function as if they were CMV. However, despite of this confusion, the nurse should be aware of the differences and know the implications for caring for patients receiving this mode of ventilation. Because the patient cannot achieve a spontaneous breath, attempts to breathe results in patient effort with no flow delivered. This can lead to sensations of air hunger and significantly increase the work of breathing. With CMV, alveolar ventilation and the respiratory contribution to acid-base balance are completely controlled by the clinician. Acid-base balance should thus be closely monitored and ventilator settings must be adjusted to changing physiological scenarios such as fever, change in nutritional intake and stress. Respiratory muscle weakness and atrophy may result if CMV is used for an extended period, thus prolonging the weaning process (Hamed *et al*, 2006:78).

Adverse hemodynamic effects may occur with use of this mode because every breath is delivered under positive pressure. Patient-ventilator asynchrony caused by the flow rate or respiratory settings that are inadequate to meet the patient's ventilatory needs may occur (Elliot *et al*, 2007:284; Pierce, 2007:215). As the tidal volume and rate are controlled, the patient might be at risk from hypercapnia, hypoventilation and volutrauma (Urden *et al*, 2006:672). CMV may require the use of sedatives or neuro-muscular blocking agents, which may compromise patient safety in the event of a ventilator mishap and may prolong the weaning times and, ultimately, the safety and cost in critical care units, which have been proven to impact on the quality of patient care (Shelledy, Rau and Thomas-Goodfellow, 1995:68). The professional nurse should be aware of these implications for practice in using the CMV mode in the mechanically ventilated patient as these adverse effects might be harmful to the patient, thereby compromising his/her safety.

Assist-Control (A/C) mode

In using assist-control ventilation, the ventilator delivers a controlled ventilator breath in response to the patient-initiated breath. The patient cannot breathe independently of the ventilator. The patient can initiate inspiration and control the breathing frequency. If the patient fails to initiate inspiration, the ventilator automatically goes into a backup mode and delivers the pre-set rate and tidal volume until an inspiratory effort is sensed (Hamed *et al*, 2006:78; Pierce, 2007:217). The A/C mode thus allows the patient to control the rate of breathing and yet it guarantees the delivery of a minimal pre-set rate and volume. The ventilator performs the bulk of the ventilatory work. This mode of ventilation is often used as initial mode of ventilation to fully support a patient, such as when a patient is first intubated or when the patient is too weak to perform the work of breathing, for instance, when emerging from anaesthesia (Morton and Fontaine, 2009:594).

Disadvantages of using the A/C mode include respiratory alkalosis due to the patient's tendency to hyperventilate. Hyperventilation may also lead to the formation of auto-PEEP, because of the shortened expiratory time. The acid-base balance of the patient must be monitored closely. Respiratory muscle atrophy may result as the patient may not participate in breathing when becoming dependent on the ventilator. Variability in the patient's hemodynamic status may occur with this mode as every breath is delivered under positive pressure (Pierce, 2007:217). Professional nurses are often required to set the ventilator mode or to adjust it according to the patient's clinical condition. It is, therefore, important that they are aware of the disadvantages in using the A/C mode and should monitor the patient meticulously.

Synchronised Intermittent Mandatory Ventilation (SIMV) mode

In SIMV mode, the ventilator delivers gas at a pre-set tidal volume and rate while allowing the patient to breathe spontaneously. Ventilator breaths are synchronized with the patient's respiratory effort (Urden *et al*, 2006: 672). At times, SIMV might be confused with IMV (intermittent mandatory ventilation), but there is a definite difference between the two modes. With IMV, the mandatory breaths are delivered at a precise time, regardless of where the patient is in the ventilatory cycle, whereas with SIMV, the ventilator synchronises the delivery of the mandatory breath when it

senses the patient's inspiratory efforts. The main difference between the SIMV and A/C modes is in the volume of the patient-initiated breaths. Patient-initiated breaths in the A/C mode results in the patient receiving a guaranteed tidal volume, whereas in SIMV, spontaneous breath tidal volume is variable because it depends on patient effort and lung characteristics (Pierce, 2007:218).

Traditionally, SIMV was created as a mode in which the patient could interact with the ventilator using the respiratory muscles, thus becoming a popular weaning mode. This was achieved by lowering the SIMV rate, allowing the patient to initiate more spontaneous breaths, and therefore, assuming a greater portion of the ventilatory work. As the patient demonstrates the ability to generate more work, the mandatory breath rate is decreased accordingly, thus making weaning off the ventilator possible (Morton and Fontaine, 2009:95). Although SIMV has been used traditionally as weaning mode, it was found in randomised trials that SIMV is, in fact, inferior to both spontaneous breathing trials and pressure-support ventilation as a mode of weaning (Brochard Rauss, Benito, Conti, Mancebo and Rekik, 1994:896-903; Estaban, Frutos, Tobin, Alia, Solsana and Valverdu, 1995: 345-350; Meade, Guyatt, Snuff, Griffith, Hand and Toprani, 2001:425S). According to Pierce (2007:218), compared to other weaning modalities, SIMV is associated with the longest weaning times and the lowest success rates.

SIMV is indicated for use in patients who have a normal respiratory drive but whose respiratory muscles are unable to perform all the work of breathing. Although using SIMV has been proven to have fewer disadvantages than the A/C mode, for instance, less respiratory alkalosis, less atrophy of the respiratory muscles and better distribution of gas within the lung, it does have disadvantages that the health care practitioner should be aware of. Patient-ventilator asynchrony, patient discomfort, inadequate ventilation and potentially barotrauma are possible complications linked to the use of SIMV. During this mode, the work of breathing might be increased, which will promote respiratory fatigue. The patients should be monitored for hypercapnia, further increase in the work of breathing and inadequate spontaneous tidal volume (Urden *et al*, 2006:672).

In a study conducted by Shelledy *et al* (1995:67), it was found that SIMV with pressure support significantly increases minute volume and ventilatory equivalents when compared with assist-control or SIMV alone, and was thus the most efficient mode of full ventilatory support. They found no difference in ventilatory efficiency between assist-control and SIMV. However, very little objective evidence supports the choice of a particular mode of mechanical ventilation in the spontaneous breathing patient. One possible criterion for the selection of a particular mode is the effect on the work of breathing (Fenstermacher and Hong, 2004:260).

It was reported in a study done by Estaban *et al* (2000:1455) that assist-control ventilation is used in 40 to 72% of patients who are connected to mechanical ventilators in North America, South America, Spain and Portugal. In a survey published by Venus, Smith and Mathru (1987:530-533), 72 % of physicians in the United States listed SIMV as their preferred ventilator mode. Ten years later, SIMV on its own was used in only 6% of patients receiving mechanical ventilation in North American critical care units. However, the use of a combination of SIMV and PS or A/C appears to be the most commonly used mode of ventilation in the United States. In Uruguay, the popularity of the SIMV and PS combination is also quite common (Leung, Jubran and Tobin, 1997:1940). An interesting feature was the infrequent use of certain modalities, such as SIMV as a stand-alone mode, non-invasive ventilation, permissive hypercapnia and the other new modes of ventilation, as reported in the study conducted by Estaban *et al* (2000:1450-1458). No literature pertaining to South Africa could be found in studies conducted nationally on the utilisation and implementation of the different volume ventilator modes for the critically ill patient.

Pressure modes

During a pressure mode, a breath is delivered at a pressure that is constant for every breath. Pressure modes include pressure support ventilation, pressure-controlled ventilation, airway pressure release ventilation and volume-guaranteed pressure-option (Morton and Fontaine, 2009:597). A brief description of these pressure modes follows.

Pressure-Support Ventilation (PSV)

In this mode of ventilation, a pre-set positive pressure is used to augment the patient's inspiratory efforts. It is a ventilator-generated flow augmentation of each individual breath that the patient triggers. PSV is a spontaneous breathing mode used as the primary mode of ventilation in patients with stable respiratory drives to overcome any imposed mechanical resistance (Urden *et al*, 2006:672). PSV allows the tidal volume and inspiratory flow to be more adaptable to the patient's own ventilatory demands. This manner of supporting the patient's own ventilatory effort may be responsible for an improved comfort and synchrony with the ventilator, and has been shown to reduce the work of breathing and prevent diaphragmatic fatigue in patients with respiratory failure (Chiumello, Pelosi, Calvi, Bigatello and Gattinoni, 2002:925).

PSV has been used to limit barotrauma and to decrease the work of breathing, which can result from endotracheal tube and breathing circuit resistance. In a comparison between PSV and A/C, patients on PSV showed significantly higher tidal volume, minute ventilation and inspiratory time in association with a significantly lower pressure in airways (Tejeda, Boix, Alvarez, Balanza and Morales, 1997:1323). Pressure support, when used in combination with SIMV, is thought to reduce the work of breathing spontaneous breaths and thus overcomes the resistance to ventilation imposed by demand valves, patient breathing circuits and artificial airways (Shelledy *et al*, 1995:68). Other advantages of this mode include improved patient-ventilator synchrony and patient comfort (Urden *et al*, 2006:672).

Pressure-support ventilation has been proposed in limiting acute lung injury. It is recommended as a ventilator mode that has been used to limit barotrauma and to reduce the patient's work of breathing (Petrucci and Lacoveli, 2004:195; Hamed *et al*, 2006:79).

In maintaining patient safety while caring for the mechanically ventilated patient, it is not only important that the professional nurses are aware of the most beneficial mode to use, but also the use of the ventilation mode that is the least harmful for the critically ill patient.

Pressure-Controlled Ventilation (PCV)

PCV is a pressure-limited, time-cycled ventilator mode. The desired pressure level is set, as is the inspiratory time and the respiratory rate. With every breath, the ventilator delivers an inspiratory flow until the pre-set airway pressure limit is achieved. As with PSV, the flow decelerates throughout inspiration; however, the cycle is time and not flow. The decreased flow at the end of inspiration results in less turbulent, more laminar flow and a more even distribution of the breath. This decelerating waveform has long been shown to improve lung mechanics and gas exchange during mechanical ventilation (Hamed *et al*, 2006:79). The PCV mode is used to control plateau pressures in conditions such as ARDS in which the compliance is decreased and the risk for barotrauma is high. It is used when the patient has persistent oxygenation problems despite a high FiO₂ and high levels of PEEP and in patients in whom it is desirable to control peak inspiratory pressures (Pierce, 2002:57; Pierce, 2007:224; Morton and Fontaine, 2009:597).

As the expiratory time is decreased when using PCV, the nurse must monitor for the development of hyperinflation or auto-PEEP. Regional alveolar over-distention and barotrauma may result from excessive total PEEP. When the PCV mode is used, the mean airway and intra-thoracic pressures rise, potentially resulting in a decrease in cardiac output and oxygen delivery (Morton and Fontaine, 2009:597). Therefore, it is necessary to monitor the patient's hemodynamic status closely. In caring for a patient who is on PCV mode in a critical care unit, it is the responsibility of the professional nurse to monitor for the complications linked to this mode in order to ensure the safety of the mechanically ventilated patient.

Airway Pressure Release Ventilation (APRV)

APRV is a spontaneous breathing mode used in patients to maintain alveolar recruitment without possible additional peak inspiratory pressures that could lead to barotrauma. During this mode, two different levels of CPAP (inspiratory and expiratory) are applied for set periods of time, allowing spontaneous breathing to occur at both levels (Urden *et al*, 2006:673). APRV has been used in trauma and ARDS patients to reduce airway pressure and lower minute volumes while allowing spontaneous breathing throughout the ventilator cycle, all with decreased sedation

and neuromuscular blocking agent use. APRV mode allows lung protective strategies to be followed with limitation of plateau and peak pressures. Because the patient is breathing spontaneously throughout both high-and low-pressure phases, the need for sedation or neuro-muscular blocking agents may be limited. This may result in a shorter duration of critical care unit stay and a reduced incidence of adverse effects associated with critical illness neuropathy. The lower peak and mean airway pressure with APRV lead to a decreased transmitted intra-thoracic pressure and a reduction the central venous pressure of the mechanically ventilated patient. The reduced intra-thoracic pressure enhances venous return and, therefore, cardiac performances with a decreased pressure requirement to support arterial pressure and oxygen delivery (Kaplan, Bailey and Formosa, 2001:221-226).

APRV has been proven as a ventilatory mode which reduces barotrauma and circulatory compromise, patient-ventilatory asynchrony and leads to improved distribution of gas in the lungs (Pierce, 2007:244). This mode may improve oxygenation and prevent ventilator-induced lung injury in the critically ill patient. Weaning in this mode is possible and has been done successfully in the mechanically ventilated patient (Morton and Fontaine, 2009:597).

APRV offers several essential preconditions, which seem potentially advantageous for ventilation of even severe ARDS lungs. It provides a nearly continuous airway pressure level favourable in keeping the alveoli open, and a short expiratory time, which favours ventilation. It aids in the preservation of spontaneous breathing, which avoids the need for muscle relaxation and deep sedation. Furthermore, it reduces the risk for barotrauma or volutrauma and makes it possible to maintain relatively low airway pressures and thereby improves the conditions for pulmonary circulation and oxygen delivery (Burchardi, 1996:1065).

Disadvantages of APRV include that tidal volume is variable and depends on compliance and resistance factors in the patient-ventilator system (Pierce, 2007:244). However, considering all positive benefits of APRV, it appears to be the safest mode to use on the mechanically ventilated patient in minimising ventilator-induced lung injury and thereby ensuring the safety of the critically ill patient.

Volume-Guaranteed Pressure Option mode (VPGO)

This mode is also known as pressure augmentation (PA) or as volume-assured pressure-support ventilation (VAPSV). VPGO mode ensures delivery of a prescribed tidal volume while using a decelerating flow pattern by means of a pressure breath. VAPSV is a spontaneous breathing mode used to treat acute respiratory illness and to facilitate weaning. In the acutely ill unstable patient, this option may provide pressure ventilation while guaranteeing tidal volume and minute ventilation at a set rate. In the spontaneously breathing patient, the option is used as a “safety” measure when pressure ventilation is desired (Rose, 2006:145). A variation of PSV is given with a set tidal volume to ensure that the patient receives minimum tidal volume with each pressure-support breath.

Advantages of this mode include increased patient comfort, decreased work of breathing, decreased respiratory muscle fatigue and promotion of respiratory muscle conditioning (Urden *et al*, 2006:673). The use of VAPSV in the acutely ill patient may provide pressure ventilation while guaranteeing tidal volume and minute volume at a set rate and may be useful in patients for whom the ability to cough and expose secretions are a problem (Morton and Fontaine, 2009:597).

2.7.4.2 Tidal volume

The tidal volume refers to the volume of gas exchanged during each ventilated breath. In normal spontaneous breathing, tidal volume is 8 to 10 ml/kg (Manno, 2005:36). On the mechanical ventilator, the tidal volume is dictated by the patient’s lung characteristics and should be set to ensure that excessive stretch is avoided. The goal for tidal volume setting is that which results in the lowest plateau pressure possible while maintaining gas exchange and patient comfort and safety (Pierce, 2007:192).

As early as the 1970s, a setting of 10-15 ml/kg tidal volume had become conventional (Pontoppidan, Geffin and Lowenstein, 1972:799). A decade later, some studies even reported the use of tidal volumes of 20-24 ml/kg (Jardin, Farcot, Biosante, Curien, Margiaraz and Bourdarias, 1981:387-392). This practice of implementing tidal volumes of 10-15ml/kg even continued in the 1990s. A tidal

volume of 10-15 ml/kg is recommended as a smaller tidal volume allows progressive airway closure and alveolar collapse, leading to increasing shunt and worsening compliance and oxygenation. However, for more than a decade, there has been growing awareness of the potential for ventilator-induced injury, which accounts for a mortality rate in mechanically ventilated patient for approximately 40-50% (Stewart, Meade, Cook, Granton, Hodder, Lapinsky Mazer, McLean, Rogovein, Schouten, Todd and Slutsky, 1998:355-361).

The traditional approach to mechanical ventilation was to ensure adequate ventilation as well as to control arterial carbon-dioxide levels and pH. To reach these goals, tidal volumes of 10-15 ml/kg of body weight were employed. These volumes are greater than observed in normal subjects at rest and, because of the heterogeneity of the mechanical properties of the injured lung, they would be expected to contribute to regional over-inflation injury during mechanical ventilation. In animals, ventilation with the use of large tidal volumes cause the disruption of pulmonary epithelium and endothelium, lung inflammation, atelectasis, hypoxemia and the release of inflammatory mediators. The release of inflammatory mediators could increase lung inflammation and cause injury to other organs. High tidal volumes cause a syndrome of ventilator-induced lung injury that is similar to ARDS (Parker, Hernandez and Peevy, 1993:131; Tremblay, Valenza, Ribeiro, Slutsky, 1997:944; Slutsky and Tremblay, 1998:1721-1725; ARDSNet, 2000:1301-1308; MacIntyre, 2005:561s-567s). The traditional approach to mechanical ventilation may exacerbate or perpetuate lung injury in patients with acute lung injury and the acute respiratory distress syndrome and increase the risk of non-pulmonary organ or system failure (Fan, Needham and Stewart, 2005:2889; Metha, Lapinsky, Hallett, Mercker, Groll and Cooper, 2001:1360-1369).

Guidelines strongly support the use of lower tidal volumes in the mechanically ventilated patients with acute lung injury or ARDS. However, there are no widely agreed upon guidelines for settings tidal volumes in patients who did not meet the acute lung injury or ARDS consensus criteria, partly because there is a paucity of randomised controlled trial evidence on the best way to ventilate patients. Based on this premise, Schultz (2008:22-26) performed a literature search for clinical studies

on the use of lower tidal volumes in patients not suffering from acute lung injury or ARDS and found that the use of lower tidal volumes in this group of patients could improve the hemodynamic tolerance of mechanical ventilation and this way may improve the outcome of the critically ill patient. Furthermore, by using lower tidal volumes, the incidence for developing acute lung injury and ARDS could be decreased.

Although smaller tidal volumes would be expected to reduce lung injury in patients receiving mechanical ventilation, concerns about causing respiratory acidosis, reducing arterial oxygenation and creating discomfort discouraged its practice (MacIntyre, 2005:562s). It is interesting to note that contradictions exist in literature with regard to setting an appropriate tidal volume. Despite the misgivings, a large clinical study was conducted to test the concept that lower tidal volumes would decrease mortality in ARDS patients. In the ARDS Network (ARDSNet) study, 861 patients with acute lung injury and ARDS were randomised to one of two ventilator protocols based on tidal volume. In the high tidal volume group, patients received mechanical ventilation with a tidal volume of 12 ml/kg, with a maximum plateau pressure <50 cmH₂O. In the low tidal volume group a maximum plateau pressure <30 cmH₂O was used. The study was stopped early because interim analysis revealed a highly significant reduction in 28-day mortality in the low tidal volume group. Mortality was 39.8% in the high tidal volume group and 31% in the low tidal volume group (ARDSNet, 2000:1301-1308). The use of lower tidal volumes (6 ml/kg/predicted body weight) has proved to significantly reduce mortality in patients with acute lung injury and it's more severe form, acute respiratory distress syndrome (Wolthuis Kesecioglu, Hassink, Determann, Korevaar and Schultz, 2007:1761-1766).

The desired volume during mechanical ventilation is based on a patient's ideal body weight, but depends on a patient's lung compliance, pathophysiology and clinical response to the set tidal volume (Elliot *et al*, 2007:283). It has, therefore, been recommended that low tidal volumes (6-8 ml/kg) and the avoidance of airway pressure of more than 30 cmH₂O be implemented for the mechanically ventilated patient in the critical care unit (Baudouin, 2004:103). Morton and Fontaine (2009:599) recommend that lower tidal volumes targets of 5 to 8 ml/kg be used as

larger tidal volumes may aggravate the damage inflicted on the lungs by the pathological process that necessitated mechanical ventilation. The use of lung protective lower tidal volume ventilation is recommended for patients suffering or who are exposed to a risk for developing acute lung injury or acute respiratory distress syndrome (Wolthuis *et al*, 2007:1762). Several other studies support the use of low tidal volumes as a lung-protective strategy in the care of the mechanically ventilated patient (Stewart *et al*, 1998:356; Morgan, 2001:18-20; Rich Douilett, Hurd and Boucher, 2003:139-145; Halter, Steinburg, Gatto, DiRocco, Pavone, Shiller, Albert, Lee, Carney and Nieman, 2007:213-223; Xiaoming, Eng, Malhortra, Saeed and Talmor, 2008:853-861).

2.7.4.3 Peak airway pressure

Peak airway pressure can be defined as the amount of pressure required to deliver the set volume. It is known that high-peak airway pressures greatly increase the risk for barotrauma (Kidd and Wagner, 1997:118). The peak airway pressure refers to the airway pressures across the respiratory cycle and is measured by the ventilator's airway pressure gauge. The peak airway pressure is an important parameter in assessing pulmonary compliance and patient-ventilator synchrony and will vary depending on the tidal volume, respiratory rate, ventilator flow pattern, lung pathology and patient compliance (Elliot *et al*, 2007:284). Peak airway pressures are often referred to as peak inspiratory pressures (PIP).

In a study done by Dreyfuss and Saumon (1998:294-323), it was found that ventilation of normal lungs with low pressures (PIP= \leq 14 cmH₂O) does not cause significant lung injury. However, it was dramatically showed that ventilation with high pressure (PIP of 30-45 cmH₂O) produces perivascular edema and that ventilation at high pressure (45 cmH₂O) leads to severe lung injury, including gross pulmonary edema and severe hypoxia as well as death within 35 minute of application. The results of this study were similar to other study findings suggesting that a low tidal volume or high PEEP and PIP <30 cmH₂O strategy is beneficial in the development of ventilator-induced lung injury (Burchardi, 1996:1063-1072; Tremblay and Slutsky, 2006:24-33; Meade, Cook and Guyatt, 2008:637-645).

2.7.4.4 Positive End-Expiratory Pressure (PEEP)

Over the decades there has been an interest in improving the method to keep the alveoli open during the breathing cycle. Although this method, called positive end-expiratory pressure (PEEP), was first developed in the 1940s by the military, it was not used in medicine until 20 years later. In the early 1970s it was introduced as a treatment for respiratory distress syndrome in newborns. Since that time, it has become the foundation for oxygenating the lungs in newborns and adults with respiratory distress syndrome (Pilbeam, 1992:366; Kidd and Wagner, 1997:118). PEEP can be defined as the pressure applied at the end of the expiratory cycle of a ventilator breath to keep the alveoli open. PEEP is used in mechanical ventilation to apply positive pressure during exhalation (Elliot *et al*, 2007:284).

There are many indications for the use of PEEP, but the most common use is for the management of hypoxemic respiratory failure as seen in ARDS, hyaline membrane disease and infant respiratory distress syndrome. However, PEEP can also be used for several other conditions and clinical reasons. The application of PEEP in cardiogenic pulmonary edema increases intra-thoracic pressure and reduces preload and afterload, which improves left ventricular end-diastolic pressure and volume and cardiac output. When applied in ARDS, PEEP helps to improve lung volume, oxygenation and prevents the alveoli from collapsing at end-expiration. Post-operatively, it helps to prevent atelectasis in the patient requiring respiratory support. PEEP may also be used to provide internal stabilization of the chest wall and minimise paradoxical chest-wall movement in fail chest if oxygenation is unsatisfactory. In patients whose PaO₂ is 60 mmHg or less in FiO₂ of 0.5 or greater, PEEP is therapeutically indicated to improve oxygenation. The addition of PEEP in the treatment of a patient with respiratory alterations does not correct the underlying condition, but only supports oxygenation until the condition is corrected, thus reducing the risk for oxygen toxicity (Pilbeam, 1992:372; Kidd and Wagner, 1997:83; Pierce, 2007:203; Elliot *et al*, 2007:284; Morton and Fontaine, 2009:599).

Contra-indications to the use of PEEP include unilateral lung disease, because the application of PEEP may result in alveolar overdistention in the healthy lung, which increases dead space and redistributes perfusion to the unhealthy lung. In lung

disease resulting in hyperinflation, for instance, emphysema or chronic obstructive lung disease, PEEP may not improve oxygenation, but may worsen gas exchange and may pre-dispose these patients to barotrauma and decreased cardiac output. In patients with an increased intra-cranial pressure, the application of PEEP may result in a reduction of venous return and a further increase in intracranial pressure. Other contra-indications for the use of PEEP include hypovolemia, broncho-pleural fistulas and untreated pneumothorax (Pierce, 2007:203). The professional nurse needs to be aware of the contra-indications of using PEEP in these conditions as it might compromise the safety of the mechanically ventilated patient.

By exerting positive pressure at end-expiration, PEEP recruits atelectatic alveoli, internally splints and distends already patent alveoli, counteracts alveolar and small airway closure during expiration and re-distributes lung water. PEEP re-distributes extravascular lung water from alveoli to the peri-vascular space, where the effects of excess lung water on gas exchange is decreased. Through these mechanisms, PEEP decreases intra-pulmonary shunting, increases functional residual capacity, improves compliance, decreases diffusion distance for oxygen and improves oxygenation (Kallet, 2004: 794; Gattinoni, Caironi and Carlesso, 2005: 70; Pierce, 2007:201).

Typical settings for PEEP range from 5-20 cmH₂O. The initial applications of PEEP in patients who are hemodynamically stable should be 5 cmH₂O and can be increased in increments of 2-3 cmH₂O. PEEP levels are adjusted in relation to clinical progress, patient compliance and comfort and the therapeutic goal. PEEP can be set as high as 20 cmH₂O, but the risk of complications, such as ventilator-induced lung injury, barotrauma and cardiovascular compromise, significantly increase at such high levels (Branson and Johannigman, 2004:744; Pierce, 2007:204).

PEEP can cause numerous complications, including barotrauma, which can lead to pneumothorax, pneumoperitoneum, pneumomediastinum and subcutaneous emphysema. An increase in intra-thoracic pressure following expiration may occur, which might impair venous return. The reduction in left ventricular preload causes a

decrease in cardiac output. The decrease venous return to the heart can also cause increased intra-cranial pressure, passive hepatic congestion, increased renal vein back pressure, decreased blood flow to the gastro-intestinal tract and exacerbations of intra-cardiac shunts. PEEP may also produce bulging of the ventricular septum into the left ventricle, reducing left ventricular end-diastolic volume thus ultimately compromising cardiac functioning. A phenomenon called auto-PEEP, or gas trapping, or breath stacking can occur if there is unintentional development of positive pressure at the end of exhalation. The auto-PEEP phenomenon has a detrimental effect on weaning the patient from mechanical ventilation (Flynn and Bruce, 1993:82; Pierce, 2007:203).

Considering the adverse effects of PEEP applications on mechanically ventilated patients, it is thus cardinal that professional nurses are aware of these complications and should monitor patients carefully in order to ensure safety while connected to a mechanical ventilator.

2.7.4.5 Fraction of inspired oxygen (FiO₂)

The major determinants of oxygen delivery in a patient are cardiac output, haemoglobin and SaO₂, whereas with the ventilator, they are FiO₂ and PEEP. When initiating mechanical ventilation on a patient in respiratory failure, it is best to be cautious and use a high fraction of inspired oxygen concentration (0.7 to 1.0) to ensure adequate tissue oxygenation. However, after an initial blood gas value is obtained, the FiO₂ may be decreased to achieve a goal of a clinically acceptable partial pressure of oxygen in arterial blood (PaO₂ > 60 mmHg) with FiO₂ of 0.5 or less. FiO₂ of 0.5 or less minimizes the risk for developing oxygen toxicity (Pierce, 2007:190). According to Schuster (1990:268-278), the FiO₂ should be set at 90% to 100% initially to ensure adequate oxygenation, and rapidly reduced to non-toxic (0.5 or less) as guided by arterial blood gases. If there is no shunting in the patient's lungs, every 10% decrease in FiO₂ will result in a 5-7 mmHg drop in PaO₂. FiO₂ weaning may be done with pulse oximetry (Fenstermacher and Hong, 2004:278).

The administration of FiO₂ of more than 0.6 is generally avoided as it can cause excessive production of oxygen free radicals, which are toxic metabolites of oxygen

metabolism damaging the alveolar-capillary membrane. Normally, enzymes neutralize the radicals, which prevent any damage from occurring. During the administration of high levels of oxygen, the large number of oxygen free radicals produced exhausts the supply of neutralizing enzymes. Thus damage to the lung parenchyma and vasculature occurs, resulting in the initiation of acute lung injury (Urden *et al*, 2006:658).

Lung injury occurs with the onset of tracheobronchitis at the tracheal bifurcation, which is frequently undetected; the first indication is usually reduced lung volume and non-cardiogenic pulmonary edema, followed by pulmonary fibrosis (Robb, 1997:358). There are various complications linked with excessive or prolonged use of oxygen in the mechanically ventilated patient. High concentrations of oxygen (>70%) often lead to rapid absorption atelectasis in hypoventilated lung units. This increases intra-pulmonary shunt. Pulmonary changes associated with high oxygen concentrations include decreased tracheal mucus flow, decreased macrophage activity, decreased vital capacity, endothelial cell damage and accompanying increased lung water, progressive formation of absorption atelectasis, decreased surfactant production, decreased compliance, decreased diffuse capacity, decreased pulmonary capillary blood volume, capillary injury and platelet aggregation in the pulmonary vasculature. Exposure for more than 72 hours causes a development of a pattern similar to ARDS. To minimize the risk in a critically ill patient, the inspired oxygen should thus be reduced to the lowest level tolerated (Pilbeam, 1992:239; Newmarch, 2006:58; Elliot *et al*, 2007:274).

2.7.4.6 Respiratory rate

The respiratory rate (RR) refers to the number of breaths the ventilator delivers per minute. The respiratory rate set on the ventilator should generally be as near physiological as possible, which is 10 to 20 breaths per minute. Typical initial rate settings are between 10 and 12 breaths per minute. To minimise the severity of hypercapnic acidosis in patients treated with lower tidal volumes, respiratory rates may be set up to 30 breaths per minute without increasing the risk for auto-PEEP (Tobin, 2001:1986). Frequent changes in the RR are often required based on observation of the patient's work of breathing, comfort and on assessment of the

PaCO₂ and the pH. Many patients, during initial use of a ventilator, require full ventilator support. The RR at this time is selected on the basis of the tidal volume, so that the minute ventilation is sufficient to maintain an acceptable acid-base status. The minute ventilation is the amount of air expired each minute and is calculated by multiplying the tidal volume by the respiratory rate (RR x VT=minute ventilation). As the patient is capable of participating in the ventilator work, the ventilator RR should be decreased or the mode changed to allow for more spontaneous breathing. The rate can be set to provide all of a patient's breaths as in controlled mechanical ventilation or it can be set at a lower rate so that the patients can maintain some respiratory effort themselves (Bucher and Melander, 1996:429; Manno, 2005:36; Elliot *et al*, 2007:283).

Over-ventilation, which leads to alkalosis, is a common problem in the patient supported by mechanical ventilation, especially if the respiratory rate is set too high. Respiratory alkalosis should be avoided because it is associated with hypokalemia, hypocalcaemia, decreased cerebral blood flow and decreased oxygen unloading from haemoglobin at the tissue level. Under-ventilation leads to acidosis, which might affect the acid-base status of the patient; therefore, it is important to set the correct RR for the mechanically ventilated patient (Pierce, 2007:193; Urden *et al*, 2006:678; Morton and Fortaine, 2009:598).

In a study of 14 patients, the efficacy of increasing the respiratory rate to promote carbon-dioxide elimination was explored. The results of this study proved that unless peak flow is increased to an acceptable level, and steps are taken to reduce the dead space, increasing respiratory rates was not an effective strategy to promote carbon-dioxide elimination. However, if a patient is on SIMV mode, adding PSV will augment spontaneous tidal volumes and promote carbon-dioxide elimination (Vieillard-Baron, Prin and Augarde, 2002:1409).

It has also been found in an animal study, conducted by Rich *et al* (2003:143), that the respiratory rate can significantly affect the degree of lung injury when large tidal volumes are administered. An increased respiratory rate significantly increases lung injury as measured by the airway inflammatory response, the accumulation of

protein-rich alveolar edema fluid and cellular lyses, ultimately increasing the risk for ventilator-induced lung injury. The data from this single study suggests that respiratory-rate increases are well-tolerated at small tidal volumes targeted during lung protective strategies, but under ventilatory conditions that may permit alveolar overdistention, reducing the respiratory rate may decrease lung injury.

2.7.4.7 Flow rate

Flow rate is the speed with which the tidal volume is delivered; it is measured in litres per minute. Generally, an initial flow rate of 40-60 L/min satisfies the patient's inspiratory demands and achieves a desirable inspiratory:expiratory (I:E) ratio. The inspiratory flow rate is the chief determinant of inspiratory time and thus of the I:E ratio. The tidal volume must be delivered within an appropriate, comfortable time and flow must meet or exceed the patient's inspiratory flow demand. If not, the patient experiences air hunger, the work of breathing is increased and patient-ventilatory synchrony results. High flow rates > 60 L/min shorten inspiratory time, thereby lengthening expiratory time and may have negative consequences of increasing peak inspiratory pressures. Slower inspiratory flow rates (20-30 L/min) prolong inspiratory time, improving the distribution of gases and reducing peak inspiratory pressures as result of a more laminar flow (Pierce, 2007:194). It is, therefore, essential to set the correct flow rate on the mechanical ventilator for the critically ill patient.

2.7.4.8 Complications related to mechanical ventilator settings

Although mechanical ventilation may be essential to maintain ventilation and oxygenation, it may cause adverse effects. In a study done by Estaban, Anzueto and Frutos (2002:351), it was noted that the survival rate in patients with respiratory failure and who require mechanical ventilation for more than 12 hours was 69%, and depended not only on factors present when initiating mechanical ventilation, but mainly on the development of complications and patient management during the subsequent course of care. Over the past two decades, critical care physicians have become more aware that mechanical ventilation may lead to or aggravate lung injury. Common types of injury reported include interstitial emphysema, cyst formation and pneumothorax. Initially, excessive airway pressure or barotrauma was

thought to be the primary cause of ventilator-associated lung injury. However, it is currently understood that several other mechanisms of injury may occur in ventilated patients, namely, volutrauma, atelectrauma and biotrauma (Hamed *et al*, 2006:81). A brief description of these complications and the implications for practice will be given.

Barotrauma

Mechanical ventilation involves “pumping” air into the chest, creating positive pressures during inspiration that might lead to an injury to the lung called barotrauma. If PEEP is added, the pressures are increased and continued throughout expiration. These positive pressures can spontaneously rupture an alveolus (Morton and Fontaine, 2009:600). Barotrauma, or pressure trauma, historically, was the injury to the lung most associated with mechanical ventilation. The incidence of barotrauma in mechanically ventilated patients varies widely and is reported to be as low as 0.5% in post-operative patients and as high as 86% in patients with ARDS. The underlying condition of the lungs plays a significant role in the development of barotrauma. In barotrauma, alveolar injury or rupture occurs as result of excessive pressure, excessive peak inflating volume or both (Slutsky, 1993:369; Ranieri and Zhang, 1999:18). The alveoli rupture or tear so that air escapes. Barotrauma can thus be referred to as an air leak phenomenon and can manifest as a pneumothorax, with tension pneumothorax being the most dangerous complication in the mechanically ventilated patient. Barotrauma is common in patients who have required prolonged mechanical ventilation, especially at high peak airway pressures. Signs and symptoms include high peak and plateau pressures, tachycardia, hypotension, agitation, diaphoresis and a drop in oxygen saturation (Schell and Puntillo, 2001:326).

Implications for practice

Early detection of changes in the inspiratory volume or pressures is essential. Depending on the severity of the clinical presentation, a diagnosis can be made only on the basis of chest radiographs. Performing a physical assessment on these patients is of the utmost importance, especially since the patients cannot communicate because of intubation. The professional nurse should monitor for signs of respiratory distress, for instance, tachypnea, patient-ventilator–asynchrony, use of

accessory muscles, diaphoresis and tachycardia, which may be the earliest indicators of barotrauma. Subcutaneous emphysema may be palpable as crepitus under the skin and can be felt unilaterally or bilaterally over the chest wall or supraclavicular area. Professional nurses should, furthermore, observe for worsening hypoxia, decreased compliance, increased peak airway pressures, cardio-vascular instability, reduced breath sounds and unequal chest expansion, which are clinical manifestations of possible barotrauma. Chest decompression can be done by inserting a needle to evacuate the trapped air (in the case of a pneumothorax) until a chest tube can be performed by the physician or qualified health care practitioner (Morton and Fontaine, 2009:602).

Low tidal volumes and limiting plateau pressures remain the preferred approach in ventilator management and reduce the risk for barotrauma (Hamed *et al*, 2006:81). The use of pressure-controlled ventilation will prevent alveolar pressures from exceeding the predetermined peak pressure and, as a result, reduce any risk for barotrauma (Cooper, 2004:360); therefore, it is essential that the professional nurse caring for the mechanically ventilated patient is aware of the best recommended practice in ventilatory strategies in order to minimise this risk.

Volutrauma

The term “volutrauma” was introduced in 1988, after it was demonstrated that lung volume is the major determinant of increased lung water. Volutrauma refers to lung parenchymal injury, induced by end- inspiratory overdistention (Hamed *et al*, 2006:81). According to MacIntyre (2005:561s), volutrauma occurs when the lung is overinflated and the alveoli are overstretched. It is not only the maximal stretch that is of importance, but also tidal stretch, rate of stretch and frequency of stretch. The term is used because it is believed that localized or regional overdistending volume causes damage. The lung damage is similar to early ARDS and is manifested by pulmonary edema, the accumulation of neutrophils and protein in the interstitial and alveolar spaces and the reduction of surfactant production (Pierce, 2007:290).

Implications for practice

When the lungs are ventilated with traditional tidal volumes of 10-12 ml/kg, they can injure; therefore, it is important to control the tidal volume settings on the mechanical ventilator. Furthermore, the plateau pressures should be controlled. To accomplish this, resultant tidal volume must be kept low (6-8 ml/kg). Pressure modes of ventilation, unlike volume modes' control pressures, may allow better lung protection (Schell and Puntillo, 2001:157).

Atelectrauma

Atelectrauma is ventilator-induced lung injury related to unstable or atelectatic alveolar units opening on inspiration and then closing on end-expiration. The repetitive opening upon application of sufficient positive pressure and closing on expiration occurs at each breath. Atelectrauma is postulated to be shear, or stress, or injury at the junctions where open and closed alveoli interface. In the injured lung, positive-pressure ventilation can force open some of the airless alveoli, but on expiration, these same alveoli again collapse. The cycling between open and collapsed is often referred to as recruitment-derecruitment of alveoli. The shear stresses occurring during recruitment-de-recruitment are high and can cause trauma, resulting in disruption of the surfactant monolayer, especially when the opening and closing cycle is repetitive. Loss or disruption of the surfactant monolayer will result in not only a requirement for higher pressures to achieve alveolar opening, but may affect the permeability of the alveolar-capillary barrier to proteins and other solutes (MacIntyre, 2005:562s). The mechanism to prevent atelectrauma is to recruit the unstable alveolar units and then maintain their opened state with the application of sufficient positive-end expiration pressure (PEEP) (Pierce, 2007:290).

Implications for practice

It is recommended that the application of low tidal volumes and sufficient low levels of PEEP be used to avoid further lung injury (Hamed *et al*, 2006:81). Professional nurses should monitor the mechanically ventilated patient continuously for the complications related to mechanical ventilation and should ensure that the mechanical ventilator settings are set correctly in order to ensure the safety of the critically ill patient.

Biotrauma

Barotrauma, volutrauma and atelectrauma can also cause the release of cellular mediators and the initiation of the inflammatory-immune response. This type of ventilator-induced injury is known as biotrauma, and is associated with the production and release of inflammatory mediators and cytokines such as tumour necrosis factor, interleukin-6, macrophage inflammatory protein-2, platelet activating factor and thromboxane B2. There are several principal mechanisms by which mediator release may occur after cyclic stretching of the alveoli. These mechanisms include stress failure of the alveolar epithelial-endothelial barrier, stress failure of the plasma membrane, alterations in cytoskeletal structure and effects on vasculature independent of stretch or rupture. Irrespective of the precise mechanism of mediator release, the clinical consequences for the mechanically ventilated patient may be devastating (Dos Santos *et al*, 2005:281).

These inflammatory mediators not only contribute to the exacerbation of local pulmonary injury but may also lead to a systemic inflammatory response, ultimately resulting in multiple organ dysfunction syndrome (MacIntyre, 2005:562s). Various studies have produced evidence that pressure or volume-associated alveolar stress can produce diffuse alveolar damage, incite inflammation, promote pulmonary edema, physically disrupt the endothelial or epithelial barrier and worsen pulmonary mechanics (Slutsky, 1999:9s; Haitsma, Uhlig, Goggel, Verbrugge, Lachmann and Lachmann, 2000:1515-1520; Houston, 2000:43).

Biotrauma can thus result in the development of acute lung injury. Injurious mechanical ventilation strategies, including large tidal volume ($VT > 12 \text{ml/kg}$) and high PEEP levels, can promote the release of inflammatory mediators in the lung and worsen lung injury. Polymorphonuclear leucocytes can be activated by conventional high-volume mechanical ventilation. Furthermore, an increased in oxidant production, CD 18 and CD63 surface expression and shedding of L –selectin are evident when these mechanical ventilation strategies are applied (Zhang, Downey, Suter, Slutsky and Ranieri, 2002:1426-1433).

Implications for practice

It is important that professional nurses monitor for the effects of biotrauma and apply mechanical ventilator strategies that minimise lung injury. It is recommended that the plateau pressure be kept at less than 30 cmH₂O. Minimal, safe PEEP should be used to avoid end-expiratory collapse and re-opening, and the tidal volume should be set at 6 -8 ml/kg (Marini and Gattinoni, 2004:250).

Cardiovascular compromise

Positive-pressure ventilation increases intra-thoracic pressure, which decreases venous return to the right side of the heart. Impaired venous return decreases preload, which results in a decrease in cardiac output. Decreased cardiac output, as reflected by hypotension, may be observed at the initiation of mechanical ventilation. The most important contributing factor to the decreased cardiac output is the lack of sympathetic tone and decreased venous return due to the effects of positive pressure within the chest (Urden *et al*, 2006:673).

Implications for practice

It is important that the nurse undertakes a comprehensive cardio-vascular assessment of the patient to determine adequacy of cardiac output and to observe for complications associated with poor cardiac output. This involves assessment of the heart rate and rhythm, blood pressure, central venous pressure, peripheral perfusion, urine output, chest radiographs and serum electrolytes. Pulse variation assessment, which provides an estimate of the patient's fluid status, can be done (Couchman *et al*, 2007:10). The patient should be monitored for signs and symptoms of restlessness, decreased urine output, decreased capillary refill time, pallor, fatigue and chest pain. Patient monitoring and administration of supportive care is important if decreased cardiac output is observed (Morton and Fontaine, 2009:604).

Gastro-intestinal compromise

Positive pressure interferes with perfusion to the spleen and the gastro-intestinal tract and might contribute to the development of gastric ulcers. The increased air swallowing in the presence of an artificial airway may lead to gastric distention and, therefore, the placement of a nasogastric tube in the mechanically ventilated patient

is recommended. The positive pressure applied to the abdomen during mechanical ventilation may also lead to reduce gastric motility, predisposing the patient to the development of a paralytic ileus and fecal impaction (Flynn and Bruce, 1993:88). Gastro-intestinal bleeding occurs in approximately 25% of patients on mechanical ventilation through development of stress ulcers. These ulcers develop as result of either gastric hyperacidity or from transient visceral hypoxic episodes which might be due to tissue hypoxia related to the disease condition (Kidd and Wagner, 1997:125). Vomiting can be the result of pharyngeal stimulation from the artificial airway. In addition, hypomotility and constipation may occur as result of immobility and the administration of paralytic agents, analgesics and sedatives during the period of critical illness (Urden *et al*, 2006:674).

Implications for practice

The professional nurse should observe nasogastric aspirates and bowel motions for presence of altered blood, indicating gastro-intestinal bleeding. Hemoglobin levels should be checked as a significant decrease may indicate bleeding (Robb, 1997:358). Gastro-intestinal prophylaxis, in terms of antacids or H₂-receptor agents, should be commenced as early as possible in the mechanically ventilated patient in order to minimise the risk of stress ulcer development. A nasogastric tube should be inserted to minimise abdominal distention (Morton and Fontaine, 2009:602).

Renal compromise

Mechanical ventilation with positive airway pressure leads to a reduction in renal water and sodium excretion. The increase in intra-thoracic pressure results in a decrease in cardiac output and mean arterial pressure. Low-pressure baroreceptors discharge leads to increased sympathetic activity, raising plasma antidiuretic hormone (ADH) concentration (Gould and de Beer, 2004:77). The primary function of ADH is to decrease the amount of water lost in the urine. With losses minimised, any water absorbed from the digestive tract will be retained reducing the concentration of electrolytes (Martini and Bartholomew, 2007:340).

The reduction in renal perfusion and increase in renal sympathetic activity stimulate the rennin-angiotensin system. Angiotensin II formation stimulates aldosterone

production with a resultant increase in reabsorption of water and sodium. Reduced venous return and less stretch of the right atrium will decrease the release of atrial natriuretic peptide (ANP), which might contribute to increased sodium reabsorption and decreased diuresis. The higher mean intra-thoracic pressure increases venous pressure and causes some kidney congestion. These effects are not significant in a healthy kidney but may exacerbate the situation if associated with other co-morbidities (Gould and de Beer, 2004:77).

Implications for practice

The mechanically ventilated patient may present with extensive edema, including sclera and facial edema and might need diuretics in order to manage the edema (Morton and Fontaine, 2009:604). The patient's weight should be monitored frequently to allow fluid status trends to be determined. Intake and output fluid balances should be meticulously monitored. Ensuring urine output is greater than or equal to 0.5 ml/kg/hour is one way of assessing adequate renal function. Serum levels of urea and creatinine should be checked to detect any renal impairment. Diuretics should be administered as prescribed and indicated. The nurse should monitor the patient's hydration status, clinical and hemodynamic parameters in order to assess for any signs and symptoms of dehydration (Urden *et al*, 2006:673; Pierce, 2007:299; Couchman *et al*, 2007:12).

Hepatic compromise

Hepatic flow depends on a balance of flow through the hepatic artery and portal circulation. The reduction in cardiac output, associated with the application of positive pressure ventilation, leads to a proportional reduction in hepatic blood flow. In addition, raised mean intra-thoracic pressure leads to increased hepatic venous congestion, which has an effect on portal vein blood flow. Hepatic cellular function may be compromised, especially if it is associated with other co-morbidities (Gould and de Beer, 2004:77). The downward movement of the diaphragm and impaired venous return to the right side of the heart may lead to an increase in portal vein pressure, followed by decreased portal venous blood flow to the liver and impairment of bile and hepatic vein flow (Pierce, 2007:299).

Implications for practice

Hepatomegaly may be present due to venous back pressure. The nurse practitioner should thus observe for signs of ascites. A dysfunctional liver will alter the metabolism of many drugs, especially sedatives. The use of sedation protocols and scoring systems will thus assist in preventing the accumulation of sedatives. The nurse practitioners should observe for signs of clotting deficiency due to increased pro-thrombin time. Jaundice may not be present; however, the nurse practitioner should monitor for any signs and symptoms of abnormal hepatic function. Regular measurements of liver function tests are recommended (Rob, 1997(a):299; Winters and Munro, 2004:525).

Neurologic compromise

Persons who present with neurological alterations or who have undergone neurological procedures are at risk of having an increase in intra-cranial pressure and/or decrease in cerebral perfusion pressures (CPP) when positive-pressure ventilation or PEEP are applied (Pierce,2007:299). The increased intra-thoracic pressures from positive-pressure ventilation increase superior vena cava jugular vein and extra-thoracic pressures, diminishing cerebral venous return and thus increasing intra-cranial blood volume and pressure. CPP will be compromised with reduced cardiac output and hypotension associated with raised intra-thoracic pressures. Positive-pressure ventilation has no adverse effects on intra-cranial pressure in individuals with normal cerebrovascular hemodynamics (Rob, 1997(a):299).

Implications for practice

The nurse practitioner should be aware of the effects of positive pressure ventilation on the patient who presents with neurological alterations. Nursing care practices related to maintaining or minimising raised intra-cranial pressure should be performed. The most optimal ventilator strategies in avoiding increased intra-cranial pressure should be used (Pierce, 2007:299).

Patient-ventilator asynchrony

The normal ventilator pattern is usually initiated by the establishment of negative pressure within the chest. The application of positive pressure can thus lead to

patient difficulties in breathing on the ventilator. To achieve optimal ventilator assistance, the patient needs to breathe in synchrony with the machine. The selected mode of ventilation, the settings and the type of ventilator circuit used can also increase the work of breathing and may lead to the patient breathing out of synchrony with the ventilator. Patient-ventilatory asynchrony can result in a decrease in effectiveness of mechanical ventilation, the development of auto-peep and physiological distress in the patient. Patients who are not breathing in synchrony with the ventilator appear to be fighting or “bucking” the ventilator (Urden *et al*, 2006:674).

Implications for practice

To minimize this problem, the ventilator must be adjusted to accommodate the patient’s spontaneous breathing pattern and to work with the patient. If this is not possible, the patient may need to be sedated and/or pharmacologically paralyzed (Urden *et al*, 2006:674).

2.7.4.9 Alarms

Setting appropriate ventilator alarms and responding promptly to the alarms are an integral part of ventilator patient management and safety. Alarms warn of technical or patient events that require attention or action of the caregiver. Alarms may provide audible or visual warnings depending on the severity of the condition of the patient. A ventilator alarm is considered as a high priority in a critical care unit. When it sounds, it may indicate a problem with the patient’s airway or breathing, the two highest priorities in the ABCs (airway, breathing and circulation). Patient safety for ventilator patients can be enhanced by using reliable alarm systems (Seckel, Speakman, Bradtke and O’Brein: 2005:212; Pierce, 2007:312).

Alarm systems are necessary to warn nurses of developing problems and must never be ignored or disarmed. Alarms are considered a key tool in improvement of the safety of patients. The purpose of alarm systems is related to communicating information that requires a response or awareness by the operator. When an alarm is triggered, a caregiver is tasked with noting the alarm, identifying its source and responding appropriately. The importance of monitoring ventilator alarms in the critical care unit was illustrated in the report from the Joint Commission on

Accreditation of Health Care Organizations (JCAHO) in America that reviewed 23 reports of death or injury related to mechanical ventilation. Of the 23 events, 65% of the incidences of death or injury were related to ventilator alarms (Korniewicz *et al*, 2008:36).

Alarms systems should be monitored at least once per shift. It is essential to set alarms sensibly so that changes to normal set parameters are detected early and the relevant action taken. The safety of mechanically ventilated patients is dependent on the nurse making vigilant observations and responding to alarms promptly. The most common alarms that are used by most institutions include low-pressure alarms, high-pressure alarms, volume alarms and apnea alarms (Morton and Fontaine, 2009:600). Low-pressure alarms are usually set 10 cmH₂O below peak airway pressure limits and are used to detect patient disconnection events and leaks in the system. High-pressure alarms limits are set about 10-20 cmH₂O above the peak airway pressure. Anything that increases airway resistance can trigger them. Examples of clinical conditions that cause a high-pressure alarm include events such as coughing, increased secretions, decreased compliance and tube kinking. Clearing the airway or tubing will most frequently correct the problem (Pilbeam, 1992:199; Flynn and Bruce, 1993:81; Kidd and Wagner, 1997:119; Newmarch, 2006:63; Morton and Fontaine, 2009:600).

The low exhaled tidal volume alarm indicates that there is a loss of tidal volume or a leak in the system. When this alarm goes off, the nurse should focus on checking to see whether the artificial airway cuff is adequately filled with air or has a leak. The patient might also be disconnected from the mechanical ventilator, causing activation of the volume alarm. High minute ventilation alarms are set to warn of rise in minute ventilation by 20% of the established value. The minute ventilation of the product of the respiratory rate and tidal volume varies accordingly. Setting the correct respiratory rates are important in minimising complications such as respiratory alkalosis and acidosis. Respiratory alarm limits should thus be set correctly and monitored for any increase or decrease in the respiratory rate. Low-pressure oxygen or air inlet alarms are activated when the pressure at air or oxygen inlet falls below 35psi, and most ventilators provide pressure-sensor alarms to detect this. Ventilator

failure alarms will sound in the event of mechanical ventilation failure. Alarms are battery powered in the event of electrical failure (Flynn and Bruce, 1993:81; Pierce, 2007:325; Morton and Fontaine, 2009:600).

Considering the importance of ventilator alarms in the critical care unit, it is important that the professional nurses monitor the alarms at least once per shift or whenever there is a change in adjusting the ventilator settings.

2.7.4.10 Summary of mechanical ventilator settings

From the discussions above the importance of ensuring the safety of the mechanically ventilated patient in the critical care unit has been shown. Meticulous attention should be given to the ventilator settings, including the ventilator modes used, whether on initiation or on continuous ventilator support of the patient. Setting and monitoring the correct tidal volume, FiO₂, respiratory rate, flow rate and PEEP on the mechanical ventilator can have a significant effect on the outcome and safety of the mechanically ventilated patient. Furthermore, as discussed in this section, it is evident that there are various new approaches to the applications of the ventilator settings in minimising ventilator-induced lung injury. Therefore, professional nurses working in critical care units should be knowledgeable regarding the latest and best recommended practice for the setting of mechanical ventilators correctly. They should also be able to monitor for complications arising from setting incorrect settings while caring for the mechanically ventilated patient.

2.8 SUMMARY OF CHAPTER

This chapter aimed to give the reader an understanding of the core concepts of this study. The narrative, traditional literature review was used in the construction of the data collection instrument to explore and describe the current nursing care practices to ensure the safety of a patient while on a mechanical ventilator. The next chapter will describe the research design and method used in this study.

“Patience and perseverance have a magical effect before which difficulties disappear and obstacles vanish.”

John Quincy Adams

IN THIS CHAPTER

In Chapter 1, an overview of the study was presented. In Chapter 2, a description of the narrative literature review was given in order to give the reader an insight into the broader contexts of mechanical ventilation.

This chapter provides:

- A detailed discussion of the research design, method and measurement of quality of the study for the **two steps in Stage One**, namely:
 - The quantitative approach
 - The systematic review;
- A comprehensive description of **Stage Two**, which comprises of the development of the evidence-informed clinical guidelines;
- A description and application of the measures taken to ensure the quality of the research;
- Ethical considerations as applied throughout the study.

3.1 INTRODUCTION

Successful research will depend on the identification and formulation of a research problem, developing a definite plan and the application of research methods suited to the specific research. Research can be categorised into two broad categories: quantitative and qualitative research designs. Along with the research design, the research method is as important as it describes the process that has been followed in executing the research plan or blueprint.

The purpose of this chapter is to provide a comprehensive description of the research design and the method used to reach the objectives of the study which are as follows:

- To explore and describe the four identified nursing care practices related to the safety of the mechanically ventilated patient, as performed by professional nurses, in critical care units in the Nelson Mandela Metropolitan area.
- To identify two of the four nursing care practices that are performed least according to best recommended practices.
- To explore and describe existing literature for the two identified nursing care practices related to the safety of the mechanically ventilated patient in a critical care unit.
- To formulate two evidence-informed clinical guidelines to assist professional nurses in performing nursing care practices related to the safety of the mechanically ventilated patients in a critical care unit.

The most significant nursing care practices related to the artificial airway in the mechanically ventilated patient that have been identified based on my own working experiences in the critical care units, as well as from informal discussions with the professional nurses in these units, are as follows:

- Endotracheal tube verification;
- Endotracheal tube cuff pressure monitoring;
- Endotracheal tube suctioning;
- Mechanical ventilator settings.

3.2 STAGE ONE

Stage One comprises of two steps, namely the quantitative approach and the systematic review, which will be discussed in this section of the research study.

3.2.1 STEP ONE: QUANTITATIVE RESEARCH

This section will describe the research design, method and measurements of quality pertaining to the quantitative approach as applied in the study.

3.2.1.1 Research design

Research design refers to the blueprint for conducting a study that maximizes control over factors that could interfere with the validity of the study (Burns and Grove, 2009:696). The research design for step one in Stage One of the study was quantitative, explorative, descriptive and contextual and was used to explore and describe the four identified current nursing care practices related to the safety of a mechanically ventilated patient in a critical care unit.

3.2.1.1.1 Quantitative research

Quantitative research implies that data obtained from participants by means of a data collection instrument can be analysed in terms of numbers that can be quantified or summarised. Quantitative research is concerned with systematic measurement, statistical analysis and methods of experimentation if required (Fox and Bayat, 2007:7). The definition is supported by Brockopp and Hasting-Tolsma (2003:20) stating that quantitative research is an approach to structuring knowledge by determining how much of a given behaviour, characteristic or phenomenon is present. Quantitative research methods are particularly concerned with objectivity and the ability to generalize the findings to others when describing and examining relationships amongst variables (Burns and Grove, 2009:23).

Quantitative research has the following characteristics, as illustrated by Fox and Bayat (2007:78):

- Data is in the form of numbers, which allows greater precision in reporting results;
- The focus is narrow and concise;
- Data is collected by means of a structured data collection instrument;
- Results are based on larger sample sizes;
- Analysis of results is more objective. Methods of mathematical analysis in the form of computer software packages can be used for data analysis;
- Analysis progresses by way of charts, statistics and tables. The data in this study is presented in the form of graphs, tables and figures.

The research study was quantitative in nature as it involved a formal, objective, systematic process in which numerical data were used to obtain information about the four nursing care practices related to the safety of the mechanically ventilated patient. Data was collected by means of a structured questionnaire which was completed by the professional nurses in the critical care units in the Nelson Mandela Metropole. Data analysis involves the use of mathematical methods and is graphically presented in this research study. Statistica Version 9.0 was used to capture and analyse the data, which was done with the assistance of a statistician. In the research study, generalisations of the data findings are made using data numbers and statistical analysis, which justified the use of a quantitative rather than a qualitative approach.

3.2.1.1.2 Explorative study

Exploratory research aims to explore what exists. This approach can also be used when a researcher examines a new interest or if the topic of interest is relatively new (Fox and Bayat, 2007:30). Exploratory designs are used to employ an open, flexible and inductive approach in an attempt to look for new insight into a phenomenon (Blanche, Durrheim and Painter, 2006:44). An exploratory design was used as the study aimed to explore the four nursing care practices related to the safety of a mechanically ventilated patient as performed by professional nurses in the critical care units in the Nelson Mandela Metropole. The analysed data provided new insight into the nursing care practices that are currently performed by these nurses. Exploring these identified nursing care practices provided the researcher with valuable information in determining if current nursing care practices are based on the best available evidence.

3.2.1.1.3 Descriptive study

Descriptive research aims to describe a certain phenomenon or occurrence in a specific context. Burns and Grove (2009:45) write that this approach is used to generate new knowledge about concepts or a topic about which limited or no research is conducted. Descriptive studies help researchers to discover new meaning, describe what exists, determine the frequency with which something occurs and categorize information. The research study is descriptive as it aimed to

describe and categorize information by means of a structured questionnaire, which reflected the current nursing care practices as performed by professional nurses caring for mechanically ventilated patients in critical care units in the Nelson Mandela Metropole.

3.2.1.1.4 Contextual study

It is important to understand the context or the environment in which the research study takes place. The context can also be referred to as the setting or the location where the study is conducted. Burns and Grove (2009:362-363) differentiate between three common settings for conducting research, namely the natural, partially controlled and highly controlled settings. Uncontrolled, real-life settings where studies are conducted are referred to as natural settings and this is often where descriptive studies take place. Conducting a study in a natural setting means that the researcher does not manipulate or change the environment for the study. The collection of data by means of a structured questionnaire took place in the critical care environment as participants were not allowed to take the questionnaires home. The participants were in their natural environment while completing the questionnaire, implying that they could be observed and could reflect upon their current nursing practices in caring for mechanically ventilated patients and could relate these to the questionnaire, which allowed them to answer the questions as honestly as possible.

Holloway and Wheeler (2002:34) add another dimension to this context, namely the conditions in which the study takes place, which basically means the surroundings, circumstances or setting where the study is conducted. Although the research study took place in the critical care units of the private and the public health care institutions, the environment is the same: one where nursing care is rendered to the adult mechanically ventilated patient. All the critical care units have the same or similar types of mechanical ventilators, and the operational principles of mechanical ventilation are universal. The nursing care practices, namely endotracheal tube verification, endotracheal cuff pressure monitoring, suctioning, and monitoring ventilator settings are common practices in the care of the mechanically ventilated patient.

3.2.1.2 Research method

According to Bak (2004:26-27), it is important to specify what kind of research method will be used in a research study. The research method describes the plan used to conduct the research study systematically and concisely and is schematically presented in Figure 3.1.

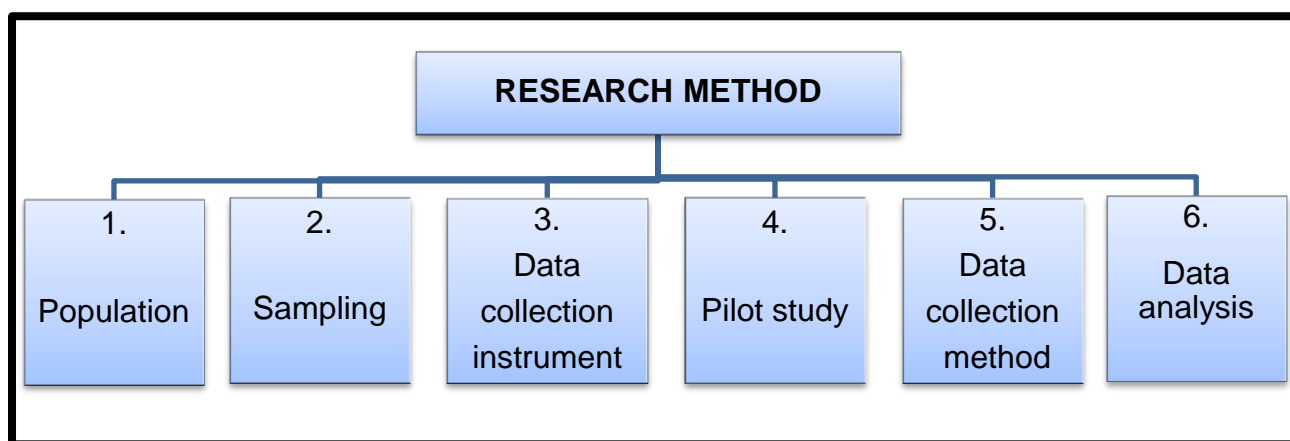


Figure 3.1 Schematic presentation of research areas used for the quantitative approach in the research study

3.2.1.2.1 Population

The research population refers to particular types of individual that meet a certain criteria for inclusion in a given setting. The target population is the entire set of individuals who meet the sampling criteria set out for the specific setting (Burns and Grove, 2009:344). In this study, the research population refers to all the professional nurses working in the critical care units in the Nelson Mandela Metropole, while the target population refer to the professional nurses working in adult critical care units, thus excluding the professional nurses working in the neonatal and paediatric critical care units.

In order to establish the target population for the study, an informal survey was conducted where the unit managers of each adult critical care unit in the Nelson Mandela Metropole were contacted by e-mail or by phone. The information supplied was related to the types of patient admitted to the respective critical care units, numbers of professional nurses working in the units, and the average percentage of mechanically ventilated patients admitted per month to the critical care units. The

professional nurses included those who are permanently employed as well as those professional nurses who are employed on a part-time basis (often referred to agency workers as they are not employed by the health care institution but by a nursing care agency). An overview of the information provided by the unit managers of the adult critical care units in the Nelson Mandela Metropole is illustrated in Table 3.1.

Table 3.1 Survey of the critical care units (Institutional statistics, Critical Care Units: Nelson Mandela Metropole: 2009)						
Institutions	Type of units	Type of patients	Permanent employed PNs	Agency workers (PNs)	Total number of PNs*	Average % *MV patient occupancy/month
CCU 1	Private	Multi-system disorders (MSD)	25	10	35	75% (16 beds)
CCU 2	Private	MSD	12	8	20	67% (8 beds)
CCU 3	Private	MSD	11	9	20	60% (10 beds)
CCU 4 (pilot study)	Private	MSD	8	6	14	40% (8 beds)
TOTAL: PRIVATE					89	
CCU 5	Public	MSD	12	None used	12	45% (6 beds)
CCU 6	Public	MSD	18	-	18	50% (6 beds)
CCU 7	Public	MSD	45	-	45	80% (12 beds)
TOTAL: PUBLIC					75	
TOTAL NUMBER OF PN's WORKING IN THE CRITICAL CARE UNITS					164	

*(PNs =professional nurses; MV =Mechanically Ventilated)

In Table 3.1, multi-system disorders refer to patients who are admitted to the critical care unit with one or more diverse of conditions/diseases and not necessarily bound to a single disease/speciality only (e.g., cardio-thoracic or neurology). The type of patients admitted in these units can include any medical or surgical disease condition, for instance, renal failure, diabetic keto-acidosis, head injuries, spinal cord injuries, abdominal trauma and/or surgery, acute emergencies and obstetric patients. Note that the patients requiring mechanical ventilation per month varies from 40 to 80%.

3.2.1.2.2 Sampling

Sampling is the process of selecting a group of individuals who can be used in a research study (LoBiondo-Wood and Haber, 2010:221). A sampling method describes the strategies that will be used to obtain an adequate sample size, if required for a study. A sample is a group of individuals taken from a larger population that is selected for inclusion in the research study (Burns and Grove, 2009:349). This section of the research addresses the sampling strategy and size used in the study.

Sampling strategies are generally grouped into two categories, namely probability and non-probability sampling methods. In non-probability sampling, elements are chosen by non-random methods, while probability sampling uses some form of random selection when the sample units are chosen. The types of non-probability sampling include convenience, quota and purposive strategies. For the purpose of this research study, a non-probability, non-randomised, convenience sampling method was chosen in collecting data. A convenience sampling is the use of the most readily accessible persons available to the researcher for participation in the study (LoBiondo-Wood and Haber, 2010:226). Due to the small numbers (12-45) of professional nurses that are working in critical care units (see Table 3.1) and the concern of the researcher to obtain an adequate number of participants for inclusion in the research study, it was decided to use a convenience sampling strategy. All the available and willing professional nurses in the adult critical care units in the Nelson Mandela Metropole were included in the research study.

According to LoBiondo-Wood and Haber (2010:226), there is no single rule that can be applied in the determining a sample's size. A general rule of thumb is always to use the largest sample possible as smaller samples produce less accurate results. Considering the use of a convenience sampling strategy in this study, all the available and willing professional nurses in the adult critical care units were included, thus yielding to a total sample size of 164 professional nurses. However, after exclusion of those participants used in the pilot study, only 150 professional nurses were included in the study (See Table 3.1).

3.2.1.2.3 Data collection instrument

Data collection is the precise, systematic gathering of information relevant to the research purpose or specific objectives, questions or hypothesis of a study (Burns and Grove, 2003:42). Data collection can be done by means of forms developed or modified for recording demographic data, information from patient records, observations or values from physiological measures (Burns and Grove, 2009:695).

In this research study, data was collected by means of a structured questionnaire. Questionnaires are simply lists or pre-written questions, which can include a wide range of questions. The questionnaire used in this study included closed questions, with a yes/no variety, rating scales, filter questions and forced choice items. Rating scales require the respondent to indicate a degree or preference or agreement from a limited range of choices, while forced choice items set out a possible range of responses from which participants then choose (Walsh, 2001:63). Open-ended questions were also included in the questionnaire and participants had to indicate their answers in the relevant spaces provided. The questionnaire construction was based on the narrative literature review.

The questionnaire (Annexure E) was divided into five different sections: Section A comprised the demographic data; Section B explored and described endotracheal tube placement verification; Section C addressed endotracheal tube cuff pressure monitoring; Section D explored and described current practices regarding airway patency with specific reference to endotracheal tube suctioning practices and Section E addressed mechanical ventilator settings.

3.2.1.2.4 Pilot study

A pilot study is defined as a smaller version of a proposed study, which is conducted to refine the research methodology or strength of the study design (Burns and Grove, 2009:44).

According to Burns and Grove (2009:44), a pilot study must be designed to:

- Determine whether the proposed study is feasible in terms of resources;
- Identify problems with the study design;
- Determine whether the sample is representative of the population or whether the sample technique is effective;
- Develop or refine the data collection instrument;
- Assess the reliability and validity of the data collection instrument;
- Refine the data collection and analysis plan;
- Assess the researcher's data analysis techniques.

One adult critical care unit, comprising of 14 professional nurses, in the Nelson Mandela Metropole was included in the pilot study. The critical care unit in the private sector has been chosen as it employs the least professional nurses, namely eight permanent employees and six agency workers(see Table 3.1, critical care unit 4 (CCU 4). Approximately 40% of patients admitted per month require mechanical ventilation (Institutional Statistics: Critical Care Unit: Private Health Care Institution: Nelson Mandela Metropole, 2009). In comparison with the other critical care units in the private health care institutions, the percentage of mechanical ventilation is the least for this specific unit. Therefore, it was decided to use this particular critical care unit for the pilot study.

Consent was obtained from the hospital and unit manager of the hospital prior to conducting the pilot study. A pre-arranged time and date for doing the pilot study was established with the unit manager in order to avoid disruptions in the normal activities performed in the critical care unit. The research objectives and purpose were explained to the participants and the informed consent was obtained from individuals who wanted to participate in the pilot study. On the specified date, the pilot study was conducted with only six of the 14 professional nurses on duty. The

remaining staff was off duty or on sick leave. Due to administrative duties, the unit manager was not available for inclusion in the pilot study. Five out of the 14 participants in the critical care unit of the private health care institution were available and willing to participate in the pilot study. The questionnaires were handed out to the participants who completed it within half hour without needing any clarification from the researcher. The results of the pilot study proved that the questionnaire tested what was expected. The questions were clearly understood and the participants completed it to the best of their ability and comprehensively possible. No change with regard to the content of the questionnaire was made and minor editorial corrections were noted and made.

It is recommended that it is best to discard the data that was obtained in the pilot study rather than including it in the final study, as researchers often adjust their data collection tools as result of things learned from the pilot study. The results obtained from this pilot study were not included in the final study results.

3.2.1.2.5 Data collection method

Consent was obtained from the participants and various stakeholders before embarking on the study. Once participants agreed to participate in the study, questionnaires were distributed in the critical care units within the Nelson Mandela Metropole. The questionnaires were given to the participants at the beginning of each shift, day and night. It was made clear that the participants were not allowed to take the questionnaires home and had to complete them while on duty in order to ensure the reliability of the responses. The unit managers assisted in co-ordinating this process, which was repeated until all the shifts had been included at one institution. The same procedure was executed in all the adult critical care units in the Nelson Mandela Metropole.

Due to the logistics and geographical location of the critical care units across the Nelson Mandela Metropole, the researcher could not be present at the beginning of each shift in each unit to clarify any questions. However, where possible, I remained in the unit for 10 to 15 minutes at the beginning of the data collection process, there after participants could contact me by phone, if required. The participants were not

allowed to obtain the answers to the questionnaire from textbooks, share information or complete the questionnaires at home, as their answers had to be based on working knowledge. They were thus instructed to post the completed questionnaires into sealed boxes, which were placed at the central nursing stations or unit managers' offices in each unit, before going off duty. The researcher collected the questionnaires at a pre-arranged time and date from the unit managers, who assisted with the process. The data collection process continued over a period of three weeks, which allowed the professional nurses on all the shifts to be included in the study.

Although the initial survey (as illustrated in Table 3.1) revealed that 150 professional nurses (excluding the 14 professional nurses employed in the critical care unit used for the pilot study) would be available for inclusion in the research study, only 134 were available. In the public sector, 11 professional nurses were not available as six were on leave, three were on study leave and two were off sick. In the private sector, five were not available as two professional nurses were on leave and three agency workers were not required to work at the time of the study. Although 134 questionnaires were handed out in the critical care units of both the private and public sectors, only 101 were returned, of which one questionnaire was incomplete and could not be used. In the public sector, 21 participants refused to participate, while in the private sector, only two participants refused. Reasons such as the questionnaire being too lengthy and lack of time to complete it were given as the reasons to refuse. Furthermore, 10 questionnaires were not returned (three in the public sector and seven in the private sector). A total of 100 completed questionnaires, 40 from the critical care units in the public sector and 60 from the private sector were available for analyses.

3.2.1.2.6 Data analysis

The purpose of analysing data collected in a study is to describe the data in meaningful terms. In using a quantitative approach that uses numbers to organize, analyze and interpret data, the researcher had to make sense of a set of numbers and communicate them in some logical fashion to the reader. Data analysis allowed the researcher to make sense of the data that was collected, provide information that

is understandable and discover relationships and differences of the phenomenon being explored. Data presentation by means of tables and graphs helped to summarise the data, thus making it easier to understand (Brown and Saunders, 2008:18).

Data analysis comprises of four steps: identification of the study objectives, data preparation, implementation of analysis and data presentation (Myatt, 2007:7). These four steps, as applied in the research study, are discussed below.

Identification of the study objective

The objective of the study with regard to the data collection instrument was to collect data on the current nursing care practices related to endotracheal tube verification, endotracheal tube cuff pressures, endotracheal tube suctioning and mechanical ventilator settings. Professional nurses in the public and private adult critical care units in the Nelson Mandela Metropole were included for participation in the research study.

Data preparation

The process of data collection and preparation is critical to the confidence with which decisions can be made. The data needs to be put into a tabular format in order to characterize all the variables. Data also needs to be cleaned by resolving any ambiguities, errors and removing redundant and problematic data. Details concerning the steps taken to prepare data for analysis should be recorded. This not only provides documentation of the activities performed, but also provides a methodology to apply to a similar data set in the future (Myatt, 2007:17).

On collection of the completed questionnaires, the data analysis process started by ensuring that the data was reliable and represented the defined target population. All questionnaires were checked for comprehensiveness and completeness. As enrolled nurses are employed in the critical care units in both public and private sectors, the demographic section of all the questionnaires had to be checked to ensure that only professional nurses completed the questionnaires, especially since the researcher was not available on all the shifts to hand out the questionnaires.

Coding is the process of transforming data into numerical symbols that can be entered easily into the computer (Burns and Grove, 2009:432). Data was coded after the collection process was completed. Apart from the reference number on each questionnaire, a number was assigned to each questionnaire from the private and public divide. Numbers 1-40 were assigned to the questionnaires collected from professional nurses in critical care units in the public sector, while numbers 41-100 were assigned to questionnaires collected from professional nurses in the private sector. The coding process was necessary to assist in capturing the findings from the different health care sectors and the allocated numbers were thus only reflected in the data verification and frequency tables and not in the final presentation of data; however, these aided in differentiating between the nursing care practices of the professional nurses in the public and private sectors respectively.

Each variable for each question was then coded for capturing to the data capture sheet prepared by the statistician. Data were categorised by using constant, dichotomous, discrete and continuous variables. It was decided to categorise demographic variables to allow for cross tabulation, if required during the analysis process. The variables were categorised as follows:

- Group: public=1 and private=2;
- Gender: male=1 and female=2;
- Years' experience: <=5 years=1; 6-10 years=2; 11 and more years=3;
- Post-basic qualification category: Yes=1; no=2;
- Position held: non-leadership (including all the permanent and agency worker)=1; leadership (unit managers, shift leader and clinical facilitator/mentor)=2.

The variables for the questions in Sections B, C, D and E of the questionnaire were coded from 1-8 depending on the responses to the questions posed. Data tables for the capturing of the data were created by a statistician.

Having performed the preliminary data characterization, the data cleaning process was then done prior translating it into a suitable form for data analysis. Questionnaires were re-checked for missing data. Variables measured on interval

and ratio scales were cleaned by checking for the correct responses. Variables that were not noted by the participants and missing data points were removed from the data tables.

Data transformation was done in order to make sense of the raw data. Data transformations included using normalization methods such as minimum-maximum formulas and decimal scaling. Factor analysis was done to assess the interrelationships among large numbers of variables and disentangles those relationships to identify clusters of variables that were most closely linked together. Similarity grouping measurements were done for each response in each section. The care practice items were weighted with the digits 0, 1 and 2 and 3 respectively. The higher weighting (2 or 3) constituted the best nursing care practice as recommended in the narrative literature review. The lower weighting (1) represented adherence to what is marginally accepted as constituting best practice. It is thus suitable but not necessarily best practice. The weighting of 0 represented non-adherence to either of the aforementioned.

Frequency tables for every response in each section were created by the statistician using Statistica version 9.0. These frequency tables indicated the responses for both the public and private sectors. Furthermore, in order to establish the quality of nursing care practices, a rating scale ranging from low, average and high was created. A rating in the high category constituted adherence to best recommended practices. A rating in the average category indicated practices that are marginally accepted but not necessarily best recommended practice. The rating in the low category indicated non-adherence to recommended best practice. The higher the nursing care practice score, the closer the adherence to best practice recommendations. Similarly, the lower the nursing care practice score, the less likely was the adherence to best practice recommendations.

Each section on the different nursing care practices was analysed using a percentage ranging from 20% to 99%. Frequency distribution tables were created for each of the nursing care practices, as well as a combined representation of all four nursing care practices. Correlation analysis between the public and private sectors

for each section, as well as the combination of the four nursing care practices was done.

Implementation of the data analysis

Implementation of data as analysed comprised two major tasks: summarizing the data and finding hidden relationships amongst variables. Data was summarized using tables and graphs. According to Myatt (2007:36), tables can be used to present both detailed and summary level information about a data set. It allows the reader to look at individual observation or summaries. Graphs visually communicate information about variables in data sets and the relationship between them. Graphs present the data by visually replacing numbers with graphical elements. It enables us to visually identify trends, ranges, frequency distributions and relationships and make comparisons. Summary tables were used to display the demographic data and complications related to over-inflation and under-inflation of the endotracheal tube cuff pressures. Various graphs can be used to display and summarise data. To ensure consistency, bar graphs were used throughout the study to display and summarise the data.

Descriptive, inferential and correlation statistics techniques were used to describe and summarize the data. According to Brown and Saunders (2008:2), descriptive statistics are concerned with quantitative data and the methods for describing them, whereas inferential statistics make inferences about populations by analysing data gathered from samples and deal with methods that enable a conclusion to be drawn from this data. Correlation statistics quantify relationships within data. The descriptive, inferential and correlation statistics that were used were the Chi-square and p value calculations and were applied in Chapter 4 of this study. The p value is frequently presented to illustrate the likelihood of the results of a topic, with its value always being between zero and one. A p value of 0.5 indicated that there is a 1 in 2 probability of the results being due to chance. In this case, it would be unlikely to accept the results of the study as being significant. Conventionally, a p value of 0.05 or below would be accepted as being statistically significant. That means a probability of 1 in 20 that the result is due to chance (Craig and Smyth, 2007:135).

Within this study, the Chi-square test of independence was used to explore if there were relationships between the responses from the professional nurses in the critical care units of the public and private health care sectors. A Chi-square p value less than 0.05 was considered statistically significant. For statistically significant results, Cramer's V was calculated to determine whether the results were practically significant, indicated by V values greater than 0.10.

Finding hidden relationships refers to the identification of important facts, relationships or trends in the data, which are not obvious from a summary alone (Myatt, 2007:3). Within this research study, the relationship between the public and private sectors was explored with specific reference to each nursing care practice section, as well as the combination of the four nursing care practices.

Data presentation

Data presentation involves setting up a plan to deliver the results of the analysis to the identified consumer, which, in this case, is the reader of the research project. The report of the data analysis is presented in Chapter 4 of this study.

3.2.2 RELIABILITY AND VALIDITY OF THE QUANTITATIVE APPROACH

In quantitative approaches, measurement, which is a process of assigning numbers to objects according to some rule, was used. Instrumentation, on the other hand, is the application of specific rules to develop the measuring instrument. Instrumentation produces trustworthy evidence that can be used to evaluate the outcome of the research study (Burns and Grove, 2009:371). Measurement and instrumentation are important as they reflect the quality of the research. Reliability and validity are some of the quality measurement methods applicable to this research study and are discussed below.

3.2.2.1 Reliability

Reliability refers to the consistency of measure obtained by the use of an instrument (Burns and Grove, 2009:377). The data collection instrument must be proven to produce the same results from one research session to another. However, the questionnaire must be used for the same type of population in order to ensure that it

is reliable. Reliable instruments enhance the power of a study to detect significant differences actually occurring in the population under study. In order to prove that the results were reliable a pilot study was conducted. The statistician was consulted to assess whether the questionnaire used in the study was eliciting the correct responses. The format of the questions posed as well the analysis of the different questions was discussed to ensure that this was reliable. No content changes were made to the questionnaire and the main study was then done.

3.2.2.2 Validity

According to Walsh (2001:15), validity refers to the issue of whether data collected is a true reflection of what is being studied. Until recently, validity has been categorised into three types: content, predictive and construct, each with its own sub-types. According to Burns and Grove (2009:380), validity is currently only categorised as **construct validity**, which includes **content and predictive validity** as the sub-types. Construct validity examines the fit between the conceptual and operational definitions of variables and determines whether the instrument actually measures the theoretical construct that it purports to measure (Burns and Grove, 2009:693).

Content validity assesses the extent to which the measuring instrument includes all the major elements relevant to the construct being measured. Content validity testing determines clarity and relevance of the content of the measuring instrument (Burns and Grove, 2009:382). The sources that have been used in constructing the measuring instrument need to be assessed. These sources can include literature, representatives of the relevant population and content experts. Content validity of the questionnaire in the study was ensured by using relevant literature sources in constructing the structured questionnaire. The questionnaire was discussed with various experts in the field of critical care, who included a clinical facilitator in critical care nursing, a lecturer in the field of critical care nursing, a professional nurse working in the critical care unit, the research promoter and the statistician, who specifically assessed the content of the questionnaire. The pilot study revealed that the content of the questionnaire was clear and understandable to the participants. The questionnaire was based on the results from the narrative literature review done

on the four identified nursing care practices as well as the core concepts of the study.

Predictive validity refers to an instrument where future performance or attitudes are proposed or predicted based on an instrument score (Burns and Grove, 2009: 715). Predictive validity was not used in this research study.

Readability of an instrument used in the study is another essential aspect to consider in measuring the reliability and validity of that instrument. Readability has never been formally identified as a component of content validity but Burns and Grove (2009:384) suggest that it should be considered, as incomprehensible content cannot be valid. Although there are various readability formulas available for test the readability of an instrument, these were not used in this study. The structured questionnaire was submitted to the various experts above who had assessed the layout, technical care, readability of the instrument and clarity of the questions asked. The participants did not report any uncertainties in completing the questionnaires during the pilot study, thus proving that the structured data collection instrument used for this research study was valid.

3.2.3 STEP TWO: SYSTEMATIC REVIEW

Step Two in Stage One of the research study comprised of a systematic review, which was done in order to explore and describe existing literature for the two identified nursing care practices related to the safety of the mechanically ventilated patient in a critical care unit. The two nursing care practices were identified following the data analysis from the structured questionnaires, indicating the nursing care practices that were done least according to best recommended practices. This section aims to discuss the design, method and measurements of ensuring quality in performing a systematic review.

3.2.3.1 Research design

A literature review that is performed systematically, as in the case of a systematic review, is a research methodology in its own right (Aveyard, 2010:19). This section

describes the differences between a systematic review and a narrative literature review.

3.2.3.1.1 Systematic review

The systematic review is a fundamental component of evidence-based practice. According to Egger, Smith and Altman (2001:5), a systematic review is defined as a review that has been prepared using a systematic approach to minimising biases and random errors which is documented in a materials and methods section. Systematic reviews are essential tools for health care workers, researchers, consumers and policy makers who want to keep up with the evidence that is accumulating in their fields. In performing a systematic review, the lack of adequate evidence in the field of interest might be demonstrated and areas where further research studies are needed are identified. Systematic reviews allow a more objective appraisal of the evidence than narrative literature reviews and may contribute to resolve uncertainties when original research, reviews and editorials disagree. Systematic reviews use rigorous methods to reduce bias and can provide reliable summaries of relevant research evidence (Craig and Smyth, 2007:186).

A systematic review allows for critical synthesis of research evidence, which involves analysis of all available and relevant evidence in a systematic, objective and robust manner. Systematic reviews use objective, explicit and transparent methods, which allow the reader to follow how conclusions were reached. In areas where no evidence exists, or where current evidence is inconclusive, systematic reviews may be helpful indicating where further primary research is required (Bruce and Mollison, 2004:13).

3.2.3.1.2 The purpose of a performing a systematic review

The body of knowledge on which healthcare is based is changing rapidly and so what is taught to nursing students might remain relevant for only a limited period of time. Keeping up to date with this changing knowledge can be very difficult. According to Evans (2001:52) it has been estimated that approximately 20 000-30 000 biomedical journals are published annually. As a result of this, the number of clinical trial reports available has become too large for clinicians to comprehend on

an on-going basis. Further, the quality of published research is highly variable. The use of inappropriate research methods, poor standards of statistical analysis or inadequate sample size often make research findings inconclusive or contradictory. This makes it difficult to know which studies should be used as the basis for clinical practice. As a result, systematic reviews have become an increasingly important means by which research results are collected, sorted, appraised and summarised. Systematic reviews help in overcoming the problems associated with large amounts of published research and variations in quality between studies. While there is a range of approaches to reviewing research literature, properly conducted systematic reviews are seen to be the most reliable (<http://www.joannabriggs.edu.au>).

3.2.3.1.3 Systematic review versus a narrative literature review

In contrast to the narrative review, which might simply reflect the findings of a few papers that support an author's particular point of view, a systematic review entails systematic and explicit methods to identify, appraise and synthesize relevant studies in a specific subject (Craig and Smyth, 2007:101). Narrative literature reviews are undertaken with no defined method or systematic approach. A narrative literature review might fail to identify, include or appraise all the available evidence or specify the process by which judgements, conclusions and recommendations are made. Narrative literature reviews do not routinely incorporate all relevant up-to date scientific data. Furthermore, narrative literature reviews only attempt to summarise a body of literature and draw conclusions about the topic in question. The body of literature is made up of the relevant studies and knowledge that address the subject area. It is selective in the material it uses, although the criteria for selecting specific sources are not always apparent to the reader (Aveyard, 2010:16).

According to Rolls and Elliot (2008:202), a systematic review is underpinned by a rigorous process of:

- Developing a well-focused clinical question;
- Conducting an exhaustive search for literature related to this question by developing a well-focused searching strategy;

- Reviewing published and unpublished literature in a systematic way to identify the quality of research undertaken to verify the reliability and validity of the study findings;
- Appraising the literature;
- Developing a synthesis of these evaluations.

Narrative literature reviews, on the other hand, have no focussed research question, no focussed searching strategy and no clear method of appraisal or synthesis of literature (Aveyard, 2010:19).

In this research study, both approaches to searching for literature were used. A narrative literature review was done to give the reader insight into mechanical ventilation and the core concepts of the study, as well as all the four identified nursing care practices. The data obtained from the narrative literature review was necessary in order to guide the construction of the questionnaire. Due to the scope of the study, it was decided to perform two systematic reviews. The selection for the two nursing care practices to be included in the systematic review was based on the data analysis from the structured questionnaires. The nursing care practices that obtained the lowest score, implying that they were done the least according to best practice recommendations, were included for selection into the systematic review. As far possible, it was aimed not to include literature that has been used in the narrative review in the systematic review of the two identified nursing care practices.

3.2.3.1.4 The rationale for performing systematic reviews in this research study

According to Craig and Smyth (2007:206), systematic reviews are an important element of evidence-based practice, and evidence-informed practice when considering different types of evidence in order to draw conclusions. As illustrated in Chapter 1 of this study, there is an increasing emphasis been placed on basing health care decisions on best available evidence, thereby reducing health care costs and improving the quality of patient care. Within a critical care unit, decision-making is crucial and should be based on sound, valid and reliable evidence. Furthermore, it is important that nursing care practices be aimed at providing safe, effective and

sufficient patient care. If the evidence is presented in a way which makes the application easier, then clinicians may be more likely to use it (Bazian, 2005:270). The systematic review provided summaries on the best available evidence and guided the development of evidence-informed clinical guidelines to distil the large body of knowledge into a convenient, useable format.

A systematic review allowed the analysis of all available and relevant evidence in a systematic objective and robust manner, thus increasing the scientific rigour of the research study and the clinical guidelines formulated in this process. Ultimately, these clinical guidelines (which are based on the best available evidence), if implemented, will be able to reduce variations in practice. In Chapter 4 of the study, various practice variations were identified with regard to current nursing practices of professional nurses in the critical care units in the Nelson Mandela Metropole. Evidence-informed guidelines, based on the systematic review, aimed to both standardize care amongst professional nurses in the critical care units and to improve ultimately the quality and safety of care rendered to the mechanically ventilated patient.

3.2.3.2 Research method

Although the systematic review is referred to as secondary research, performing a systematic review also requires a technique and plan in collecting and analysing data. The method as applied in conducting the systematic review is illustrated in Figure 3.2 and will be discussed in this section.

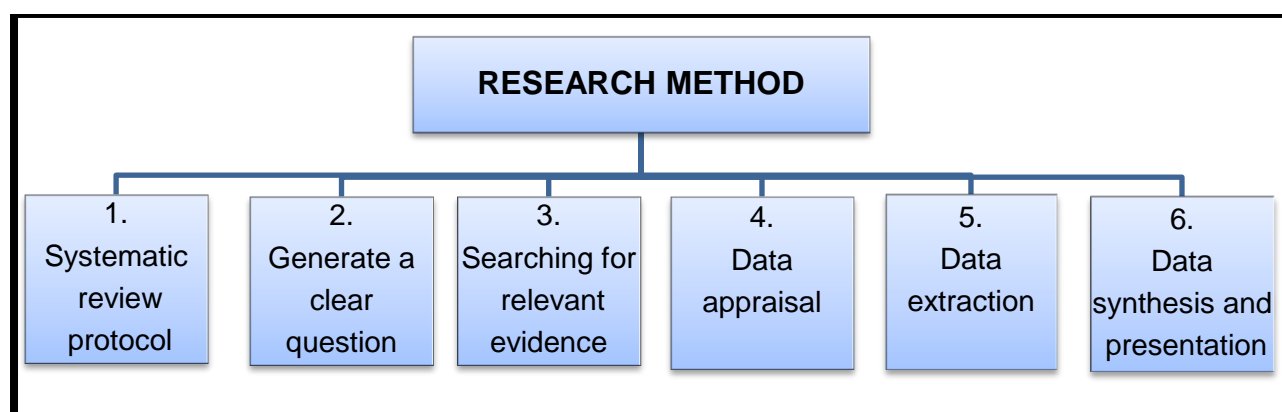


Figure 3.2 Schematic presentation of research method in the systematic review

3.2.3.2.1 Systematic review protocol

If a systematic review is to provide a useful summary of primary research, the review must utilise the same standard and rigour as the research it seeks to summarise. To facilitate this, the systematic review needs to follow a pre-planned protocol. The systematic review protocol ensures that the review is conducted with the same rigour expected of all research. Developing a protocol for a systematic review reduces the risk of bias from reviewers choosing only research that supports their own views as it sets out the specific processes that will occur throughout the review. The protocol should state the review question, how studies will be allocated, selected, appraised and then synthesised (Jones and Evans, 2000: 68; Evans, 2001:52; Pearson *et al*, 2007:57).

The data analysis revealed the two nursing care practices that were done least according to best recommended practices. The review protocols for the two identified nursing care practices included in the systematic review are reflected in Annexure G (Systematic review protocol for endotracheal tube suctioning) and Annexure H (Systematic review protocol for endotracheal tube cuff pressure monitoring).

3.2.3.2.2 The review question

As with any research, it is important to have a clear question or problem formulation. In the evidence-based process, it is the clinical question that drives each step of the process in searching for relevant evidence, sorting the best evidence from weaker, less valid evidence and ascertaining whether the evidence is applicable to patients and the settings in which it is to be used. The more explicit the question, the easier it is to develop a search strategy, as the main key components of the question asked will inform it. The less focused the question, the greater the incidence of finding a large amount of non-relevant studies when searching the literature in the various databases (Craig and Smyth, 2007:29).

In the evidence based practice approach, it is recommended that clinical questions be asked in the PICO format (patient population, intervention of interest, comparison intervention or status and outcome) to yield the most relevant and best evidence. However, due to the diverse variables that were found within these identified nursing

care practices, it was decided to use the PPC format, where P represents the population, P refers to the phenomenon of interest and C represents the context (*JBI Comprehensive Training Module 1*, 2010). In the research study, the population refers to the adult intubated patient, the phenomena of interest are endotracheal tube suctioning and endotracheal tube cuff pressure monitoring and the context is the critical care unit.

Derived from the PPC format, as identified, the review questions posed for the nursing care practices related to the safety of the mechanically ventilated patient in the critical care unit were as follows:

Endotracheal tube suctioning:

- How should endotracheal tube suctioning in an adult mechanically ventilated patient in a critical care unit be done in order to minimise and/or prevent the complications associated with the procedure?

Endotracheal tube cuff pressure monitoring:

- What nursing care interventions are the most effective in monitoring endotracheal tube cuff pressure to minimize the complications of over-inflation or under-inflation in the adult intubated patient in a critical care unit?

3.2.3.2.3 The search for relevant evidence

The next step after formulating the review question is to determine the source from which the best evidence is most likely available. An extensive, comprehensive and unbiased systematic search for all studies that meet the inclusion criteria (described in the systematic protocol and in Chapter 5) should be done. This search should attempt to identify all relevant published and unpublished studies using a variety of source (Jones and Evans, 2000:68). However, this process can yield large numbers of potentially irrelevant titles and abstracts. Therefore, it is recommended to develop a search strategy prior to undertaking the literature search. A search strategy refers to the searching method the researcher uses to identify the relevant literature source. According to Pearson *et al* (2007:60), it is important to develop a thorough search strategy as a poorly structured search strategy can diminish the quality of the

review should it fail to identify research papers pertinent to the review questions. During the systematic review, the search strategy was done in three different steps (see Table 3.2) in order to identify the relevant studies.

Table 3.2 Search Strategy		
Step one	Initial search of literature	<ul style="list-style-type: none"> • Searched databases, for instance, MEDLINE (Pubmed) CINAHL, JBI systematic review library and the Cochrane Library • Became familiar with the topic • Identified key search terms for each data base • Develop and document the search terms
Step two	Conduct search	<ul style="list-style-type: none"> • Searched all the databases using the identified search terms • Used inclusion and exclusion criteria (as explained in the systematic review protocol and Chapter 5) to determine which papers had to be retrieved
Step three	Bibliography search	<ul style="list-style-type: none"> • Searched the reference lists and bibliographies of all papers for additional studies • Search for grey literature for instance unpublished thesis

Step One comprised of an initial search of the major databases, which included CINAHL, MEDLINE (via PubMed), the JBI systematic review library, the Cochrane Library, clinical evidence from the British Medical Journal (BMJ) and the National Guidelines Clearinghouse and Google Scholar, using broad terms for each identified nursing care practice. These online data bases contain summaries of studies, overviews of diseases and summaries of the latest evidence to support treatment. Full text articles were available for access via these databases. Electronic versions of CINAHL (Cumulative index to nursing and allied health literature) was available as part of the EBSCO Host online services. MEDLINE (Medical literature analysis and retrieval system online) was accessed through via PubMed, EBSCO Host and Ovid Technologies. The Cochrane Library, which consists of six databases including the

Cochrane Database of Systematic Reviews, the Cochrane Controlled Trials Register and Database of Abstracts of Reviews, was accessed through Willey Interscience. The JBI systematic reviews were accessed online from the JBI site. Ovid Technologies and Science Direct via EBSCO were used to gain access to the other online databases. Google Scholar was a good place to start searching as it assisted in identifying key terms, but did not always granted access to subject-specific databases and full text academic journals.

The initial search results assisted to determine the type of database that is appropriate for the review questions asked, especially since mechanical ventilation and critical care were contextualized to certain databases only. Furthermore, the initial search assisted the author in becoming familiar with the topic; it gave me a feel for the landscape of literature that is available or accessible from the vast amount of databases. Some databases granted free access while others required subscription or purchase of the specific articles required, which aided in budgeting for the study. The initial search also assisted in identifying the key searching tools required for each database, as databases have their own language that can enable the searcher to find information more promptly. Searching tools, which are words or symbols used to assist in performing an optimal search, were used. These searching tools included the use of the Boolean logic, truncation, wildcard, thesaurus, index terms and MeSH headings (in PubMed). Search terms were then developed and documented. Note that due to the fact that the databases had different requirements for use of searching tools, which can be found on the database descriptions, the search terms had to be adjusted accordingly, as reflected in Annexures I and J.

During Step Two of the searching process, all databases was searched, using the identified search terms and inclusion and exclusion criteria set for each identified nursing care practice. It was important to decide what studies should be included, as well as excluded in the systematic review. This was done according to inclusion and exclusion criteria so that bias could be avoided. It was important to be precise in defining the inclusion and exclusion criteria as the reader of the review report needs to know the focus and the limitations of the review. Specifying unambiguous inclusion criteria would ensure that articles are similar enough to be statistically

combined (Jones and Evans, 2000:67). It is recommended by Pearson *et al* (2007:60) that the following should be considered when developing criteria:

- The types of studies to be included and excluded;
- The types of participants to be included in the studies;
- The intervention, activity or phenomenon;
- The types of measure outcomes;
- Language of publication;
- The time period.

The inclusion and exclusion criteria for each of the nursing care practices were initially formulated in the systematic review protocol and the application thereof is reflected in Chapter 5 of this study. Characteristics for the excluded studies are documented in Annexures K and L. In using the developed search terms and the inclusion and exclusion criteria, the search process was more manageable as it is can be quite frustrating to find evidence that is relevant and robust to the formulated review question in a haystack of information available.

In Step Three, all the reference lists and bibliographies of all papers found were searched for additional studies. This can also be referred to as pearl growing and was done to identify any additional studies missed during the databases searches. The comprehensiveness of searching and documenting the databases searched is a core component of the systematic review's credibility. In addition to databases of published research, there are several online sources of grey or unpublished literature that should be considered. Grey literature is a term that refers to papers, reports, technical notes or other documents produced and published by governmental agencies, academic institutions and other groups that are not distributed or indexed by commercial publishers. Many of these documents are difficult to locate and obtain. Rather than compete with the published literature, grey literature has the potential to complement and communicate findings to a wider audience (Pearson *et al*, 2007:35). Other databases that were found during this searching process included Highwire, Ingenta, the online Worldviews on Evidence-based Nursing. Through pearl growing, various journals besides the typical critical care journals were discovered, for instance, *Annals of Emergency Medicine*, *The New England*

Journal of Medicine, Anaesthesia Analogue, Acta Anaesthesiologica Scandinavica and Resuscitation.

Unpublished studies were also sought to help minimise the risk of publication bias, which results from the tendency that research showing a positive outcome is more likely to be accepted and published in journals than research that fails to demonstrate any benefit. The search for unpublished data was difficult and searching databases for conference proceedings uncovered some of the unpublished research. The Critical Care Society of Southern Africa was contacted by e-mail and telephonic communication to ensure that all relevant studies were located and reported. The Nesibopho Guidelines that were developed as part of the initiative linked to the Critical Care Society were found. Colleagues at other higher education institutions were contacted and databases at university libraries were searched to establish if any unpublished dissertations and theses were available. Two dissertations exploring the knowledge of professional nurses of mechanical ventilation were found and one thesis on clinical guidelines for neonatal critical care units was found. However, these studies were not quite applicable to the research focus. Hospital and unit managers in the critical care units of the public and private domain in the Nelson Mandela Metropole were contacted to establish if any clinical guidelines on the nursing care practices for review were available. None was identified on the topics in question. Note the discussion on the availability of institutional guidelines in Chapter 4.

Abstracts as well as full articles were used. In cases where only the abstracts were available and the article was proven to be of value, the librarian assisted in obtaining the full article, either by means of electronic request or interlibrary loans. In addition, journals were hand-searched, either online or in hard-copy form. Refer to Annexure F for the list of journals that have been hand-searched. Hand searching was done to increase the chances of including all the possible studies relevant to the review.

On completion of the searching process, the papers found had to be assessed in terms of the level of evidence they provided. It is recommended that once the review question has been formulated, the literature needed to answer the question needs to

be identified. The literature can be identified by using a hierarchy or levels of evidence (Aveyard, 2010:42). The level of evidence in itself does not tell the full worth of a study but is another tool that helps one think about the strengths and the weaknesses of a study and the nature of the evidence provided in the findings and conclusions. There are various hierarchies of evidence models available, of which the model as described in LoBiondo-Wood and Haber (2010:16) has been used in this research study (see Table 3.3). The rationale for using this level of hierarchy of evidence is because the study's objective is evidence-informed, thus drawing on a wider variety of evidence than just a single type of study, and this hierarchy of evidence provides for inclusion of the different types of evidence found.

Due to the fact that numerous literature papers were found on the topic of research, it was decided to adapt the level of evidence hierarchy by adding the literature papers to the Level VII evidence level. The decision was also based on the fact that the critical appraisal tool for the opinion papers would make provision for the appraisal of literature papers.

On completion of the searching process, all the papers found were read and re-read to assess if the literature was relevant to the review question. Furthermore, the papers found were re-read to assess the study methods used in each paper found. In identifying the study design, the papers could be categorised according to the hierarchy of evidence levels. Abstracts were also reviewed and if found that they should be included in the review, the librarian was contacted for assistance in obtaining the full-text article. The process was done for the two respective identified nursing care practices. The amount of studies, according to this evidence hierarchy, found for each of the two identified nursing care practice is illustrated in Chapter 5 of this study.

Table 3.3 Levels of evidence hierarchy (LoBiondo-Wood and Haber, 2010:16)	
Level I	Systematic review or meta-analysis of randomised control trials Clinical practice guidelines based on systematic reviews
Level II	A well-designed randomised controlled trail or randomised cross over studies
Level III	Controlled trial without randomization (quasi-experimental study)
Level IV	Single non-experimental study: <ul style="list-style-type: none"> • Cohort studies, correlation, case control • Descriptive, survey and/or observational • Case reports • Retrospective • Single-group repeated measure
Level V	Systematic reviews of descriptive and qualitative studies
Level VI	Single descriptive or qualitative study
Level VII	Opinion of experts and/or reports or expert committees/conference papers Literature review papers or best practice information sheets or guidelines (added by the researcher for the purpose of this study)

3.2.3.2.4 Data appraisal

Once a comprehensive literature search were conducted and articles and/or studies have been retrieved and assessed for inclusion and exclusion eligibility (as indicated in the systematic review protocol), the next stage of the systematic review process was to critically appraise the evidence found.

Critical appraisal, also called a critique of literature, is an organized, systematic approach to evaluate a research study or a group of research studies or other pieces of evidence found using a set of established critical appraisal criteria to objectively determine the quality of evidence provided by literature to determine its applicability to research, education or practice (LoBiondo-Wood and Haber, 2010:57). Critical appraisal should aim to assess the validity of the selected studies, determine the reasons why, other than chance, there is a difference between study results and

provide sufficient information for the reader to determine if the systematic review is applicable to their clinical practice. Furthermore, the purpose of critical appraisal is to include those studies that are of a high quality and to exclude the studies that are of a poor quality in the systematic review. The appraisal achieves this by evaluating critical components of the study design (Evans, 2001:54). Critical appraisal is very important as it assesses the relevance and quality of the paper to the review question (Aveyard, 2010:92).

Once the papers found were categorised according to the hierarchy of evidence levels, the papers were re-read to become familiar with them and to make absolutely sure regarding the type of study design used in each study. The rationale for doing this was to ensure that the correct critical appraisal was chosen for the type of paper to be appraised.

In order to facilitate the process of critical appraisal, various critical appraisal tools are available, for instance, the appraisal tools designed by the Public Health Research Unit at the University of Oxford (available at www.phru.nhs.uk/casp/casp.htm), which is known as the Critical Appraisal Skills Programme (CASP). Other critical appraisal tools include the Pedro Scale, the JADAD scoring system, RevMan (used by the Cochrane Systematic Review Group), RAPid (available via www.joannabriggs.edu.au/services/rapid), Catmaker accessed via <http://cebmh.warner.ox.ac.uk/cebmh/education-critical-apraisal.htm> and the SUMARI software packages (Pearson *et al*, 2007:98). Alternatively, critical appraisal tools can be self-developed according to the characteristics of the studies included in the review.

For the purpose of this research study, the SUMARI (System for Unified Management, Assessment and Review of Information) Version 4.0 software package, developed by the Joanna Briggs Institute, was used (www.joannabriggs.edu.au). Because the research study is based on the JBI theoretical framework, it was decided to use SUMARI as it assists reviewers in all components of the systematic review process, from systematic review protocol

development to critical appraisal, data extraction and synthesis of both quantitative and qualitative evidence.

SUMARI or the JBI-SUMARI is a software suite designed to assist health and other researchers, scientists and practitioners to conduct systematic reviews. SUMARI has a management component (the Comprehensive Review Management System: JBI-CReMS) that manages the systematic review process, including protocol development, facilitation of critical appraisal, data extraction, data synthesis and report development processes. CReMS can be used as a stand-alone program to manage and archive a review, or alongside the four analytical modules developed to articulate with it. Whenever a protocol is entered and confirmed in CReMS, the review details and the details of studies and/or papers selected for retrieval are automatically uploaded into the analytical modules selected by the reviewer. Similarly, as studies and papers are appraised, extracted from and synthesised, the results are uploaded to CReMS to generate an ongoing, editable report builder.

CReMS links to the four analytical modules of JBI-SUMARI namely:

- Joanna Briggs Institute Qualitative Assessment and Review Instrument (JBI-QARI). The module (accessible through CReMS) is designed to facilitate critical appraisal, data extraction and meta-aggregation of the findings of qualitative studies;
- Joanna Briggs Institute Meta Analysis of Statistics Assessment and Review Instrument (JBI-MAStARI). The module (accessible through CReMS) is designed to conduct the meta-analysis of the results of comparable cohort, time series, descriptive studies, case reports or review papers using a number of statistical approaches.
- Joanna Briggs Institute Narrative, Opinion and Text Assessment and Review Instrument (JBI-NOTARI). The module (accessible through CReMS) is designed to facilitate critical appraisal, data extraction and synthesis of expert opinion texts and of reports.
- Joanna Briggs Institute Analysis of Cost, Technology and Utilisation Assessment and Review Instrument (JBI-ACTUARI). The module (accessible through CReMS) is designed to facilitate critical appraisal, data extraction and synthesis of

economic data (SUMARI suite accessed via www.ioannabriggs.edu.au). A schematic outline of SUMARI version 4.0 is given in Figure 3.3.

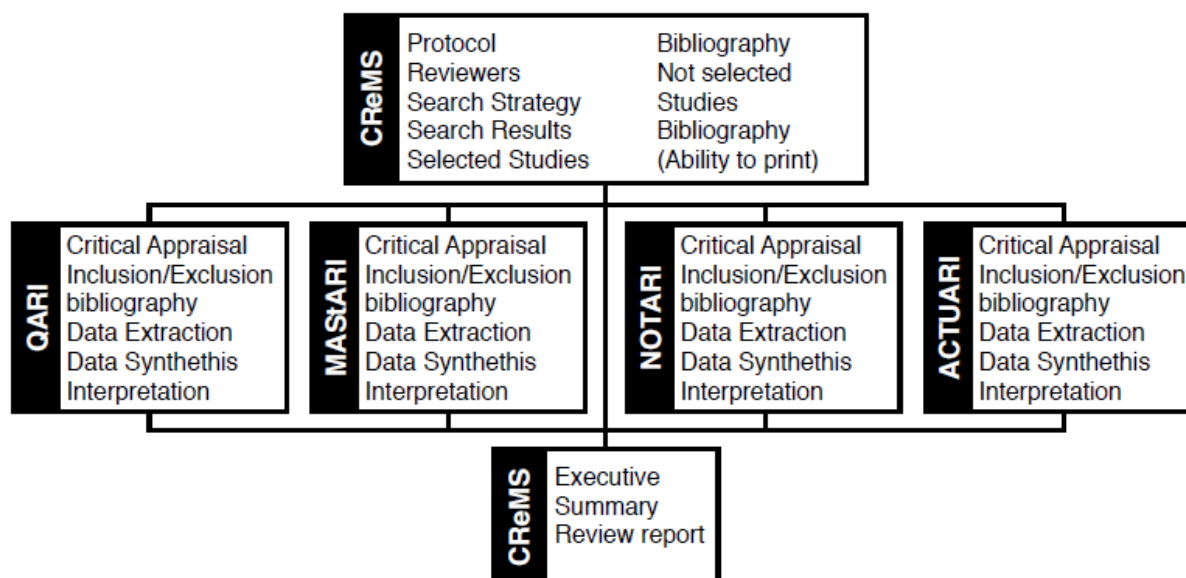


Figure 3.3 Outline of SUMARI suite (www.ioannabriggs.edu.au).

Once all the papers found were categorised, the systematic reviews were registered on the JBI SUMARI software suite. According to the evidence found, the critical appraisal tools in the MAStARI and the NOTARI modules were used to appraise the evidence. The JBI MAStARi was designed to enable reviewers to systematically review and combine the results of quantitative healthcare research. The critical appraisal tools in the JBI NOTARI module in the software package were used to appraise the Level VII evidence found, including opinion or expert, conference, committee and literature review papers.

However, despite the fact that the SUMARI software suite is quite comprehensive, it did not allow for the critical appraisal of clinical guidelines found. Therefore, the Appraisal of Guidelines Research and Evaluation (AGREE) appraisal tool, that was developed as part of an international collaboration of researchers and policy makers, was used. The instrument provides a standard framework for the development and implementation of clinical practice guidelines. A checklist of 23 items across six different quality domains provides a useful tool for the generation and evaluation of

guidelines. The AGREE instrument is generic and can be applied to all types of clinical practice guidelines (Schmidt and Brown, 2009:325). In this research study, the AGREE instrument was used to critically appraise the clinical practice guidelines or best practice guidelines found (see Annexure M).

Due to the diverse levels of evidence found in the study, different critical appraisal tools were used. Each tool is designed to assess the validity of study design and methods used and reported. Critical appraisal of Level I evidence addressed aspects related to the rigour of the searching process and reporting of data. Critical appraisal of randomised controlled trials (Level II) and quasi-experimental studies (Level III) assess if patients were randomised to study groups, the method of allocation, whether the allocation to treatment groups was concealed from the allocator, if the groups included in the study have been comparable at entry, whether the outcomes have been measured in the same manner for all participants, if the statistical analysis used was appropriate and if the rates of patient follow up have been reported as adequate. Furthermore, it is important to assess the degree to which possible bias has been limited. Source of bias in RCT designs includes selection, performance, attrition and detection biases.

Selection bias usually arises out of an inadequate randomisation of participants. In order to minimise the chance of selection bias, strategies, for instance, blinding until treatment allocation can be used. Blinding in this context means ensuring that neither the researchers nor the research participants are aware of who is allocated to the control or the experimental groups. Randomization should ensure that every participant has an equal chance of being in any of the study groups. In performing critical appraisal, the appraiser, therefore, needs to establish how well this was achieved (Jones and Evans, 2000:70; Pearson *et al*, 2007:74).

Performance bias occurs if additional therapeutic interventions are provided preferentially to one of the comparison groups (Egger *et al*, 2001:90). Performance bias is avoided by concealment of the treatment group and might be achieved through blinding both those participants and carers that might affect the study result. This can be referred to as double blinding (Pearson *et al*, 2007:76).

Detection bias refers to the tendency to look more carefully for an outcome in one of the comparison groups. Detection bias arises if the knowledge of the patient assignment influences the process of outcome assessment. Detection bias is thus avoided by the blinding of those assessing outcomes, including patients, clinician investigators, radiologists and review committees (DiCenso *et al*, 2005:548).

Protocol deviations and loss of follow-up may lead to the exclusion of patients after they have been allocated to treatment groups, which may introduce **attrition bias**. Possible protocol deviations include the violation of eligibility criteria and non-adherence to prescribed treatments. Loss of follow-up refers to patients becoming unavailable for examinations at some stage during the study period, either because of the patient's refusal to participate further, or because the clinician decided to stop the intervention or because the patient cannot be contacted for further follow-up (Egger *et al*, 2001:90). The critical appraisal tool makes provision for the assessment of the different types of bias that can be found. A copy of the critical appraisal tool used for experimental studies is illustrated in Annexure N.

In reviewing Level III evidence, which includes cohort studies, case control, surveys, prospective, observational and descriptive studies, the comparison made between groups, the outcomes measured, the time period for conducting the study, the attrition rate and whether an appropriate statistical analysis was used in the studies needed to be assessed. These were done using the critical appraisal tools as reflected in Annexures O and P.

No evidence was found at Levels V and VI; therefore, the critical appraisal will not be discussed. In assessing Level VII evidence, the source of the opinion had to be clearly identified as well as the background to the source of the opinion or author of the literature papers. The critical appraisal tool assess aspects for instance the material on which the opinion or paper is based, whether the opinion or paper is supported by peers. See Annexure Q for a copy of the critical appraisal tool used. The SUMARI software package made provision for the different types of critical appraisal tools to be used as illustrated in Table 3.4.

Table 3.4 Evidence hierarchy and software packages used for critical appraisal		
Level	Type of evidence	Software modules
Level I	Systematic review or meta-analysis of randomised control trials Clinical practice guidelines based on systematic reviews	Joanna Briggs Institute Meta Analysis of Statistics Assessment and Review Instrument (JBI-MAStARI) Appraisal of Guidelines Research and Evaluation (AGREE) instrument [Note: this appraisal tool is not part of SUMARI as discussed before]
Level II	A well-designed randomised controlled trial	JBI-MAStARI software
Level III	Controlled trial without randomization (quasi-experimental study)	JBI-MAStARI software
Level IV	Single non-experimental study <ul style="list-style-type: none"> • Cohort, correlation, case control • Descriptive, survey and/or observational • Case reports 	JBI-MAStARI software
Level V	Systematic reviews of descriptive and qualitative studies	Joanna Briggs Institute Qualitative Assessment and Review Instrument (JBI-QARI). Not used as no evidence related to the topic found
Level VI	Single descriptive or qualitative study	JBI-QARI. Not used as no evidence related to the topic found
Level VII	Opinion of experts and/or reports or expert committees, conference papers Literature review papers or best practice information sheets or guidelines (added)	Joanna Briggs Institute Narrative, Opinion and Text Assessment and Review Instrument (JBI-NOTARI) software

Once the study design and method of each paper to be critically appraised were assessed, two reviewers independently performed the critical appraisal using the SUMARI software packages. Consensus was reached and the primary reviewer, namely the researcher, concluded the assessment process in order to move onto the next phase, namely data extraction.

3.2.3.2.5 Data extraction

The data for a systematic review are made up of the results from the included studies. Data extraction is the process of taking the results from these studies in a systematic and repeatable way, and preparing it in such a way that similar results can be grouped together for analysis or synthesis. Data that meets the inclusion criteria for the systematic review should be extracted from the results of each study using a data extraction tool. The process of data extraction should be carried out with as much care as assessing for the methodological quality of the included studies. Having decided which studies are eligible for inclusion, the reviewer needs to tabulate the characteristics of the key variables that are of interest to the review. This description of the key characteristics should include the study methods, details of the participants, the precise nature of the interventions and the outcomes measured. A brief summary of major findings and any other results pertinent to the review topic should be noted on the data extraction sheet. For each study excluded, the reviewer needs to state in the review the reason for exclusion (Craig and Smyth, 2007:189).

The JBI-MAStARI and JBI-NOTARI software Version 4.0 respectively allowed for extraction of the data once the studies and/or papers found were critically appraised. In the JBI MAStARI, the extraction details page listed a range of fields which described the study method, setting, participants, number of participants, intervention, author's and reviewer's conclusion (see Annexure R).

The data extraction tool for the JBI NOTARI was different as was the MAStARI software package. Data extraction in the JBI NOTARI involved extraction fields such as the type of text, to whom the study referred or related to, the setting, geographical context of the study or paper and cultural context (see Annexure S).

No data extraction tool was available when using the AGREE instrument. Due to the limited number (4) of clinical or best practice guidelines found, it was deemed unnecessary to develop and pilot a data extraction tool. On completion of critically appraising the clinical guidelines, data was presented in a summarized manner.

3.2.3.2.6 Data synthesis and presentation

Data analysis in performing a systematic review is concerned with the pooling of results from studies that are similar. Two well-known approaches for synthesizing data collected from a systematic review are mainly used: meta-analysis and meta-synthesis (Pearson *et al*, 2007:92).

Meta-analysis refers to the statistical processes that are used to combine the results of studies of a similar nature. The statistics from different papers are combined to compress different sets of results into one bigger and more meaningful set of results. Meta-analysis has the advantage that many and varying results from each study can be summarized into one study. However, unless the focus or design of all the studies is the same, combining the results will not be possible or appropriate. This approach can further only be used for quantitative data of a similar type. When statistical analysis is not possible, current practice is to develop a summary of the results (Aveyard, 2010:126; Pearson *et al*, 2007:92). Results from the quantitative evidence found were critically appraised using the critical appraisal tools in the MASTARI module. Data was extracted using the extraction tools available in the MASTARI module. As mentioned before, the different modules in SUMARI are directly linked and entered into the CREMS. The MASTARI module in itself does not make provision for meta-analysis but once all the data is captured on the CREMS, it automatically synthesizes the data. If the results are similar in nature, meta-analysis will be possible and the data will be presented in the form of a graph, called a forest plot. The forest plot presents the individual study results with their confidence intervals as horizontal lines and a box in the middle of that line representing the mean effect. However, after entering the data into the MASTARI, no meta-analysis was possible. The results were thus summarized and presented in that way. The analysis and the presentation of the study results entered into the JBI MASTARI software package are discussed in Chapter 5 of this study.

Meta-synthesis refers to combining results that are obtained from qualitative studies. The results of qualitative studies are interpreted rather than summarized and involves determining keywords, phrases and ideas that occur in the same way in all or some of the studies in order to develop new concepts from the relationships

identified (Aveyard, 2010:127). No qualitative evidence was found that could be related to the systematic review questions. Therefore, meta-synthesis was not used.

Once data was extracted using the JBI NOTARI software package, conclusions or recommendations were drawn from the studies reviewed. The process of categorising the conclusions or recommendations and synthesising these categories is called meta-aggregation of data and is specific to the JBI NOTARI module in the SUMARI. Included papers were read and re-read by the primary reviewer. The identified conclusions or recommendations for each paper were then entered into the conclusion field. Once all the conclusions were drawn for the various papers reviewed, categories were assigned to the various conclusions. Categories are groups of conclusions that reflect similar relationships between similar phenomena, variables or circumstances that may inform practice (JBI SUMARI user guide, Version 4.0 accessed via www.joannabriggs.edu.au). The categories were formulated based on the items that were repeated in the conclusions or recommendations, for instance, normal saline instillation, hyperinflation and frequency of the suctioning procedure. Synthesis of data involved the aggregation of categories to summaries the findings of the individual studies into a final recommendation(s). The data as reported by categories and synthesis are discussed in Chapter 5 of this research study.

On completion of the critical appraisal process of the clinical or best practice guidelines found, only one of the three was included in the systematic review. The data extracted was summarised and the themes were linked to the data found in the literature papers, and were, therefore, not separately presented, but rather integrated into the results obtained from the Level VII evidence.

3.2.4 ASSESSMENT OF THE QUALITY OF STUDIES INCLUDED FOR CRITICAL APPRAISAL IN THE SYSTEMATIC REVIEW

Given that the systematic review aims to summarize the best available evidence by means of pooling the results of sufficiently similar results, it is important to note that pooling of poor quality evidence may lead to outcomes that are less desirable for patients. Therefore, it is of cardinal importance to ensure that whatever evidence is

used to make recommendations and to formulate clinical guidelines is not only based on the best available evidence, but a rigorous process is followed to ensure the validity and reliability of the results. All papers selected for inclusion in the systematic review needed to be subjected to rigorous appraisal by two appraisers or reviewers independently.

The major aim of critical appraisal of any type of evidence is to establish the validity and reliability of the evidence for practice. Validity in this context refers to the soundness of the evidence, in other words, it is about the degree to which the evidence can be accepted as trustworthy and believable. When considering critical appraisal of evidence for practice, it is important to understand that validity of evidence relates to the power it has to convince us that it is sound and supportable. Reliability of the study findings refers to whether the effects have sufficient influence on practice, clinically and statistically (Melnik and Fineout-Overholt, 2005:80; Pearson *et al*, 2007:75).

No matter whether the evidence being appraised arises out of randomised control trials or results from a qualitative study, its validity and reliability still have to be assessed. In order to assess the quality of the studies included in the systematic review, various critical appraisal tools were used for the various types of evidence found. For instance, when the evidence arose from research, validity and reliability were linked to the rigour of the research process utilised. Criteria used to assess rigour differed according to the research traditions that underpinned the research process reported. When evidence arose out of opinion or a summary of ideas as reflected in literature papers, the validity was dependent on the strength and the authority of the source and expression of the opinion that renders it supportable and relevant. The validity of evidence arising from randomised control trial (RCT) or pseudo-randomised studies refers to the degree to which possible bias has been limited (Jones and Evans, 2000:70; Pearson *et al*, 2007:74).

The critical appraisal process through the use of the various critical appraisal tools, which assessed different aspects of each study, included the terms of the research

design, methods and statistical analysis. These ensured that the studies included in the review were valid, reliable and of a good quality.

3.3 STAGE TWO: DEVELOPMENT OF EVIDENCE-INFORMED CLINICAL GUIDELINES

The overall purpose of Stage Two of the research study was to develop evidence-informed clinical guidelines for the two nursing care practices that were performed the least according to best recommended practices. The two identified nursing care practices include endotracheal tube suctioning and endotracheal tube cuff pressure monitoring. This section aims to describe the process of guideline development. The actual clinical guidelines will be presented in Chapter 6 of this study. The items for discussion in this section are reflected in Table 3.5.

Table 3.5 Items for discussion on evidence-informed clinical guidelines

- Definition of evidence-informed clinical guidelines
- Purpose of evidence-informed clinical guidelines
- Clinical guideline development process

3.3.1 Definition of evidence-informed clinical guidelines

According to Thompson (2008:91), evidence-informed clinical guidelines are defined as systematically developed statements to assist practitioner and patient decisions about appropriate health care for specific clinical circumstances. Clinical guidelines can be seen as the tools which are essential for the implementation of evidence-based practice. The word “systematically” implies that clinical guidelines should be formulated after a defined search for and assessment of relevant information and they should have a strong basis in evidence. Mead (2000:110) supports this by stating that clinical guidelines should be formulated and based on the synthesis of the best research evidence. According to Rees and Booth (2005:315), the development of guidelines must be supported by systematic, rigorous and explicit methods of evidence review and synthesis, thus supporting the fact that a systematic review is the essence and core of evidence-informed or evidence-based guidelines. Bazian (2005:270) states that the process for collecting, analysing and synthesizing

the data must be valid and reliable in order to make a sound evidence-based recommendation.

In this research study, evidence-informed clinical practice guidelines on endotracheal tube suctioning and endotracheal tube cuff pressure monitoring were developed based on the results of the systematic review.

3.3.2 The purpose of evidence-informed clinical guidelines

Evidence-informed clinical guidelines have a definite role and purpose in delivering health care. Lohr, Eleazer and Mauskoft (1998:5) argue strongly in favour of clinical guidelines and suggest that good clinical guidelines can change the process of health care and improve the quality and safety of patient care, thereby contributing to the cost-effectiveness of health care to patients. Evidence-informed clinical guidelines make explicit recommendations with a definite intent to influence the practice of the health care practitioners, determine and set standards and indicators for clinical practice and ensure standardisation of practice. They improve knowledge by making health care practitioners aware of the latest recommendations for practice and change attitudes of health care practitioners about the standards of care they deliver, thereby causing a shift in practice patterns and of always doing things the same way (Thompson, 2008:91).

Clinical guidelines are mechanisms for reducing inappropriate variations in clinical practice and discouraging practices that do not have convincing or sufficient evidence of effectiveness. Evaluations of clinical guidelines have demonstrated that improvements in the quality of care delivered in health care services are possible, thus reducing costs and improving patient safety (Thompson and Dowding, 2002:149). Clinical guidelines support quality improvement initiatives and have been proven to reduce, ineffective or wasteful health care practices (Miller and Kearney, 2004:814-815; Swinglehurst, 2005:309).

The purpose of the two clinical guidelines developed in this research study was to enhance and improve the quality of nursing care rendered to mechanically ventilated

patients in critical care units thereby enhancing patient safety as nursing care will be guided by the best recommended practice when implemented.

3.3.3 Clinical guideline development process

The National Institute for Health and Clinical Excellence (NICE) Clinical Guidelines Advisory Committee (<http://www.nice.org.uk>) in England suggests an eight-step approach in the formulation of evidence-informed clinical guidelines, which was applied in the development of the evidence-informed clinical guidelines in this research study. The steps for guideline development are described in Figure 3.4.

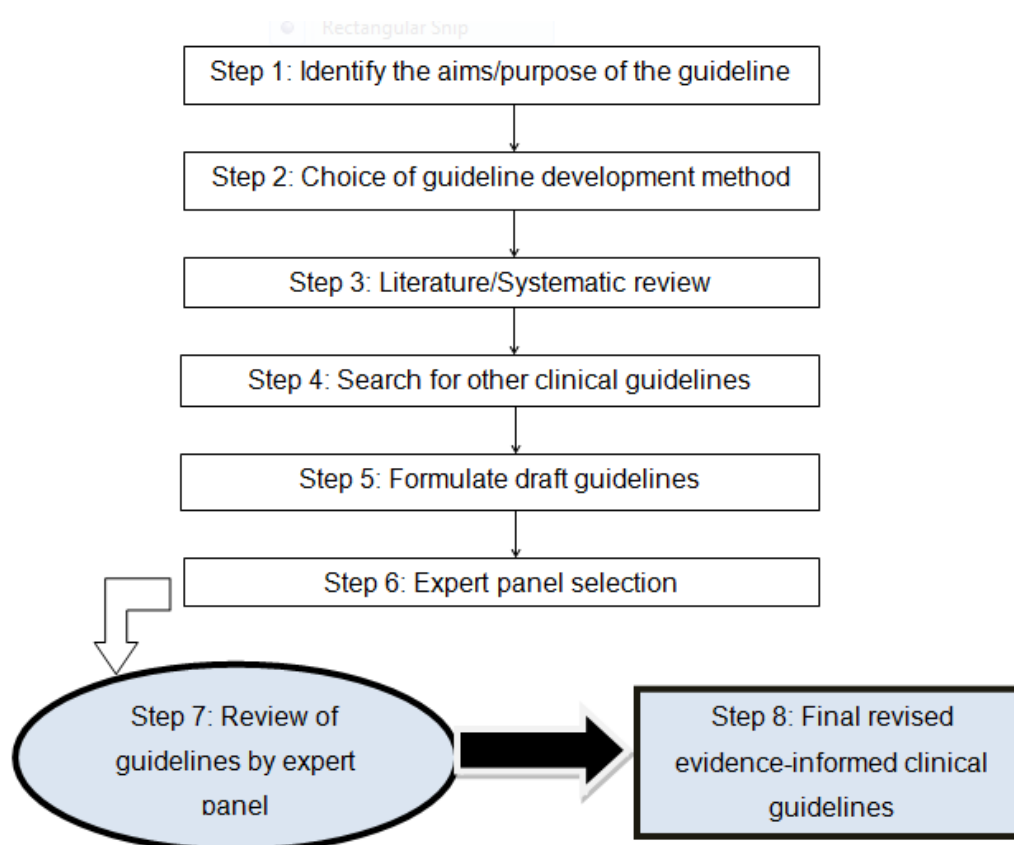


Figure 3.4 The clinical guideline development process

Step 1: Identify the aims/purpose of the guideline

The aims and/or purpose and components of the guidelines should be defined. The purpose of the two guidelines formulated in this research study was as follow:

Endotracheal tube suctioning:

- To provide recommendations, based on the best available evidence, on the methods and techniques related to endotracheal tube suctioning in order to minimize or prevent suctioning-related complications.

Endotracheal tube cuff pressure monitoring:

- To provide recommendations, based on the best available evidence, for nursing care interventions that are the most effective in monitoring endotracheal tube cuff pressure to minimize the complications of over- inflation or under-inflation of the endotracheal tube cuff.

Step 2: Choice of guideline development method

There are various methods to consider in developing clinical guidelines. Woolf (1996:511) describes three broad methods of guideline development, namely:

- Evidence-linked guideline development;
- Informal consensus approaches;
- Formal consensus approaches.

The evidence-linked guideline development method is when recommendations are based on a systematic review of literature. Explicit linkage is made to the level of supporting evidence in developing the clinical guideline. This linkage enables health care practitioners to make decisions about the level of adherence to the guideline. If a strong level of evidence is used in developing the guideline, health care practitioners are more likely to adhere to the guideline and vice versa (Thompson and Dowding, 2002:152). Within this research study, this method of guideline development was considered as the clinical guidelines are based on evidence drawn from the systematic review.

Informal consensus approaches are when committees at local level formulate recommendations without drawing on research evidence. This method tends to be based on poorly defined criteria, often lacking explicit statements of consensus, resulting in guidelines that tend to be subjective and ill defined (Thompson and

Dowding, 2002:152). Due to the nature of this study, this approach was not considered.

The formal consensus method refers to the implementation of methods such as Delphi, nominal group technique or consensus development conferences, which provide a structure for the group decision-making process on the guideline to be formulated. This method is criticised for not providing an explicit linkage between recommendations and the quality of evidence (Thompson and Dowding, 2002:152).

Within this research study, it was decided to combine the evidence-linked method with the formal consensus method as the recommendations were based on a systematic review. An expert panel, as discussed later in Step 6, reviewed the draft guideline.

Step 3: Literature/systematic review

It is recommended all the literature that is required for the clinical question to be answered be searched, categorised and analysed prior the guideline development. A systematic search of literature regarding the topic areas must be undertaken. A narrative literature review was initially undertaken on all four identified nursing care practices to aid in the development of the structured questionnaires. Based on data analysed, a systematic review was then performed on the two identified nursing care practices, namely endotracheal tube suctioning and endotracheal tube cuff pressure monitoring.

Step 4: Search for other clinical guidelines

Other guidelines relevant to the topic should be identified through a literature search. This implies that a search must be done to identify existing guidelines on the topic. A search for guidelines on the nursing care practices related to endotracheal tube suctioning and endotracheal tube cuff pressure monitoring was done on internationally and nationally published literature. Two international clinical guidelines on endotracheal tube suctioning, namely the clinical practice guideline for suctioning the airway of the intubated and non-intubated patient (Brooks, Anderson, Carter, Downes, Keenan, Kelsey and Lacy, 2001:163-182) and the American Association

Respiratory Care clinical practice guideline: endotracheal suctioning of mechanically ventilated adults and children with artificial airways (Branson, Campbell, Chatburn and Covington, 1993:500-534) were found. National best practice guidelines, namely the Nesibopho Best Practice Guideline on endotracheal suctioning of adults (Perrie and Scribante, 2007:1-10) and endotracheal tube cuff pressure monitoring (Perrie and Scribante, 2007:1-5) was found. If existing guidelines are available, they should be critically appraised using a tool. The AGREE (Appraisal of Guidelines Research and Evaluation Instrument) tool was used in the critical appraisal of these guidelines found.

Step 5: Formulate draft guidelines

Following the systematic review process, draft clinical guidelines were formulated on the two identified nursing care practices. There is no definite format for the presentation of guidelines. They can be presented in the form of a full guideline, a summary sheet or a reminder sheet in the patient's notes. A combination including text, algorithms and option lists can all be used as long as the final product is explicit, logic and unambiguous (Miller and Kearney, 2004:816).

For the purpose of this research study, it was decided to develop a full guideline using the structure and layout as set out in the AGREE appraisal tool. As discussed before, the AGREE tool is used to appraise clinical guidelines and therefore it was appropriate to base the guideline formulation on a similar approach and layout. Due to the fact that the clinical guideline was devised as part of an academic degree, the AGREE tool was adapted as required. The formulated clinical guideline comprises of five sections:

- Scope and purpose: where the objectives, clinical review questions and target group for whom the guideline was developed are addressed;
- Rigour of development: this section addresses the methods for searching for evidence in a synopsis, inclusion and exclusion criteria, methods for formulating the clinical guidelines and expert panel inclusion;
- Results and discussion: aimed at discussing the results and recommendations derived from the results. The presentation and clarity of the

recommendations and results are also addressed in this section of the guideline;

- Clarity and presentation;
- Editorial independence;
- Stakeholder involvement: to give the reader information about the stakeholders involved in the review of the guideline.

Detailed summaries of each article appraised for inclusion into the systematic review were composed. These summaries were used to formulate recommendations. According to Pearson *et al* (2007:108), levels of evidence, sometimes referred to as the hierarchy of evidence, should be used to determine the quality of evidence used for inclusion in the systematic review. However, when it comes to deciding whether or not to incorporate into practice a particular activity or intervention, grades of recommendations can be used. The grades indicate the strength of recommendations to be used in practice.

The United States Preventive Services Task Force (USPSTF) grading system, accessed via the link www.ahcpr.gov/clinic/uspst-fix.htm, has been used to rank the recommendations for practice. It is suggested that Grade A might include Level I and Level II types of evidence, where Grade B indicates a quasi-experimental, non-randomised control trial (Level III evidence). Grade C indicates well-done, observational, descriptive and cohort studies (Level IV) and Grade D recommendations can be assigned to case studies or expert opinion (Level VII). However the allocation of the grades depends on the quality of the study as assessed in performing the critical appraisal. See Table 3.6 for an explanation of the grades of recommendations.

Table 3.6 Grades of recommendation (USPSTF)	
Grade	Explanation
A	Strongly recommended that clinicians adopt this. Good evidence found to suggest that this intervention improves health outcomes and benefits the patient.
B	Recommended that clinicians adopt this. At least fair evidence found to suggest that the intervention or activity improves health outcomes and benefits the patient.
C	No recommendation for or against adoption. At least fair evidence that the activity or intervention improves health outcomes, but the benefits and harms are too close to justify a general recommendation.
D	Recommend against routinely adopting this activity or intervention. At least fair evidence found that suggest that it is ineffective or that the harms outweigh the benefits.
I	The evidence is insufficient to recommend for or against routinely adopting this. Evidence that is effective is lacking, of poor quality or conflicting and the balance of benefits and harms cannot be determined.

Once the summaries of the literature (see Chapter 5) pertaining to each respective nursing care practice were made, the information was used to formulate recommendations. Grades were allocated to the recommendations in terms of the hierarchy of evidence on which the recommendations were made. These recommendations were then incorporated into the draft guideline for submission to the expert panel for review. Based on the evidence-informed clinical guidelines it was decided to develop clinical algorithms for the two nursing care practices respectively. The algorithms are presented in Annexures W and Y.

Step 6: Expert panel selection

An expert panel should be selected to ensure validity of the evidence-informed clinical guideline. Practitioners who have expertise and a high degree of knowledge and skill in a certain field are titled experts (Pearson *et al*, 2007:33). According to Hewitt-Taylor (2004(b):47), the expert panel must represent subject expertise and

representation from the appropriate discipline. The different backgrounds of the panel members may help to minimize individual biases. The group members should function as experts in their field and contribute to the generation of the guideline recommendation by sharing their clinical experiences and knowledge on the available evidence. The panel should consist of at least six to 12 members, as too few member limits adequate discussion and too many members hamper effective functioning of the group (Van Hoecke and Van Cauwenberge, 2007:709). Active involvement in the guideline creation process might include serving on the panel that develops guidelines, providing evidence, expert opinion or viewpoints to such panels or persons or acting as a reviewer of the draft clinical guidelines (Todd, Biskupiak and Weingarten, 1998:8).

In this study, the expert panel only acted as reviewers of the draft evidence-informed clinical guidelines. In order to ensure a selection of members from both public and private sectors, and to include as far as possible a representative of the multi-disciplinary team and based on the above criteria, particular members were approached to request their participation in reviewing the clinical guidelines. A letter of request for participation was issued granting formal consent for participation (see Annexure T). Following consent, the expert panel included three professional nurses, one from the public and two from the private sector respectively, who hold an additional qualification in Critical Care Nursing. A respiratory therapist, intensivist, anaesthetist and a sales consultant from a respiratory equipment manufacturing company were also included as members of the review panel. The eighth member of the group was a nursing lecturer at one of the local universities, teaching Critical Care Nursing.

Step 7: Review of guidelines by expert panel

The draft evidence-informed clinical guidelines were sent to the panel of experts in hard copy format or via e-mail. To enable the panel of experts to validate the clinical guidelines, a reference list for each guideline was attached.

Craig and Smyth (2007:239) state that clinical guidelines should be valid, cost-effective, reproducible, reliable, representative, clear, flexible, and must be reviewed

in relation to the latest evidence available. A reviewer assessment sheet, based on the AGREE tool, comprising of the essential attributes of a clinical guideline was used for the reviewing process (see Annexure U). The panel of experts had to review the clinical guidelines, make any comments, suggestions or recommendations and return them to the researcher for adjustments in order to prepare the final guideline.

Step 8: Final revised evidence-informed clinical guidelines

Once comments were received from the expert panel, revisions were made to the draft evidence-informed guidelines. Adjustments to the evidence-informed clinical guidelines were then made in the light of the comments. The final evidence-informed clinical guidelines were then formulated and are presented in Chapter 6 of this research study and as Annexures V and X.

3.4 ETHICAL CONSIDERATIONS

The ethics of science are concerned with what is wrong and what is right in the conduct of research. Because scientific research is in the form of human conduct, it is expected that such conduct has to conform to generally accepted norms and values (Mouton, 2001:238). According to Walsh (2001:70) research ethics refer to the standards and behaviour of the practical procedures that the researcher is expected to follow. There are various ethical considerations to adhere to in conducting research. Ethical considerations applicable to this research study are discussed below.

3.4.1 Voluntary participation

Participants must feel free and willing to participate in a research study. It must also be clearly stated in the initial letter of consent that the participants have the right to withdraw from the research study at any time and that participation is voluntary (Brockopp and Hasting-Tolsma, 2003:181). This aspect of voluntary participation was clearly stated in the consent letter and discussed with the participants prior embarking on the research study (see Annexures A & B).

3.4.2 Informed consent

Informed consent is the process of providing an individual with sufficient understandable information regarding his or her participation in a research project. It includes providing potential participants with information about their rights and responsibilities within the project and documenting the nature of the agreement. After participants have been given the necessary information about the project they can decide whether or not to become involved in the research. Informed consent may be obtained by allowing individuals to read materials and make a decision on the basis of their understanding of what they have read or by discussing the proposed research project with the researcher (Brockopp and Hasting-Tolsma, 2003:169). In this research study, an informed consent form was prepared, discussed and signed by the participants and the researcher prior to embarking on the research study (see Annexures A & B). Some of the professional nurses preferred not to participate in the research study, as reflected in Chapter 4 of this study.

3.4.3 Permission to conduct research

Written permission to conduct the research study at the various health care institutions was obtained from the various stakeholders, namely the hospital and unit managers prior embarking on the research study (see Annexures C & D).

3.4.4 Confidentiality

Confidentiality refers to the researcher's responsibility to protect all data gathered within the scope of the project from being divulged to others. Mechanisms used to protect the data that are collected in a research study include using a locked file, limiting access to the data to those individuals who are intimately involved in the research (Brockopp and Hasting-Tolsma, 2003:176). Furthermore, all research participants have the right to privacy. This includes the right to withdraw from the research study at any point they wish to, the right to remain anonymous and to have the confidentiality of their data protected. The confidentiality of the participants in the research study was protected by ensuring that reference numbers were used on the questionnaire. The questionnaires were deposited in sealed boxes on completion of data collection, thus protecting the participants' identities. Questionnaires will be kept

for a period of five years after completion of the research study. Thereafter they will be destroyed.

3.4.5 Anonymity

Anonymity refers to the act of keeping individuals nameless in relation to their participation in a research project. Mechanisms used to ensure respondent anonymity include keeping the master list of respondent names and matching code numbers in separate locations, under lock and key, after providing each respondent with a number or code name, destroying the list of actual names and using code names when discussing data (Brockopp and Hasting-Tolsma, 2003:177). In the research study, anonymity was maintained by allocating a reference number to each questionnaire.

3.5 SUMMARY OF CHAPTER

This chapter discussed the research design and method which are cardinal in planning and performing the research study. The two stages and the respective steps were comprehensively described in order to orientate the reader to the plan followed in doing this research study. The next chapter will describe the systematic review reports for the two identified nursing care practices, namely endotracheal tube suctioning and endotracheal tube cuff pressure monitoring.

“In the confrontation between the stream and the rock, the stream always wins- not through strength but by perseverance.” H Jackson Brown

IN THIS CHAPTER

In Chapter 1 an overview of the study was given in order to orientate the reader to the context of the study. The literature review was presented and discussed in Chapter 2. In Chapter 3 the research design and method, including an in-depth discussion of the two stages of the research study, were described.

4.1 INTRODUCTION

This chapter will discuss:

- The sample of professional nurses used in the study;
- The results and discussion of the data analysed from the structured questionnaires that were distributed amongst professional nurses in the Nelson Mandela Metropole;
- A comparison of the results obtained from the participants in the critical care units of public and private hospitals in the Nelson Mandela Metropole; (note that although it was not one of the research objectives to explore the relationship between the private and public divide, it was meaningful to explore the relationship from the available data collected in the research study)
- The findings related to the four identified nursing care practices.

This section of the research study aims at addressing the following research objectives:

- To explore and describe the four identified nursing care practices related to the safety of the mechanically ventilated patient, as performed by professional nurses, in critical care units in the Nelson Mandela Metropolitan area.
- To identify two of the four nursing care practices that are performed least according to best recommended practices.

4.2 SAMPLE OF PROFESSIONAL NURSES USED

Data was collected from participants employed in critical care units in the Nelson Mandela Metropole in both the public and private health care sectors. Initially it was envisaged that 150 participants from these units would be available for inclusion in the study. However, after establishing that 16 professional nurses were ill, or on leave and study leave, and that some agency workers were not required to work during the data collection period, only 134 participants were identified to participate in the study. Of the identified participants, 23 refused to participate, while 10 questionnaires were not returned. One questionnaire was excluded from the analysis as it was incomplete. One hundred questionnaires were thus available for analysis, thus representing a response rate of 74.6%.

Data collected from the participants were as follows:

- Sixty-four questionnaires were distributed to professional nurses working in three public-sector critical care units in the Metropole. The researcher received 40 of these back for analysis. This represents a response rate of 63%.
- Seventy questionnaires were distributed to professional nurses working in three private-sector critical care units. The researcher received 61 of these back, of which 60 were analysed. This represents a response rate of 81%.

Therefore, 100 questionnaires were received back: 40 participants in the public sector and 60 participants in the private sector. Figure 4.1 shows the sampling process.

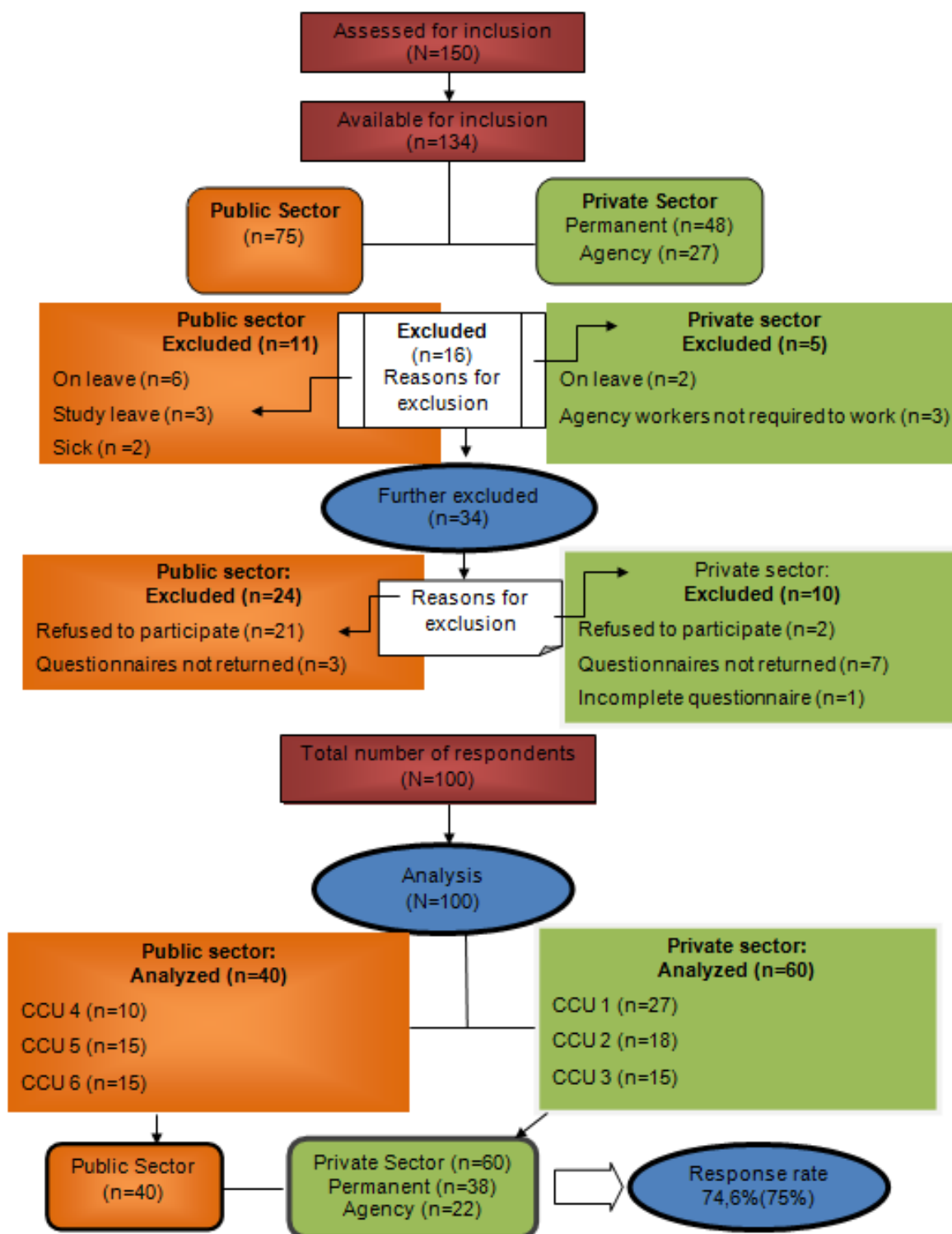


Figure 4.1: Sampling process

4.3 DATA ANALYSIS APPROACH

Data was analysed using Statistica (Version 9) and was done with the assistance of a statistician. Descriptive statistics were calculated to obtain measures of central tendency for instance the mean and median, and dispersion, or the standard deviation and frequency distribution. Figures and tables are used to enhance the interpretation of the data.

The Chi-square test of independence was used to explore if there were relationships between the responses from the professional nurses in the critical care units of the public and private health care sectors. A Chi-square p value less than 0.05 was considered statistically significant. For statistically significant results, Cramer's V was calculated to determine whether the results are practically significant, indicated by V values greater than 0.10.

In cases where tables are used for the total sample of $n=100$, for instance the demographic data, the researcher only used percentages to report the data, the cell frequencies being identical to the respective percentages. In reporting the results n_1 and n_2 refer to the size of the sample from the critical care units in the public sector and the private sector respectively.

The results as derived and analysed from the structured questionnaire are given and discussed in this part of the study. The different sections, as illustrated in the structured questionnaires, include the following:

- Demographic data
- Endotracheal tube verification
- Endotracheal tube cuff pressure monitoring
- Endotracheal tube suctioning
- Mechanical ventilator settings.

4.4 DEMOGRAPHIC DATA

The demographic data collected and analysed from the structured questionnaires is presented in this section of the research study. A summary of the items for discussion in this section is illustrated in Table 4.1.

Table 4.1 Items for discussion on demographic data	
4.4.1 RESULTS	
4.4.1.1	Gender and age
4.4.1.2	Years of employment in the critical care unit
4.4.1.3	Position held in the critical care unit
4.4.1.4	Additional qualifications
4.4.2 SUMMARY OF THE DEMOGRAPHIC DATA	
4.4.3 DISCUSSION PERTAINING TO THE DEMOGRAPHIC DATA	

4.4.1 RESULTS

The results of the demographic data are presented in Table 4.2.

Table 4.2 Distribution of professional nurses' demographic characteristics (n=100)			
Demographic characteristics	Public:n₁=40 n (%)	Private:n₂=60 n (%)	Total:n=100 (%)
Gender			
Female	38 (95)	57 (95)	95%
Male	2 (5)	3 (5)	5%
Age			
< 25 years	0 (0)	1 (2)	1%
25-30 years	1 (2)	3 (5)	4%
31-40 years	9 (23)	22 (36)	31%
41-50 years	22 (55)	27 (45)	49%
51-60 years	7 (18)	7 (12)	14%
61-65 years	1 (2)	0 (0)	1%
Time period working in			

Table 4.2 Distribution of professional nurses' demographic characteristics (n=100)			
Demographic characteristics	Public:n₁=40 n (%)	Private:n₂=60 n (%)	Total:n=100 (%)
the CCU			
< 1 year	1 (2)	4 (8)	5%
1-5 years	4 (10)	17 (28)	21%
6-10 years	12 (30)	17 (28)	29%
11-15 years	12 (30)	11 (18)	23%
>15 years	11 (28)	11 (18)	22%
Position held in the CCU			
	29 (73)	28 (48)	57%
Permanent RN	0 (0)	22 (36)	22%
Agency worker	3 (7)	1 (2)	4%
Unit manager	7 (18)	7 (11)	14%
Shift leader	1 (2)	2 (3)	3%
Clinical facilitator/mentor			
Additional Qualification			
Diploma in Critical Care Nursing	13 (33)	10 (17)	23%
B Cur Hons (CCNS)	4 (10)	6 (10)	10%
M Cur (CCNS)	1 (2)	2 (3)	3%
Other	1 (2)	6 (10)	7%
No additional qualification	21 (53)	36 (60)	57%

4.4.1.1 Gender and age

Of the 100 participants, 95 were female and 5 were male.

The age distribution of participants ranged from younger than 25 to 65. Only 1% was younger than 25, while 4% were aged between 25 and 30. Thirty-one per cent were aged between 31 and 40. The largest proportion of participants (49%) was between 41 and 50. Fifteen per cent were aged between 51 and 65. The age distribution

amongst professional nurses in the critical care units of the public and private sectors was statistically insignificant ($\text{Chi}^2(\text{d.f.}=5) = 5.16, p = .395$).

4.4.1.2 Years of employment in the critical care unit

Data revealed that 26% of participants have worked in the critical care units for less than, or equal to, five years. Twenty-nine per cent have worked in a unit for between six and ten years. Forty-five per cent of professional nurses (the highest proportion) have worked for more than ten years in a critical care unit. The difference in responses for the years of employment from professional nurses in the critical care units in the public and private sectors was statistically insignificant ($\text{Chi}^2(\text{d.f.}=4) = 7.03, p = .134$).

4.4.1.3 Position held in the critical care unit

In the sample derived from the professional nurses in the critical care units in the public sector, 29 (73%) participants were permanently employed and there were no agency workers employed during the period when the study was conducted. Furthermore, the sample included three (7%) unit managers, seven (18%) shift leaders and one (2%) clinical facilitator. In this study, the unit manager refers to the person in charge of the critical care unit, while the shift leader takes charge of the shift at a particular period. The clinical facilitator or mentor is mainly responsible for teaching and rendering in-service education in the unit.

In the critical care units of the private sector, there were 28 (48%) permanently employed professional nurses, 22 (36%) agency workers, one (2%) unit manager, seven (11%) shift leaders and two (3%) clinical facilitators. A statistical significant difference was noted between the positions held amongst professional nurses in the critical care units in the public and private sectors ($\text{Chi}^2(\text{d.f.}=4) = 23.57, p = .005, V = 0.39$). The difference might be due to the fact that a large proportion of agency workers are employed in the private sector, while only permanently employed professional nurses were employed at the time of the study in the critical care units of the public sector.

4.4.1.4 Additional qualifications

The demographic profile of the professional nurses working in the critical care units in the Nelson Mandela Metropole reflected that a mere 36% hold an additional qualification in critical care nursing. Of the 36%, only 13% had obtained a degree in critical care nursing at a higher education institutional level, while the remaining 23% had obtained a diploma in critical care nursing. Of the 100 participants in the study, it was reported that 64% had not obtained any additional qualification in critical care nursing.

4.4.2 SUMMARY OF THE DEMOGRAPHIC DATA

In the sample of the research study, the following demographic data was noted:

- 95% of participants were females;
- 49% were aged between 41 and 50;
- 45% had worked for more than ten years in a critical care unit;
- In the critical care units of the public sector, 73% were permanently employed, while 27% were in leadership (unit managers or shift leaders) or educational capacities. No agency workers were employed in the public sector at the time of the study;
- In the critical care units of the private sector, 48% were permanently employed, while 36% were agency workers. Only 16% were employed in a leadership or educational capacity;
- 36% hold an additional qualification in critical care nursing;
- 64% did not hold an additional qualification in critical care nursing.

4.4.3 DISCUSSION PERTAINING TO THE DEMOGRAPHIC DATA

The findings from the demographic section highlight the fact that females predominantly occupy the adult critical care units in the Nelson Mandela Metropole. Furthermore, they imply that nursing is a female-dominated profession. Statistics obtained from the South African Nursing Council show that in the Eastern Cape, professional nurses comprise 12 400 females and 827 males. Country-wide statistics show that there are currently 101 086 female and 6 892 male nurses registered with SANC (<http://www.sanc.co.za/stat2008/distribution%202008.xls>). No statistics are available on the gender distribution in critical care units across South Africa.

With regard to the age distribution amongst professional nurses in the research study, data obtained from SANC revealed similar statistics. The majority (34%) of professional nurses nationally are aged between 40 and 49, 5% are under 30, 21% are aged between 30 and 39, 27% are between 50 and 59, and the remaining 14 % are 60 years or older. (<http://www.sanc.co.za/stat2008/distribution%202008.xls>). No statistics on the age distribution of professional nurses in critical care units across South Africa were found.

Although only 5% of participants in the study were less than 30, it is important to acknowledge that these young nurses are the future leaders; thus, it is important to assess their view on evidence-informed nursing care. According to Ferguson and Day (2007:107), newly qualified nurses tend to rely on the expertise of others, frequently seek guidance, question their own ability to contribute to the goals of the nursing unit and fear more independent decision-making and practice. New graduates and younger nurses might not have confidence in their own judgement and rely on the judgement of others. Even if young and new nurses have been prepared to enter into evidence-based practice, they must develop their entry-level competencies as their experiential knowledge develops through practice and they might, therefore, have difficulty practising in an evidence-based manner.

A national audit done on the critical care resources in South Africa revealed that 43% of professional nurses, including neonatal trained nurses, had five years or less experience in a critical care unit. The second highest group, 29%, had between five and ten years of experience, while 16% had ten to 20 and 8% more than 20 years of critical care nursing experience. The findings of this study are not congruent with the findings obtained from the national audit. However, the national audit included all the nurses working in the adult and neonatal critical care units. In this research study, 26% of professional nurses have less than five years' experience in a critical care unit (Scribante and Bhagwanjee, 2007(b):1316). Bracco *et al* (2001:140) suggest that nursing care without expertise or minimal expertise may be considered potentially harmful for the patient. The occurrence of adverse events that result in

errors being more likely to occur when nursing inexperience is combined with staff shortages, poor supervision and lack of support.

The distribution of professional nurses showed that 27% of participants in the public sector and 16% in the private sector were unit managers, shift leaders or clinical facilitators or mentors. Some of the unit managers in the critical care units in the private sector were not included in the study as they were on leave during the data collection period. Royle, Blythe, Ciliska and Ing (2000:32) state that nurse managers, educators and nursing leadership are key people in establishing an organizational and unit culture that supports evidence-based practice and can contribute significantly to changing practice which is based on the best available practice.

Data derived from this study revealed that 36% of staff in the critical care units in the private sector was agency workers, which is a high percentage of non-permanent professional nurses. A national audit done across the nine provinces in South Africa revealed that during the month which the study was conducted in all the critical care units nationally, there were 64% permanent staff and 36% agency staff employed (Scribante and Bhagwanjee, 2007(b):1316). According to Scribante and Bhagwanjee (2007(a):69) it is not recommended practice to employ such a high percentage of agency workers in critical care units. Agency staff may be unfamiliar with or may not adhere to the unit practices and policies, of which non-adherence to infection-control policy is the most significant. Agency staff is also likely to bring with them resistant organisms from other units, compromising the safety of the critically ill patient even more.

No other research is available on the use or impact of using agency nursing staff in South Africa, but what is generally known is that their use has increased and that the majority of the agency workforce comprises nursing staff permanently employed elsewhere. It is, therefore, believed that, on average, many nurses work more than the recommended 40 hours per week. Long working hours result in decreased levels of alertness and could lead to a commensurate increased probability of adverse events, thus compromising the safety of the critically ill patient (Scribante and Bhagwanjee, 2007(a):69).

The high percentage (64%) of participants who do not hold additional qualifications in critical care nursing might influence the practice of evidence-informed nursing as most educational programmes at a post-basic level, especially Baccalaureate programmes, aim at providing the learner with theoretical knowledge, critical thinking skills, reflective practice and knowledge of the research process, which are all essential components in practising evidence-informed care (Ferguson and Day, 2007:110). The findings from this study, that only 36% of professional nurses hold an additional qualification in critical care nursing, are higher in comparison with the results of a national audit of all the critical care resources in South Africa that revealed that only 26% of nurses working in them hold an additional qualification (Scribante and Bhagwanjee, 2007(b):1316).

Although the differences in nursing care practices, or knowledge levels, of professional nurses who are experienced and those who hold an additional qualification were not explored, various studies have shown that the knowledge of critical care nurses in South Africa in a number of clinical areas is lower than the acceptable level. Nurses in South Africa, including critical care trained nurses, on average, achieved scores below the set minimum competencies indicators (Scribante and Bhagwanjee, 2007(b):1317). No studies were found in exploring if any difference exists between professional nurses who are experienced versus those who hold an additional qualification in critical care nursing with specific reference to implementing evidence-informed nursing care practices.

The findings of this study are congruent with the statistical profile of professional nurses in South Africa. Although the results of the national audit of critical resources across the nine provinces are available for comparison, they were viewed with caution as the national audit included all the categories of nurses in the adult and neonatal critical care units.

4.5 ENDOTRACHEAL TUBE VERIFICATION

This section of the questionnaire comprised 13 questions, of which eight were aimed at exploring the nursing care practices related to endotracheal tube verification. The remaining five questions explored the availability and the use of an existing

institutional clinical guideline on endotracheal tube verification; decision-making choices and an exploration of in-service education required on the topic. The items for discussion in this section of the research study are reflected in Table 4.3.

Table 4.3 Items for discussion on endotracheal tube verification	
4.5.1	RESULTS
4.5.1.1	Frequency for verifying endotracheal tube placement
4.5.1.2	Methods for endotracheal tube verification
4.5.1.3	Inspection findings to verify endotracheal tube placement
4.5.1.4	Auscultation findings to verify endotracheal tube placement
4.5.1.5	Chest radiography findings to verify endotracheal tube placement
4.5.1.6	Methods to identify carbon dioxide in exhaled gas
4.5.1.7	Normal range for carbon dioxide measurements
4.5.1.8	Calometric detection of carbon dioxide
4.5.1.9	Institutional guideline in place for endotracheal tube verification
4.5.1.10	Who developed the guideline?
4.5.1.11	Frequency of use for the existing clinical guideline
4.5.1.12	Decision-making choices
4.5.1.13	In-service education required on endotracheal tube verification
4.5.2	SUMMARY OF RESULTS FOR ENDOTRACHEAL TUBE VERIFICATION
4.5.3	DISCUSSION PERTAINING TO ENDOTRACHEAL TUBE VERIFICATION

4.5.1 RESULTS

The results of the nursing care practices related to endotracheal tube verification are presented and discussed under the different sections as set out in the structured questionnaire.

4.5.1.1 Frequency for verifying endotracheal tube (ETT) placement

The best recommended practice is to verify the endotracheal tube placement at least once per shift (see discussion section), which can be either 6- or 12hourly. Of the 100 participants comprising of 40 (n_1) professional nurses in the public sector and 60 (n_2) professional nurses in the private sector, only 53% indicated the best recommended practice response as indicated below:

- 22% [$n_1=6$ (15%); $n_2=16$ (27%)] verified the position of the ETT every **2 hours**;
- 21% [$n_1=2$ (5%); $n_2=19$ (32%)] used **4-hour** intervals;
- 19% [$n_1=8$ (20%); $n_2=11$ (18%)] used **6-hour** intervals;
- 34% [$n_1=22$ (55%); $n_2=12$ (20%)] used **12-hour** intervals;
- 4% [$n_1=2$ (5%); $n_2=2$ (3%)] **never** verified the ETT placement.

As illustrated in Figure 4.2, statistically significant ($\text{Chi}^2(\text{d.f.}=4) = 18.46, p = .001, V = 0.43$) difference were noted between the practices as performed by professional nurses in the critical care units of the public and private sectors. These differences might be due to the fact that professional nurses in the private sector used more frequent intervals to verify endotracheal tube placement. Furthermore, the study findings revealed that the professional nurses in the public sector (75%) were more inclined to verify endotracheal tube placement according to best recommended frequency periods than the professional nurses in the private sector (39%).

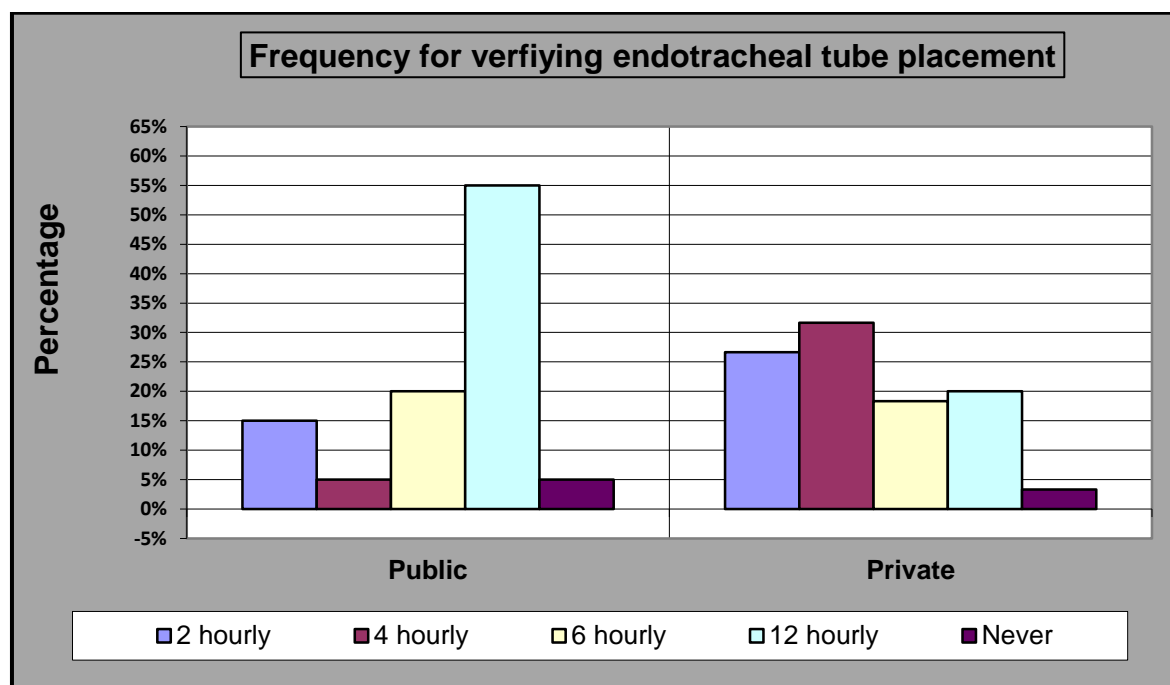


Figure 4.2 Frequency for verifying endotracheal tube placement

4.5.1.2 Methods for endotracheal tube verification

The best recommended method to verify endotracheal tube placement is using identification of carbon dioxide in exhaled gas, which none of the participants indicated.

Clinical assessment findings include inspection of the chest movements and auscultation of bilateral breath sounds. The study findings revealed that 6% [$n_1=0$ (0%); $n_2=6$ (10%)] used inspection of the chest movements as a method to verify endotracheal tube placement. A larger proportion of the participants, 53% [$n_1=20$ (50%); $n_2=33$ (55%)] used auscultation of breath sounds as a method to verify endotracheal tube placement.

Furthermore, 36% [$n_1=16$ (40%); $n_2=20$ (33%)] indicated the use of chest radiography (CXR) to verify the endotracheal tube placement. The minority of the participants indicated responses that are not best recommended practices (see discussion section) and included the following: palpation of the endotracheal tube cuff on each side of the trachea, 1% [$n_1=0$ (0%); $n_2=1$ (2%)] pulse oximetry, 3% [$n_1=3$ (7%); $n_2=0$ (0%)] and direct laryngoscopy, 1% [$n_1=1$ (3%); $n_2=0$ (0%)].

The nursing care practices as performed by professional nurses in the critical care units of the public and private sectors were significantly different ($\text{Chi}^2(\text{d.f.}=5) = 11.07, p = .049, V = 0.33$). The main reasons for the statistical difference noted might be due to the fact that 3% of professional nurses in the public sector indicated the use of direct laryngoscopy and none of the participants in the private sector indicated it. Professional nurses (7%) in the public sector indicated the use of pulse oximetry, while none in the private sector indicated this method for verification of endotracheal tube placement. Statistical differences were further noted as result of professional nurses in the private sector indicating the use of a technique involving palpating for the endotracheal tube cuff on each side of the trachea, and using inspection as a method for verifying endotracheal tube placement, while none of the professional nurses in the public sector used these methods.

The difference between the responses in terms of using chest radiographs and auscultation as methods to verify endotracheal tube placement was not statistically significant ($\text{Chi}^2(\text{d.f.}=1) = 0.40, p = .530$). The results are graphically represented in Figure 4.3.

All of these methods as indicated by the professional nurses in the critical care units of both health care sectors are not recommended as best practice and proved to be unreliable and should not be used as sole methods in verifying endotracheal tube placement in the mechanically ventilated patient (see discussion section).

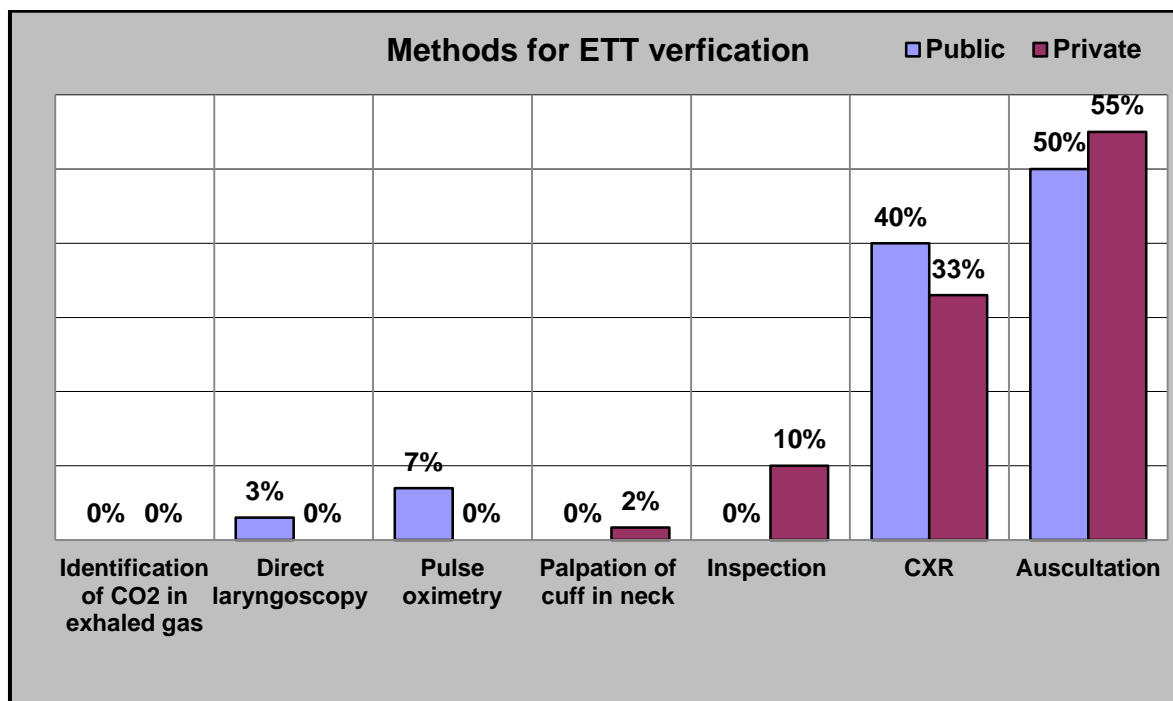


Figure 4.3 Methods for endotracheal tube (ETT) verification

4.5.1.3 Inspection findings to verify endotracheal tube placement

Figure 4.4 depicts the results for the different responses with regard to the correct inspection findings to verify the endotracheal tube placement amongst professional nurses in the critical care units of the public and private sectors. Of the 100 participants, 43% [$n_1=19$ (48%); $n_2=24$ (40%)] indicated the correct response, which is observing for symmetrical chest movement. The remaining participants indicated the following incorrect responses: 2% [$n_1=2$ (5%); $n_2=0$ (0%)] indicated that they would observe for unilateral chest movement, while 1% [$n_1=0$ (0%); $n_2=1$ (2%)] indicated that they would perform an epigastric auscultation and the remaining 54% [$n_1=19$ (48%); $n_2=35$ (58%)] indicated that they would assess for bilateral breath sounds (which is not part of the inspection findings, but rather auscultation findings). The difference between the responses from the two groups was not statistically significant ($\text{Chi}^2(\text{d.f.}=3) = 4.50, p = .212$).

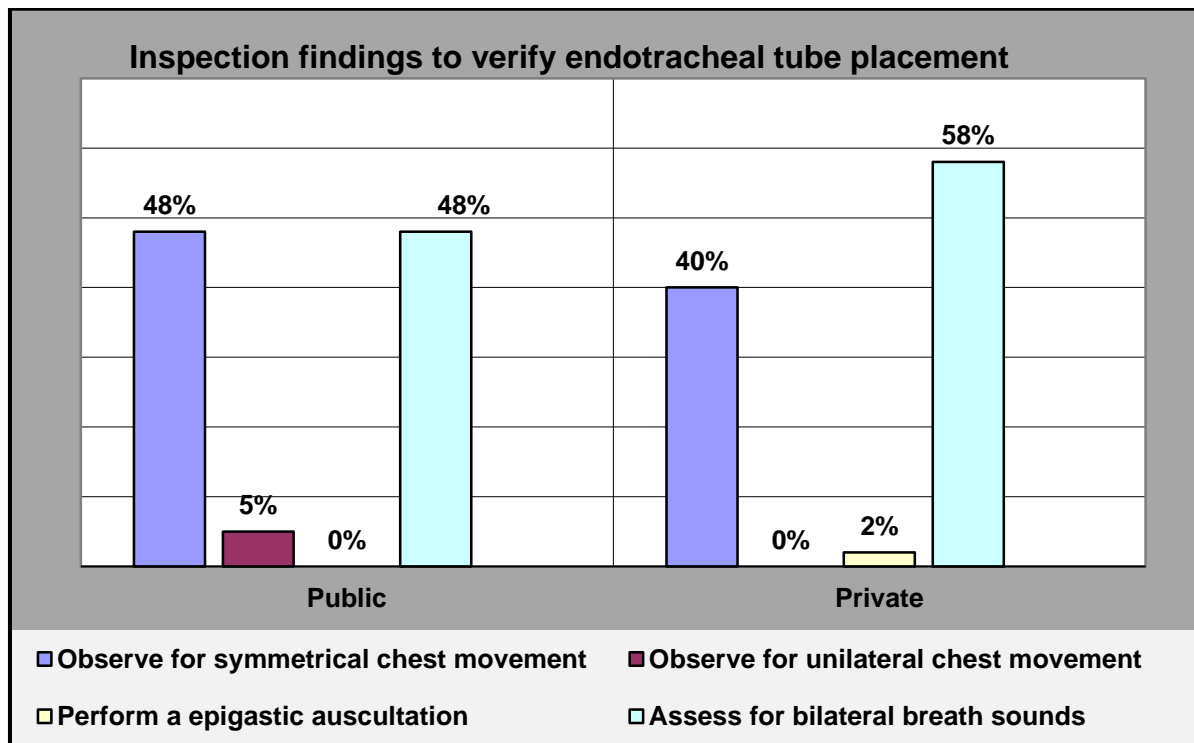


Figure 4.4 Inspection findings to verify endotracheal tube placement

4.5.1.4 Auscultation findings to verify endotracheal tube placement

It is evident (as illustrated in Figure 4.5) that professional nurses are aware of the normal findings that can be expected when performing auscultation as a method to verify endotracheal tube placement in the critically ill patient. Of the 100 participants, 96% [$n_1=37$ (92%); $n_2=59$ (98%)] correctly indicated that they would use bilateral breath sounds as auscultation findings to verify the endotracheal tube placement in the mechanically ventilated patient. The remaining participants stated the following incorrect responses: 2% [$n_1=1$ (3%); $n_2=1$ (2%)] indicated unilateral breath sounds, while 2% [$n_1=2$ (5%); $n_2=0$ (0%)] indicated diminished breath sounds as auscultation findings to verify the endotracheal tube placement. No participants indicated rhonchi as an auscultation finding. The difference between the responses from the professional nurses in the two health care groups was not statistically significant ($\chi^2(d.f. =2) = 3.168, p = .205$).

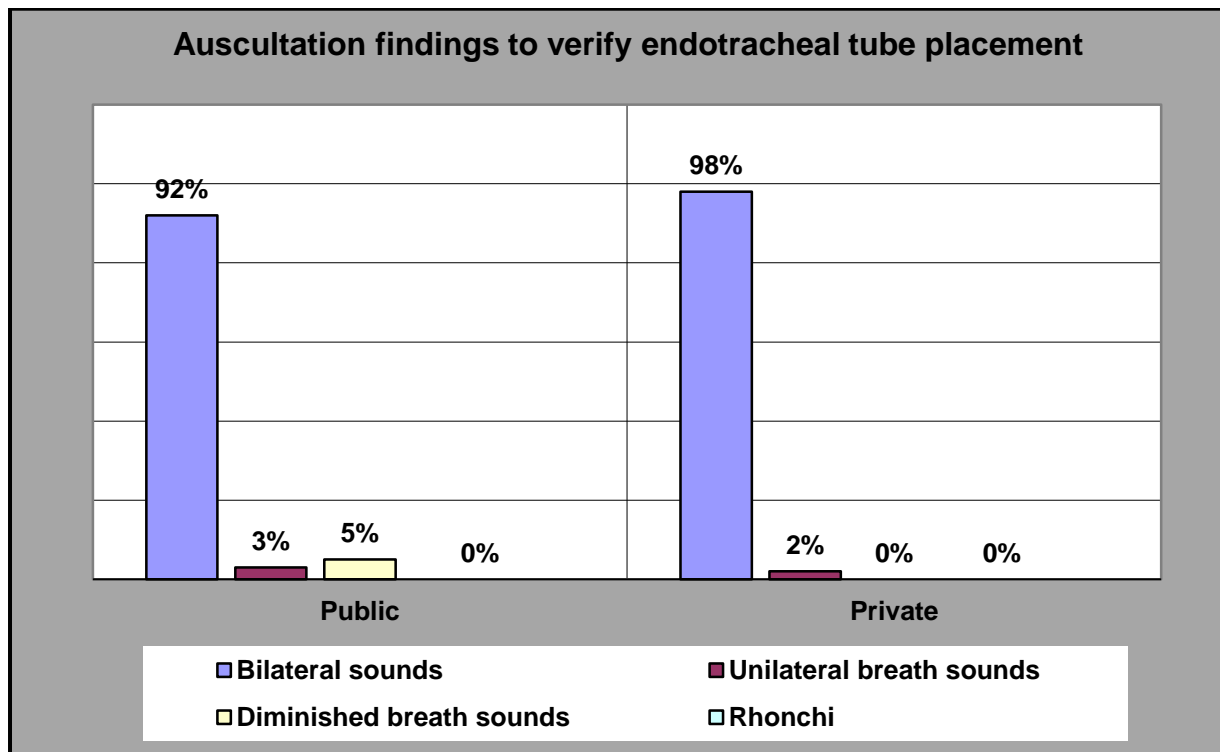


Figure 4.5 Auscultation findings to verify endotracheal tube placement

4.5.1.5 Chest radiography findings

Only 50% [$n_1=16$ (40%); $n_2=34$ (57%)] of participants indicated the correct findings when using chest radiograph in verifying correct endotracheal tube placement, namely that the endotracheal tube should be 2 to 3cm above the carina with the head in the neutral position. The remaining 50% [$n_1=24$ (60%); $n_2=26$ (43%)] indicated the incorrect response, namely that the endotracheal tube be positioned at the level of the carina or at the level of the right bronchus. None indicated that the endotracheal tube should be at the level of the left bronchus, although it is an incorrect response. The differences between the two groups was not statistically significant ($\text{Chi}^2(\text{d.f.}=2) = 3.64, p = .161$). The results are illustrated in Figure 4.6.

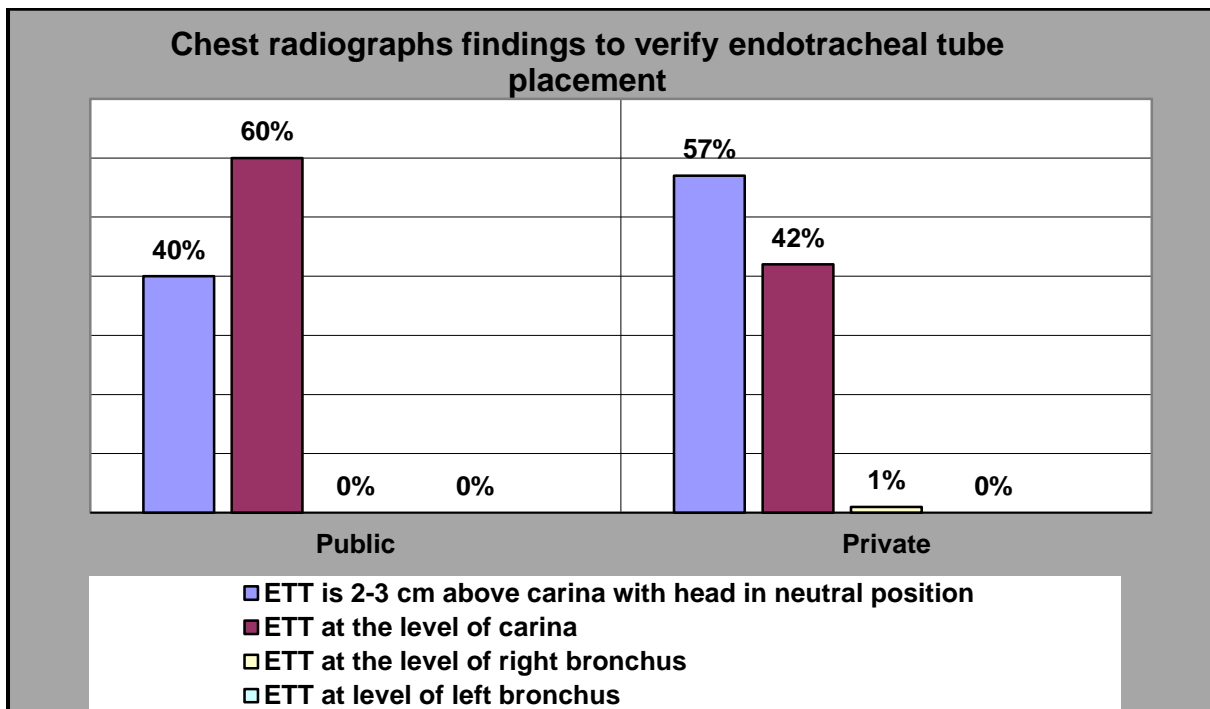


Figure 4.6 Chest radiography findings to verifying endotracheal tube placement

4.5.1.6 Methods to identify carbon dioxide in exhaled gas

This question aimed at establishing the best recommended method in identifying carbon dioxide in exhaled gas to verify endotracheal tube placement. Of the 100 participants, 72% [$n_1=33$ (83%); $n_2=39$ (65%)] indicated that they would use the best recommended practice method, namely capnography, as a method to verify endotracheal tube placement. The remaining 28% [$n_1=7$ (18%); $n_2=21$ (35%)] indicated the use of calometric detection of carbon dioxide as a method of choice, which is not the best recommended practice method. The difference in the responses from professional nurses in the two health care sectors was not statistically significant ($\chi^2(d.f.=1) = 3.65$, $p = .056$). The results are graphically displayed in Figure 4.7.

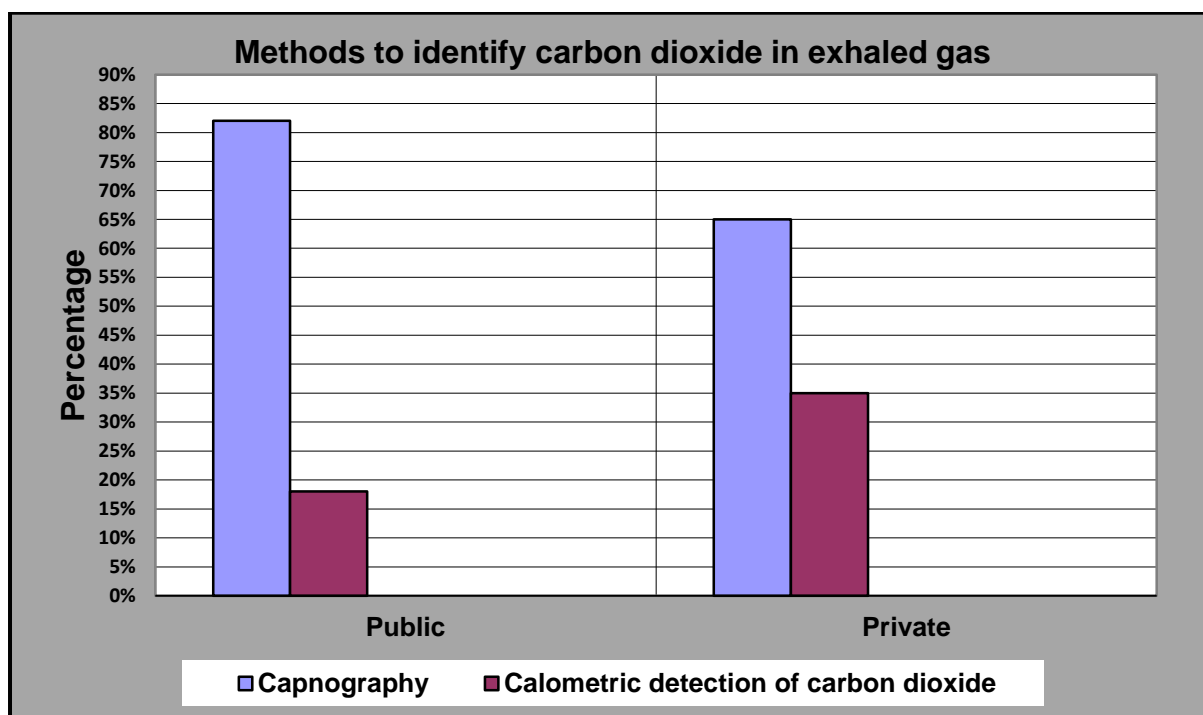


Figure 4.7 Methods to identify carbon dioxide in exhaled gas

4.5.1.7 Normal range for carbon dioxide measurements

The majority of participants, 65%, [$n_1=23$ (58%); $n_2=42$ (70%)] indicated the normal range of 35 to 45 mmHg for carbon dioxide in exhaled gas, which indicates correct endotracheal tube placement. The remaining participants indicated the following incorrect responses: a range of 50 to 80 mmHg: 22% [$n_1=13$ (32%); $n_2=9$ (15%)] and a range of 80 to 100 mmHg: 13% [$n_1=4$ (10%); $n_2=9$ (15%)]. No participants indicated the use of endotracheal tube cuff pressure > 100 mmHg. No statistically significant difference was found between the responses from the professional nurses in the public and private sectors ($\text{Chi}^2(\text{d.f.}=2) = 4.38, p = .112$). The results are graphically presented in Figure 4.8.

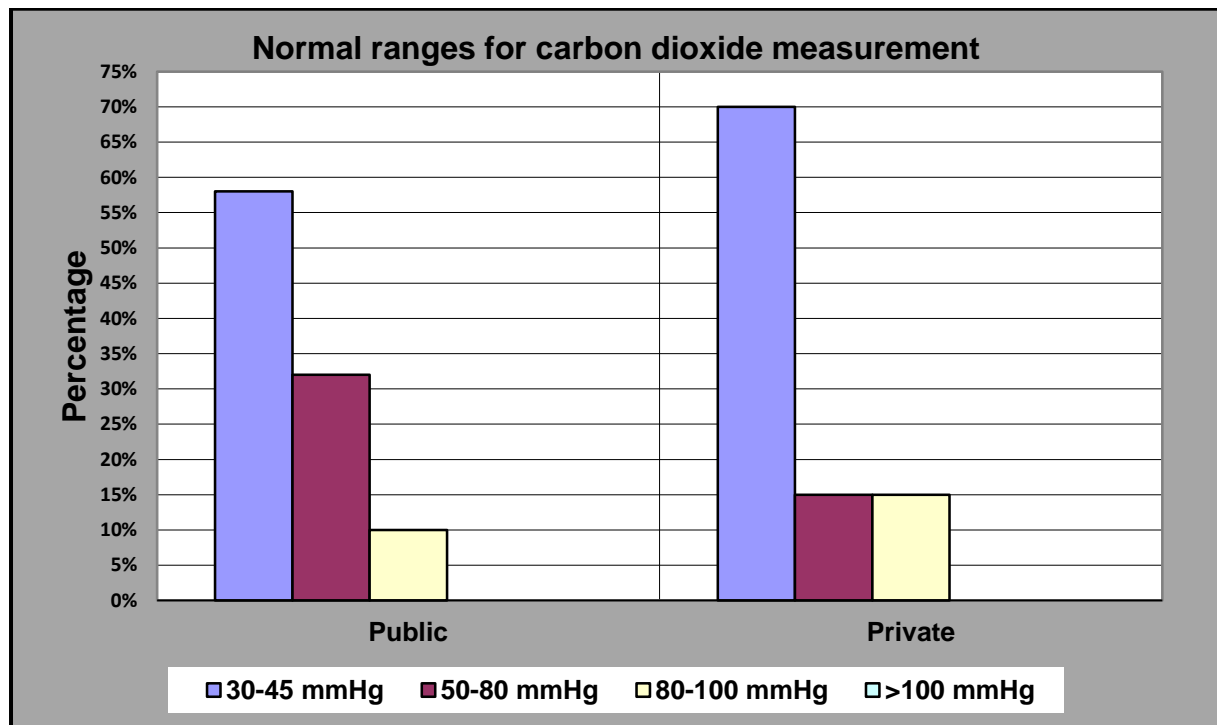


Figure 4.8 Normal ranges for carbon dioxide measurements

4.5.1.8 Calometric detection of carbon dioxide

In further exploring the use of the calometric detection as a method to identify carbon dioxide in exhaled gas, participants had to indicate the correct readings in using this method to verify endotracheal tube placement. Only 40% [$n_1=11$ (28%); $n_2=29$ (48%)] indicated the correct response, stating that the indicator paper will turn yellow if the endotracheal tube is in the correct position. The remaining 60% indicated the following incorrect responses: 55% [$n_1=28$ (70%); $n_2=27$ (45%)] of participants indicated that the indicator paper will remain purple, while 5% [$n_1=1$ (3%); $n_2=4$ (7%)] indicated that the paper will change to beige. The results are reflected in Figure 4.9. The difference in responses between professional nurses of the two health groups was not statistically significant ($\chi^2(d.f.=2) = 4.38, p = .112$).

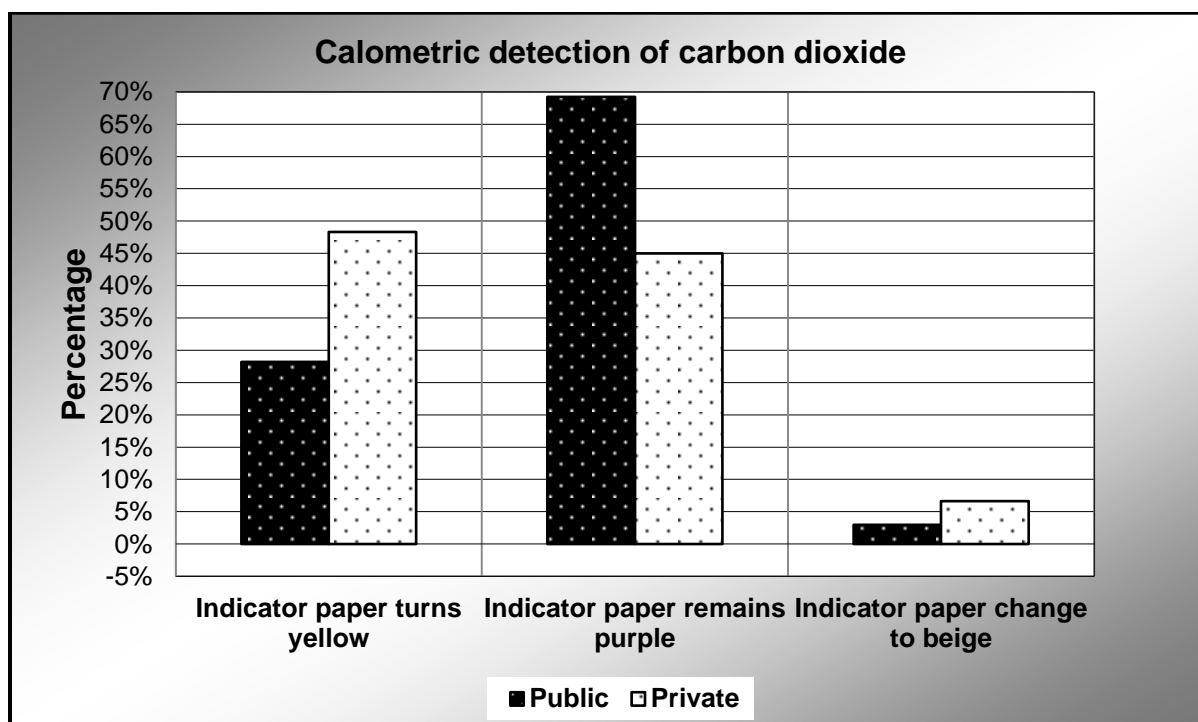


Figure 4.9 Calometric detection of carbon dioxide

4.5.1.9 Institutional guideline in place for endotracheal tube verification

The questionnaire aimed at exploring if an existing guideline on endotracheal tube verification was available in the critical care units in the Nelson Mandela Metropole to guide clinical practice. According to 32% [$n_1=7$ (18%); $n_2=25$ (42%)] of participants, an existing guideline on endotracheal tube verification was available in both the public and private sectors in the Nelson Mandela Metropole. The remaining 68% [$n_1=33$ (83%); $n_2=35$ (58%)] indicated the absence of an existing guideline to guide practice. The responses from professional nurses in the critical units of the two health groups was significantly different ($\chi^2(d.f.=1) = 6.44$, $p = .011$, $V = 0.25$).

The variance in responses might be due to the fact that a large proportion of agency workers are employed in the private sector, and they may not be aware of the available guideline. It might also be due to the fact that critical care units in two different private health groups were included in the study, where one has a definite guideline in place and the other does not have. The differences in responses might also be due to confusing the concept of unit policies and clinical guidelines as many of the critical care units have unstructured documents, which are referred to unit policies for the purpose of guiding practice. The results are reflected in Figure 4.10.

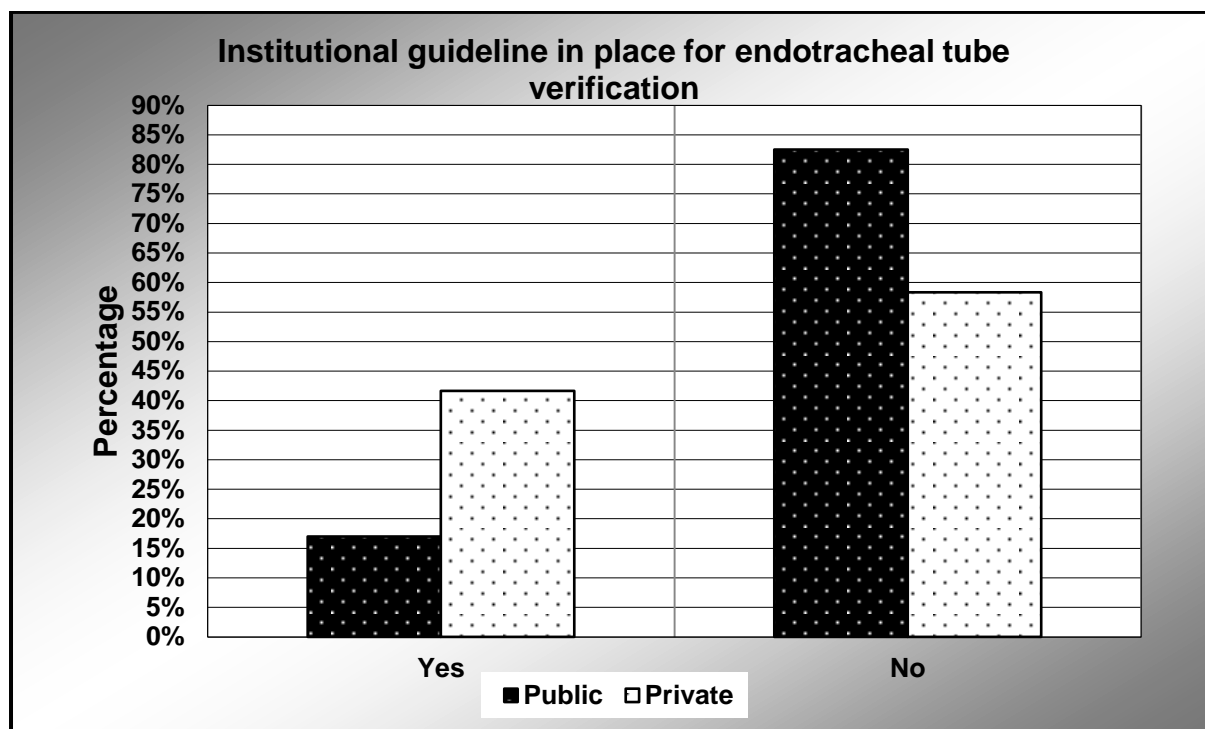


Figure 4.10 Institutional guideline in place for endotracheal tube verification

4.5.1.10 Who developed the guideline?

This open-ended question aimed to explore who developed the existing institutional guideline, if in place in a critical care unit. However, the majority of participants did not complete the question. Due to the blank responses, this question could not be statistically analysed. Participants who completed this open-ended question stated that the guideline was developed by a unit manager. However, when requesting the guideline, nothing was available and in some units procedural unit policies were only available.

4.5.1.11 Frequency of use for the existing guideline

Of the 43 participants who answered this filter question, 24% [$n_1=8$ (80%); $n_2=16$ (48%)] indicated that it is often used, 6% [$n_1=0$ (0%); $n_2=6$ (18%)] indicated it is seldom used, while the remaining 13% [$n_1=2$ (20%); $n_2=11$ (34%)] indicated that they never use the existing guideline. The difference in responses amongst professional nurses in the critical care units of the two health groups was not statistically significant ($\chi^2(d.f.=2) = 3.63, p = .162$). The results are graphically displayed in Figure 4.11.

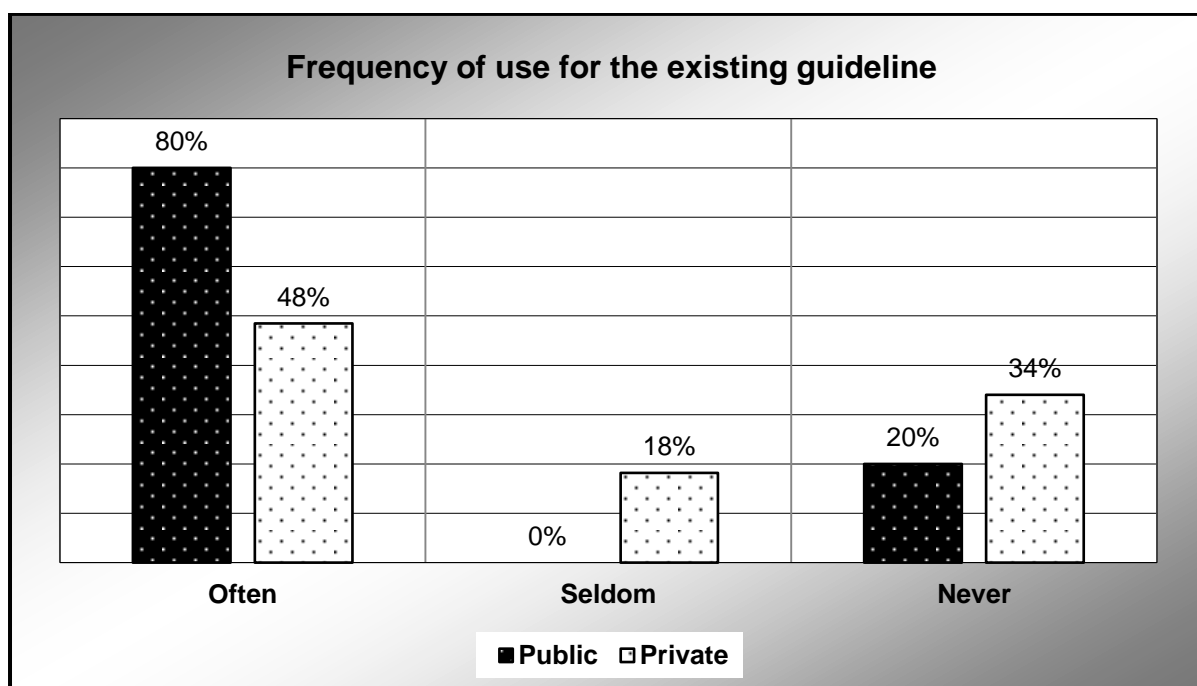


Figure 4.11 Frequency of use for the existing guideline

4.5.1.12 Decision-making choices

The response for this filter question followed if participants indicated the absence of an institutional guideline for endotracheal tube verification. Although 33 participants in the public sector indicated that they do not have a guideline in place, 35 (88%) participants answered the question. In the private sector, 35 participants indicated that they do not have a guideline in place, yet 41 (68%) participants in this sector answered the question. As this was a multi-response question, and due to the fact that not all 100 participants answered the question, a total percentage could not be calculated for this question. Therefore, the individual percentages per response for both health care sectors are reported.

In the public sector, 29% ($n_1=10$) indicated that they base their nursing care practices on own expertise, while 63% ($n_1=22$) indicated that they base their practices on what they have been taught in the unit. Only 8% ($n_1=3$) indicated that their nursing care practices related to endotracheal tube verification is based on the most recent literature. Results from the private sector reflected that 27% ($n_2=11$) base their practices on their own expertise, 58% ($n_2=24$) on what they have been

taught in the unit, while only 15% ($n_2=6$) on the most recent literature. Due to the multi response for this question, the Chi-square test could not be done. The results are displayed in Figure 4.12.

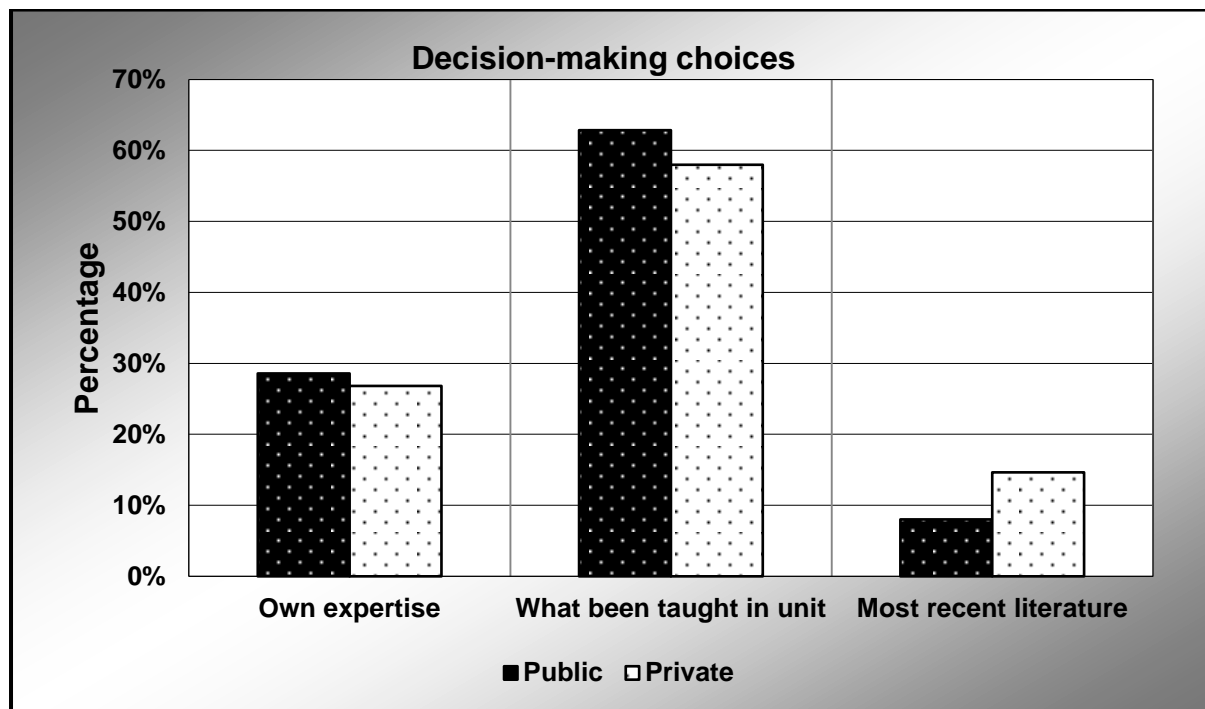


Figure 4.12 Decision-making choices

4.5.1.13 In-service education required on ETT verification

The majority of participants: 86% [$n_1=33$ (83%); $n_2=53$ (88%)] indicated the need for in-service education on endotracheal tube verification. The remaining 14% [$n_1=7$ (17%); $n_2=7$ (12%)] indicated that they do not require any in-service education related to this nursing care practice. This question was not repeated consistently in the other sections of the questionnaire and could thus not be compared for the four identified nursing care practices.

4.5.2 SUMMARY OF RESULTS ON ENDOTRACHEAL TUBE VERIFICATION

The results, as derived from the data in the structured questionnaires related to the section on endotracheal tube verification are illustrated in Table 4.4.

Table 4.4 Summary of the results on endotracheal tube verification		
Question	Correct or best recommended practice response	Incorrect or not best recommended practice response
Auscultation findings to verify endotracheal tube placement	96%	4%
Methods to identify carbon dioxide in exhaled gas in verifying ETT placement	72%	28%
Normal range for carbon dioxide measurements	65%	35%
Frequency for verifying endotracheal tube placement	53%	47%
Chest radiography findings	50%	50%
Inspection findings to verify endotracheal tube placement	43%	57%
Calometric detection of carbon dioxide	40%	60%
Methods for endotracheal tube verification	0%	100%

Please note that the table is not in ranking order as per structured questionnaire, but according to the descending percentages for incorrect responses as derived from the data analysis.

A summary on the results related to the existing guidelines and choices on decision-making are reflected in Table 4.5.

Table 4.5 Summary of the existing institutional guideline and decision-making			
The availability of an existing guideline	<u>Yes:</u> 32%		<u>No:</u> 68%
The frequency of use for the existing guideline (n=43)	<u>Often:</u> 24%	<u>Seldom:</u> 6%	<u>Never:</u> 13%
Decision-making CCU in Public sector (n=35)	<u>Own expertise</u> 29%	<u>What have been taught in unit</u> 63%	<u>Most recent literature</u> 8%
Decision-making CCU in Private sector (n=41)	<u>Own expertise</u> 27%	<u>What have been taught in unit</u> 58%	<u>Most recent literature</u> 15%
Need for in-service education on ETT verification	<u>Yes:</u> 86%		<u>No:</u> 14%

4.5.3 DISCUSSION PERTAINING TO ENDOTRACHEAL TUBE VERIFICATION

The findings of this study highlighted important information about the nursing care practices related to endotracheal tube verification as performed by professional nurses in the critical care units of the public and private sectors in the Nelson Mandela Metropole.

According to Salem (2001:813) and De Boer (2003:444) endotracheal tube verification should be done at least once per shift, depending on the method used. If the **frequency** is once per shift, it can be done at either 6 or 12-hour intervals. However, no literature was found to support the use of more frequent intervals to verify the placement and it can therefore be accepted that a frequency of once per shift is the best recommended practice. The study findings revealed that only 53% of professional nurses, with a majority comprising the public sector, verify endotracheal tube placement once per shift. It is, however, concerning that 4% of the participants in both health care sectors never verify endotracheal tube placement, a practice that

might be harmful, compromising the safety of the mechanically ventilated patient. No other studies were found to support the findings of this study.

Although there are various **methods** available to verify endotracheal tube placement, the best recommended method is using the **identification of carbon dioxide in exhaled gas** as indicated by various studies (Erasmus, 2004:674; Knapp *et al*, 1999:766; Cheifetz and Myers, 2007:424) The study findings revealed that none of the participants uses the best recommended method in verifying the endotracheal tube placement. An informal exploration for possible reasons why no participants in the critical care units in the Nelson Mandela Metropole use the best recommended method revealed the lack of resources and monitoring devices in the critical care units. Yet these devices are widely used in other high acuity areas, for instance, operating theatres and recovery rooms, and could thus be motivated for in critical care units.

Although in the light of strong position statements supporting the use of end-tidal monitoring in the confirmation of intubations by many professional societies in emergency medicine, anaesthesia and pre-hospital care, for instance the ACEP, the National Association of Emergency Medicine Physicians (NAEMSP) and the American Society for Anaesthesiologists (ASA), not all disciplines have endorsed this modality (Delorio, 2005:493). Findings from studies done in the critical care units in the United Kingdom revealed that approximately half of the units in the study did not have an end-carbon dioxide monitor and could not use this method for endotracheal tube verification (Kannen and Manji, 2003:476). No study pertaining to South Africa was found.

Other methods to verify endotracheal tube placement include the use of clinical assessment findings, which comprises **inspection of the chest wall movements and auscultation of bilateral breath sounds**. Although these methods are commonly used amongst nurse practitioners in the health care settings, they have not been proven to be reliable in verification of endotracheal tube placement. Inspection findings can be influenced by the anatomical structure and posture of the chest wall and findings should thus be interpreted with caution. The reliability of

auscultation is related to tidal volume during the test, sites of auscultation, presence of gastric distension and the experience of the examiners. Therefore, inspection and auscultation of the chest alone are regarded as unreliable sole methods in verifying the endotracheal tube placement (Salem, 2001:816; Morton and Fontaine, 2009: 544). The American College of Emergency Physicians (ACEP) support this in stating that methods such as auscultation and inspection of the chest wall are not reliable to confirm endotracheal tube placement (ACEP, 2009:141). The study findings revealed that a small proportion of professional nurses (10%) in the critical care units of the private sector use this method. The majority of participants (53%) used auscultation of bilateral breath sounds. In a study (2 392 emergency department intubations) done by Wallis and Barton (1999:s32), it was found that only 34% of the participants only used inspection and auscultation. The remaining 66% participants in their study supplemented the use of inspection and auscultation with the use of end-tidal carbon dioxide determination in exhaled gas. The study findings were thus not congruent with the results of a single study found.

Palpation of the endotracheal tube cuff on each side of the trachea between the cricoid cartilage and the suprasternal notch, while moving the tube, is not indicated as a reliable method to verify endotracheal tube placement (Salem, 2001:820). The study findings revealed that only 1% of participants use this method. No other studies were found in supporting the findings of this study.

Pulse oximetry can provide early warning of undetected hypoxia, but this measurement can be influenced by many factors, including the position of the device on the finger and changes in perfusion, skin thickness and colour and is thus not regarded as a reliable method for endotracheal tube verification (Salem, 2001:818). The study findings revealed that only 3% of participants use pulse oximetry. No other studies were found to support this research finding.

Direct laryngoscopy includes direct visualization of the endotracheal tube between the vocal cords as a method to verify the endotracheal tube placement. However, sighting of the endotracheal tube cannot be performed in all cases of direct laryngoscopy, particularly if the intubation was difficult. Furthermore, direct

laryngoscopy should only be done by a practitioner who is competent and clinically skilled in performing endotracheal intubations (DeBoer, 2003:445). The study findings revealed that only 1% of the participants indicated the use of direct laryngoscopy as a method to verify endotracheal tube placement. The findings of the study was congruent with the findings of the study done by Wallis and Barton (1999:s32) where it was found that direct visualization was only used by 3% of practitioners.

Considered for many years to be the standard of care for confirming endotracheal tube placement, many persons still highly recommend obtaining a **chest radiograph** to verify the position of the endotracheal tube. However, it might be a lengthy process to obtain and view the film. In addition, the endotracheal tube may become dislodged during or after the radiograph is obtained. Furthermore, in the standard portable anterior-posterior view, an oesophageal intubation can be very difficult to distinguish from a tracheal intubation because the oesophagus lies directly behind the trachea. The chest radiograph findings can be influenced by the patient's position, disease process and the quality of the film. The chest radiograph must be correctly interpreted and the anatomical position of the respiratory structures should be easily and correctly identified prior to verifying the endotracheal tube placement. Therefore, chest radiographs may not be best recommended as a single method for verification of the procedure (De Boer, 2003:446; Hall, White and Karrison, 1991:689; Bhagwanjee and Muckar, 1996:1335). The American College of Emergency Physicians (ACEP, 2009:141) support this in stating that chest radiographs are not reliable as sole techniques to determine endotracheal tube location. The study findings revealed that 36% of participants in the critical care units in the Nelson Mandela Metropole still use chest radiographs as a method to verify endotracheal tube placement.

In using **inspection of chest movements** as a method to verify endotracheal tube placement, it is important to observe for symmetrical, bilateral chest movements. The study findings revealed that only 43% of participants knew the correct inspection findings, which can compromise the safety of the patient when used as a sole method of verification. Performing bilateral **auscultation** of the breath sounds would

aid in this verification (Morton and Fontaine, 2009:557), which was indicated by 96% of the participants in the study. No studies were found to compare the findings of this research study.

When using **chest radiographs** as a method to verify endotracheal tube placement, interpreting the correct findings is essential. The tip of the endotracheal tube should be approximately 2-3 cm above the carina when the patient's head is in the neutral position (Urden *et al*, 2006:662). The study findings revealed that only 50% of participants indicated the correct findings. This should be noted, especially since 36% of participants use chest radiographs.

There are two **methods to use in identifying carbon dioxide in exhaled gas** in verifying endotracheal tube placement. These two methods include capnography and calometric detection of carbon dioxide. Capnography has been shown to be useful during intubation to ensure tracheal, rather than oesophageal, intubation. It is helpful in optimizing patient care including detecting misplacement of the endotracheal tube. Capnography and calometric devices both assist in detection of oesophageal intubation (Martin and Wilson, 2002:10). However, Puntervoll *et al*, (2002:455) argue that capnography, as a method of rapidly detecting oesophageal intubation, is more superior compared to calometric measurements. When asked which method is used to verify endotracheal tube placement none of the participants indicated the use of identification of carbon dioxide in exhaled gas as their method of choice, which might be due to the lack of availability of the necessary device. However when asked, which is the more superior and best recommended method 72% indicated the use of capnography.

The **normal range for carbon dioxide measurement** must be between 35 to 45 mmHg to indicate the correct placement of the endotracheal tube (Pierce 2007:72). The study findings revealed that only 65% of participants indicated the normal range for carbon dioxide in exhaled gas. No studies were found to support this research finding.

When using **calometric detection of carbon dioxide** as a method for verifying endotracheal tube placement, the paper should change to yellow indicating the correct anatomical position for the endotracheal tube (Mims *et al*, 2004:28). The study findings revealed that only 40% indicated the correct findings in using calometric detection of carbon dioxide. It is important that if professional nurses use this method, they will be required to interpret the normal findings related to it in order to ensure that the endotracheal tube is correctly placed.

The findings from the study highlighted the fact that professional nurses in the critical care units in the Nelson Mandela Metropole use methods that are not reliable and best recommended practice in confirming endotracheal tube placement. Incorrect placement of the endotracheal tube might compromise the safety of the mechanical ventilated patient and therefore, the best recommended practice to verify endotracheal tube placement is essential.

Clinical guidelines are specific recommendations that are based on the review of the best evidence on a specific topic or clinical question and have the potential to influence the quality of care, safety of the patient and patient outcomes (Melnyk and Fineout-Overholt, 2005:11). The findings in this study revealed that a relatively small percentage (32%) of critical care units have an institutional guideline in place on endotracheal tube verification. The majority of participants could not indicate who was responsible for the development of the guideline, while some stated that the guideline was developed by the unit manager. On request, no guideline was available and in some units only procedural policies were used. The process of guideline development was not explored and remains questionable.

Consistent use of tradition as a basis for practice limits effective problem solving and fails to consider individual patient's needs and preferences. Nurses can also be so entrenched in practice traditions that they fail to ask questions that could lead to changes based on evidence. Furthermore, nurses often make decisions about patient care based on personal experiences or own expertise. However, while previous experience can help to build confidence, these experiences are biased by perceptions and values that are frequently influenced by traditions, authority and trial

and error. Own expertise and the use of tradition thus cannot be regarded as the most reliable sources of evidence upon which to base patient care decisions because nurses are expected to use logical reasoning as critical thinkers and clinical decision makers (Schmidt and Brown, 2009:5). The results from this study revealed that the only 8% of participants in the public sector and 15% in the private sector use the most recent literature when making practice decisions regarding verification of endotracheal tube placement. The remaining 92% in the public sector and 85% in the private sector based their decision-making on their own expertise and tradition, which might influence the patient outcomes and ultimately the safety of the patient.

4.6 ENDOTRACHEAL CUFF PRESSURE MONITORING

This section aimed at exploring and describing the current nursing care practices related to endotracheal tube cuff pressure monitoring as performed by professional nurses in the critical care units of the public and private sectors in the Nelson Mandela Metropole. The summary of the items for discussion in this section of the study is reflected in Table 4.6.

Table 4.6 Items for discussion on endotracheal tube cuff pressure monitoring

4.6.1	RESULTS
4.6.1.1	Frequency for measuring endotracheal tube (ETT) cuff pressures
4.6.1.2	Positioning of the patient
4.6.1.3	Methods to check endotracheal tube cuff pressure
4.6.1.4	Normal range for endotracheal tube cuff pressure
4.6.1.5	Deflation and re-inflation of endotracheal tube cuffs
4.6.1.6	Management of an audible leak
4.6.1.7	Amount of air to inflate for a leak
4.6.1.8	Consequences of under-inflation of the endotracheal tube cuff
4.6.1.9	Consequences of over-inflation of the endotracheal tube cuff
4.6.1.10	Institutional guideline in place for endotracheal tube cuff pressures
4.6.1.11	Who developed the guideline?
4.6.1.12	Frequency of use for the existing clinical guideline
4.6.1.13	Decision-making choices
4.6.2	SUMMARY OF THE RESULTS FOR ENDOTRACHEAL TUBE CUFF PRESSURE MONITORING
4.6.3	DISCUSSION ON ENDOTRACHEAL TUBE CUFF PRESSURE MONITORING

4.6.1 RESULTS

The results of the study are presented in this section. The questionnaire comprised 13 questions, of which nine were aimed at exploring these monitoring practices. The remaining four explored the availability of any existing clinical guideline, and the choices the professional nurses make in aiding their decision-making.

4.6.1.1 Frequency for measuring endotracheal tube (ETT) cuff pressures

The best recommended practice for measuring endotracheal tube pressures is once per shift, which can be every 6 or 12 hours. Of the 100 participants, 52% indicated the best recommended frequency in monitoring and measuring endotracheal tube cuff pressures.

The results were as follows:

- 3% [$n_1=2$ (5%); $n_2=1$ (2%)] of participants checked the ETT cuff pressures every 2 hours;
- 29% [$n_1=3$ (8%); $n_2=26$ (43%)] used 4-hour intervals;
- 34% [$n_1=10$ (25%); $n_2=24$ (40%)] used 6-hour intervals;
- 18% [$n_1=14$ (35%); $n_2=4$ (7%)] used 12-hour intervals;
- 15% [$n_1=10$ (25%); $n_2=5$ (8%)] only checked the cuff pressures when a leak occurred;
- 1% [$n_1=1$ (3%); $n_2=0$ (0%)] never checked the cuff pressures.

The responses amongst professional nurse in the public and private sectors were statistically significant ($\text{Chi}^2(\text{d.f.}=4) = 29.75, p < .001, V = 0.55$) as illustrated in Figure 4.13. Practice variations occur amongst professional nurses in the critical care units of both health care sectors. However, the professional nurses in the public sector are more inclined to check the endotracheal tube cuff pressures according to the best recommended practice.

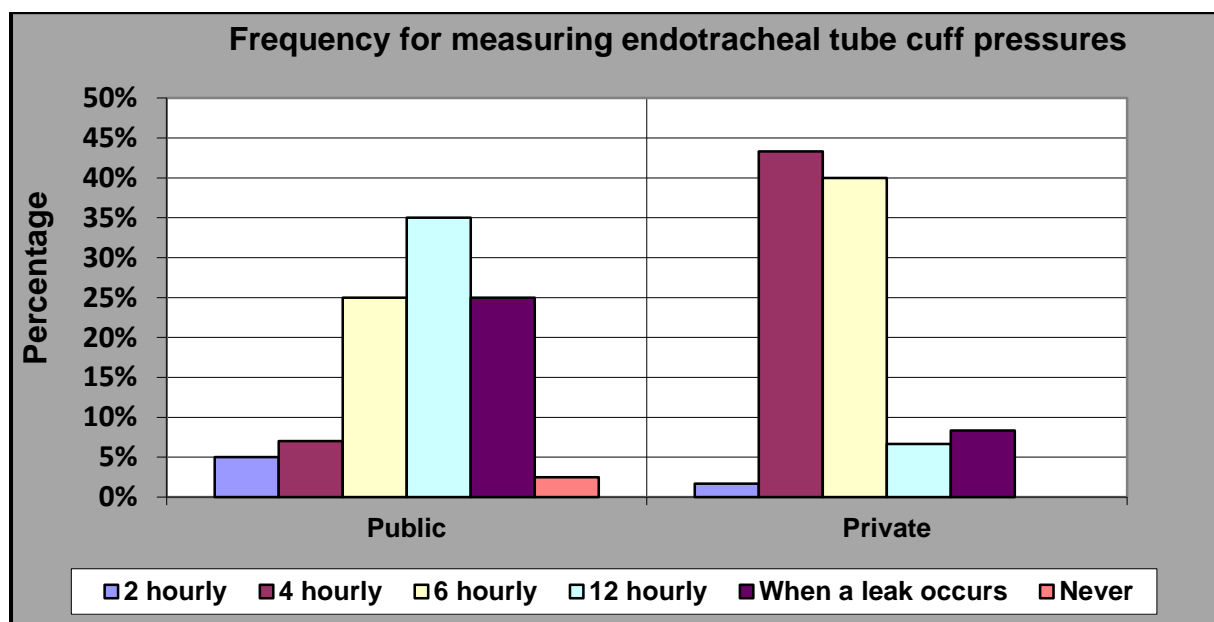


Figure 4.13 Frequency for measuring endotracheal tube cuff pressures

4.6.1.2 Positioning of the patient

Of the 100 participants only 37% [$n_1=13$ (33%); $n_2=24$ (40%)] indicated that they would place the patient in a 30-45 degree position (semi-recumbent) when measuring endotracheal cuff pressures, which is the correct response. The remaining participants indicated responses that are incorrect and not according to the best recommended practice. The following incorrect responses were noted: 14% [$n_1=2$ (5%); $n_2=12$ (20%)] participants indicated the use of supine positioning, 25% [$n_1=14$ (35%); $n_2=11$ (18%)] participants indicated that they would position the patient supine to 45 degree, while 24% [$n_1=11$ (28%); $n_2=13$ (22%)] participants indicated that they would not change the position of the patient when measuring endotracheal tube cuff pressures.

Comparing the results amongst the professional nurses in the critical care units in the public and private sectors a statistical significant difference was noted, ($\chi^2(d.f.=3) = 29.75, p < .001, V = 0.55$). Practice variances were noted amongst professional nurses in the critical care units of the public and private sector. The differences in responses are mainly noted in positioning the patient either supine or supine to 45 degrees. Positioning the patient in any other way that the best recommended way might be harmful to the patient (see 2.7.2.3). Therefore practices related to positioning the patient when measuring endotracheal tube cuff pressure in critical care units of both health care sectors are detrimental for the mechanically ventilated patient. However professional nurses in the critical care units of the private sector are more inclined to position the patient according to best practice recommendation when measuring endotracheal tube cuff pressure. The results are graphically displayed in Figure 4.14.

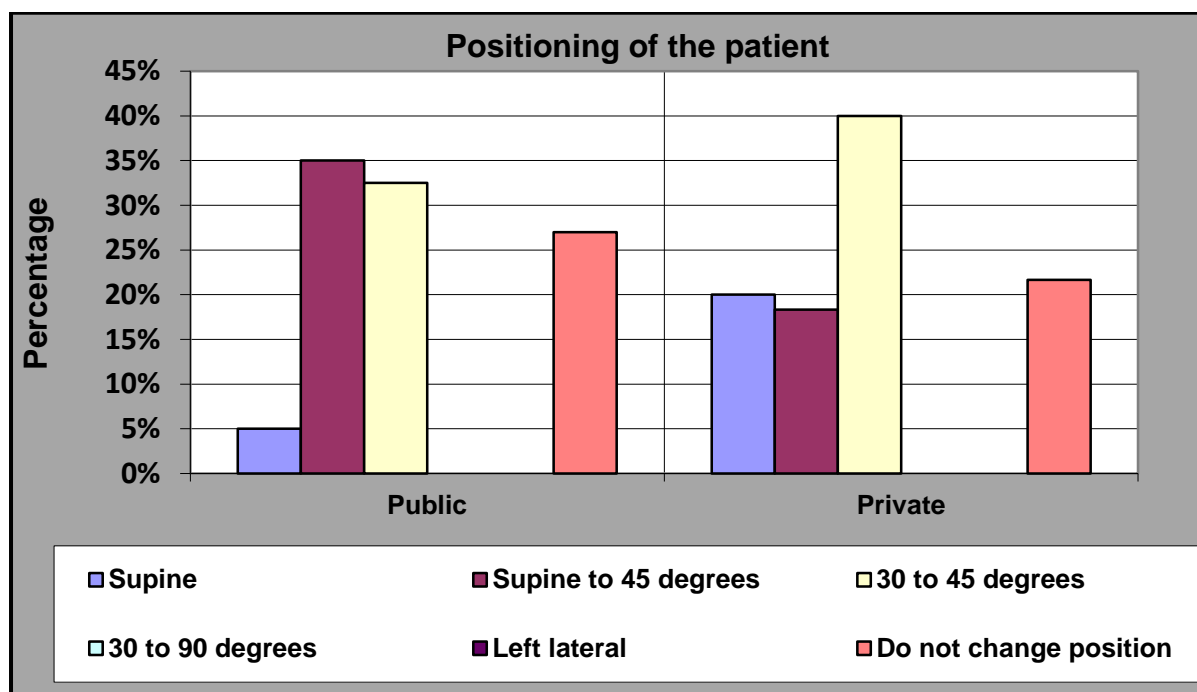


Figure 4.14 Positioning of patient

4.6.1.3 Methods to monitor endotracheal tube cuff pressure

Derived from the data analysis, 34% [$n_1=12$ (30%); $n_2=22$ (37%)] indicated the use of an aneroid manometer to monitor endotracheal tube cuff pressures, which is the best recommended method, while 24% [$n_1=10$ (25%); $n_2=14$ (23%)] of participants indicated that they would estimate the cuff pressure by feeling the cuff. Of the 100 participants 22% [$n_1=10$ (25%); $n_2=12$ (20%)] indicated that they would check cuff pressure by listening for air leaks. Of the 100 participants 20% [$n_1=8$ (20%); $n_2=12$ (20%)] indicated the use of the minimal occlusive volume technique. None of the participants indicated the use of the minimal leak technique.

No statistically significant difference was noted between the responses from professional nurses in the public and the private sectors ($\text{Chi}^2(\text{d.f.}=3) = 4.90$, $p = .179$). The results are depicted in Figure 4.15.

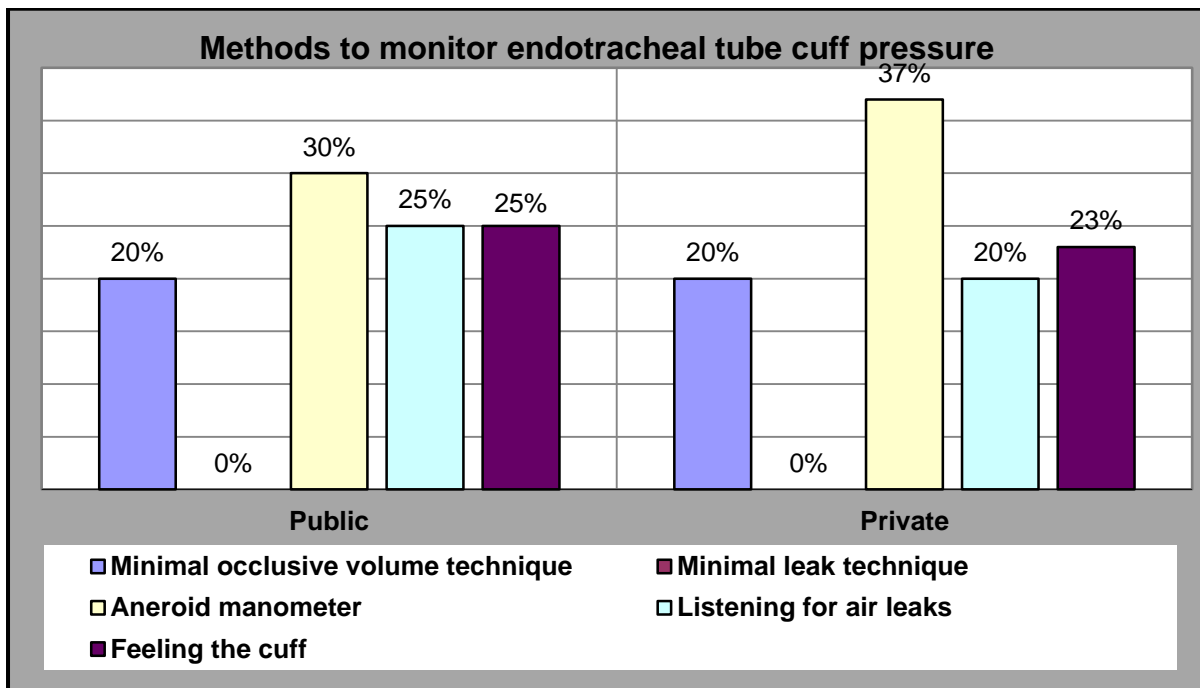


Figure 4.15 Methods to monitor endotracheal tube cuff pressure

4.6.1.4 Normal range for endotracheal tube cuff pressure measurement

Of the 100 participants only 22% [$n_1=7$ (17%); $n_2=15$ (25%)] indicated the correct normal range (18 to 22 mmHg) for maintaining adequate endotracheal tube cuff pressure in the mechanically ventilated patient. The following incorrect responses were noted: 33% [$n_1=13$ (33%); $n_2=20$ (33%)] indicated that they would maintain the endotracheal tube cuff pressures at 23 to 25 mmHg; 43% [$n_1=20$ (50%); $n_2=23$ (38%)] indicated that they would maintain it at 26 to 30 mmHg, 1% [$n_1=0$ (0%); $n_2=1$ (2%)] indicated the use of pressure of more than 31 mmHg, while 1% [$n_1=0$ (0%); $n_2=1$ (2%)] indicated that they do not know what normal cuff pressures to maintain. No statistically significant difference was noted in the responses from professional nurses in the critical care unit of the public and private sectors ($\chi^2(d.f.=4) = 2.71, p = .607$). The results are displayed in Figure 4.16.

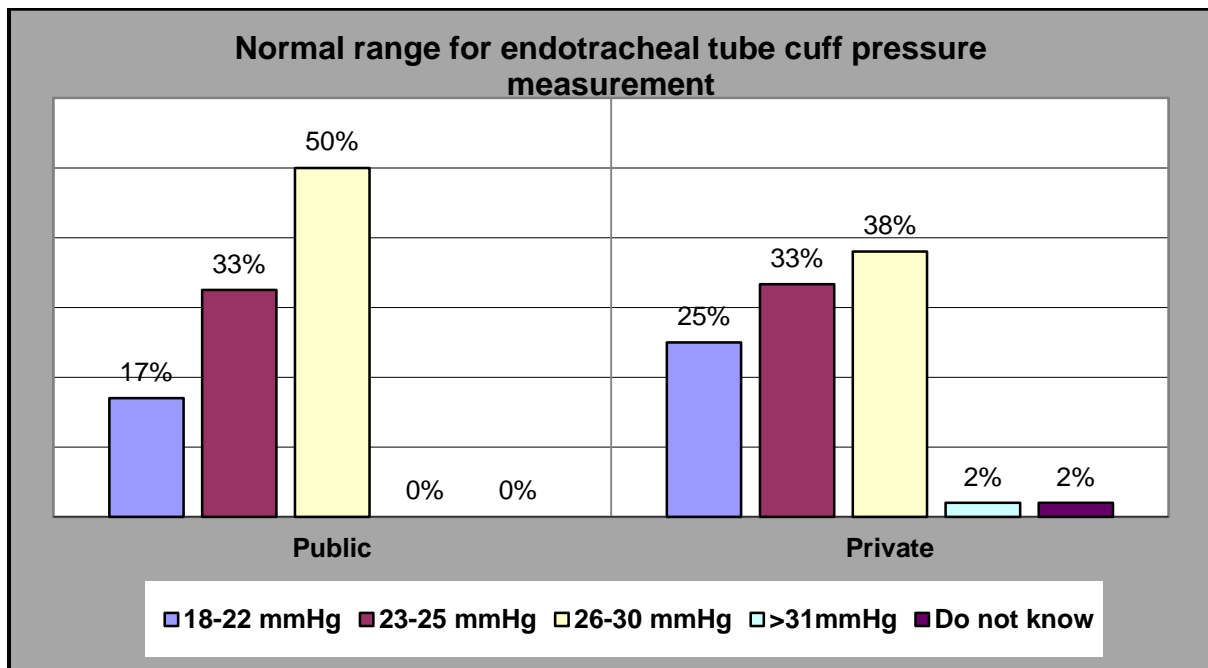


Figure 4.16 Normal ranges for endotracheal tube cuff pressure measurement

4.6.1.5 Deflation and re-inflation of the endotracheal tube cuff

The question aimed at exploring if professional nurses practice deflation and re-inflation of the endotracheal tube cuff prior to and after performing sectioning. Although 69% [$n_1=23$ (58%); $n_2=46$ (77%)] participants answered no to the question, indicating that they do not perform deflation and inflation, which is best recommended practice, a significant proportion participants [31%, $n_1=17$ (42%); $n_2=14$ (23%)] still perform this practice which is not best recommended in maintaining the endotracheal tube cuff pressure. The differences between the professional nurses from the critical care units in the public and private sector was not statistically significant ($\text{Chi}^2(\text{d.f.}=2) = 4.12, p = .420$). The results are displayed in Figure 4.17.

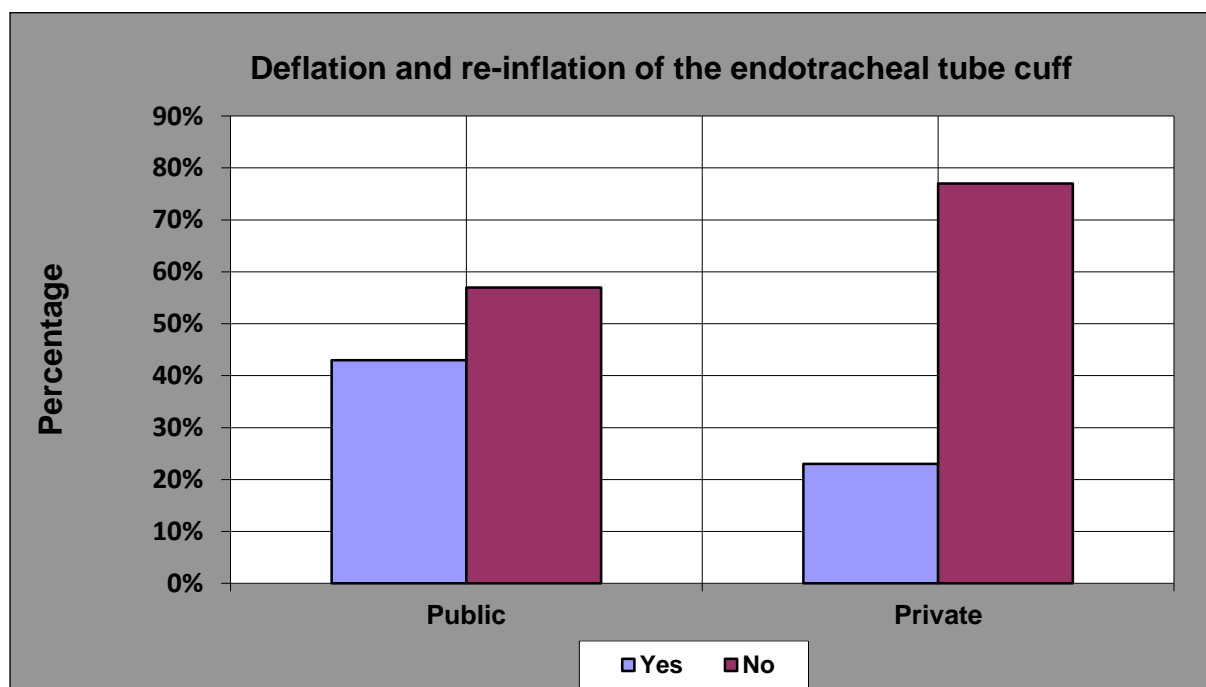


Figure 4.17 Deflation and re-inflation of the endotracheal tube cuff

4.6.1.6 Management of an audible leak

In exploring how the participants would manage an audible endotracheal cuff leak, 44% indicated the correct response, which could be either continued cuff inflation irrespective of the volume of air inserted: 15% [$n_1=10$ (25%); $n_2=5$ (8%)] or continued cuff inflation and notifying the physician: 29% [$n_1=10$ (25%); $n_2=19$ (32%)]. The following incorrect responses were noted: 2% [$n_1=1$ (2%); $n_2=1$ (2%)] indicated that they would manipulate the patient's endotracheal tube and position, 51% [$n_1=19$ (48%); $n_2=32$ (53%)] indicated that they would only assess the cuff pressure while 3% [$n_1=0$ (0%); $n_2=3$ (5%)] indicated that they would monitor for an on-going cuff leak. No statistically significant difference was noted in the responses from the professional nurses in the critical care units of the two health care sectors ($\chi^2(d.f.=4) = 7.054, p = .132$). The results are displayed in Figure 4.18.

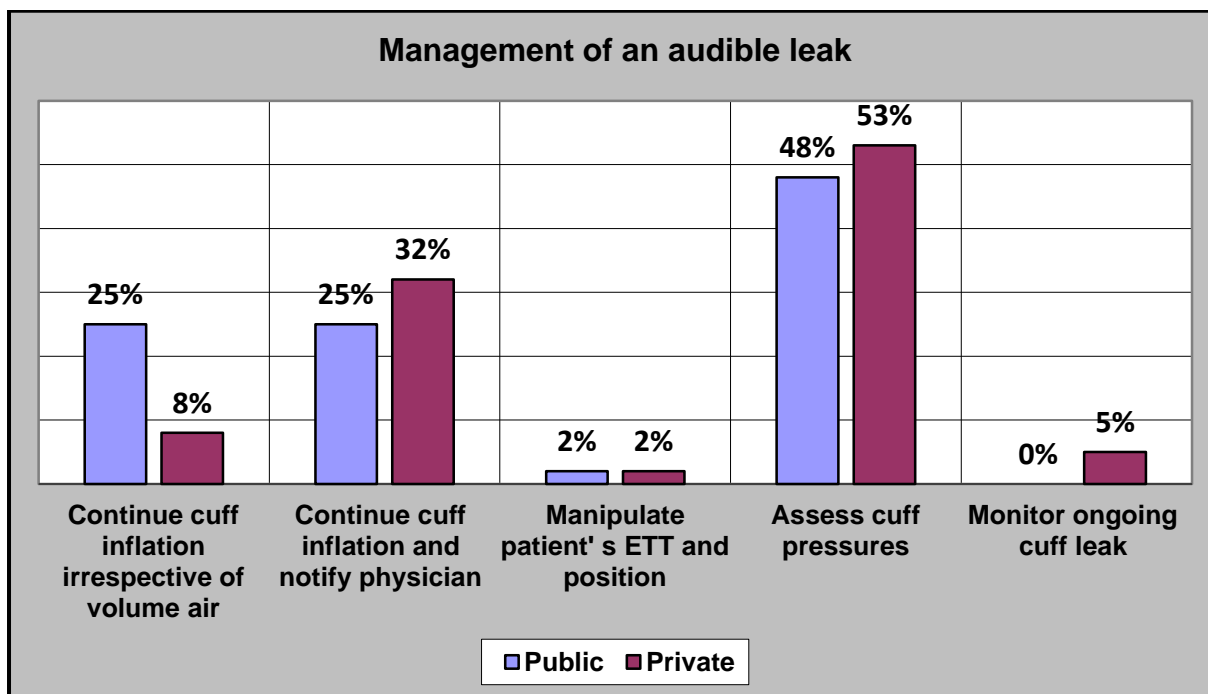


Figure 4.18 Management of an audible leak

4.6.1.7 Amount of air to inflate for a leak

In exploring the respondent's current practices on how much air they would use to inflate the cuff when an audible leak was noted, only 6% [$n_1=0$ (0%); $n_2=6$ (10%)] indicated that they would use 10 ml of air, which is the best recommended response. The remaining of the participants indicated the following incorrect responses: 36% [$n_1=13$ (32%); $n_2=23$ (38%)] indicated that they would use 2 ml of air; 23% [$n_1=9$ (23%); $n_2=14$ (24%)] indicated that they would use 5 ml of air, while 1% [$n_1=1$ (3%); $n_2=0$ (0%)] indicated the use of 20 ml of air. The remaining 34% [$n_1=17$ (43%); $n_2=17$ (28%)] indicated that they would continue inflation of the endotracheal cuff until the audible leak disappears, irrespective of the amount of air used. No statistically significant difference was noted in the responses from the professional nurses in the critical care units in the two health groups ($\text{Chi}^2(\text{d.f.}=4) = 7.150$, $p = .128$). The results are displayed in Figure 4.19.

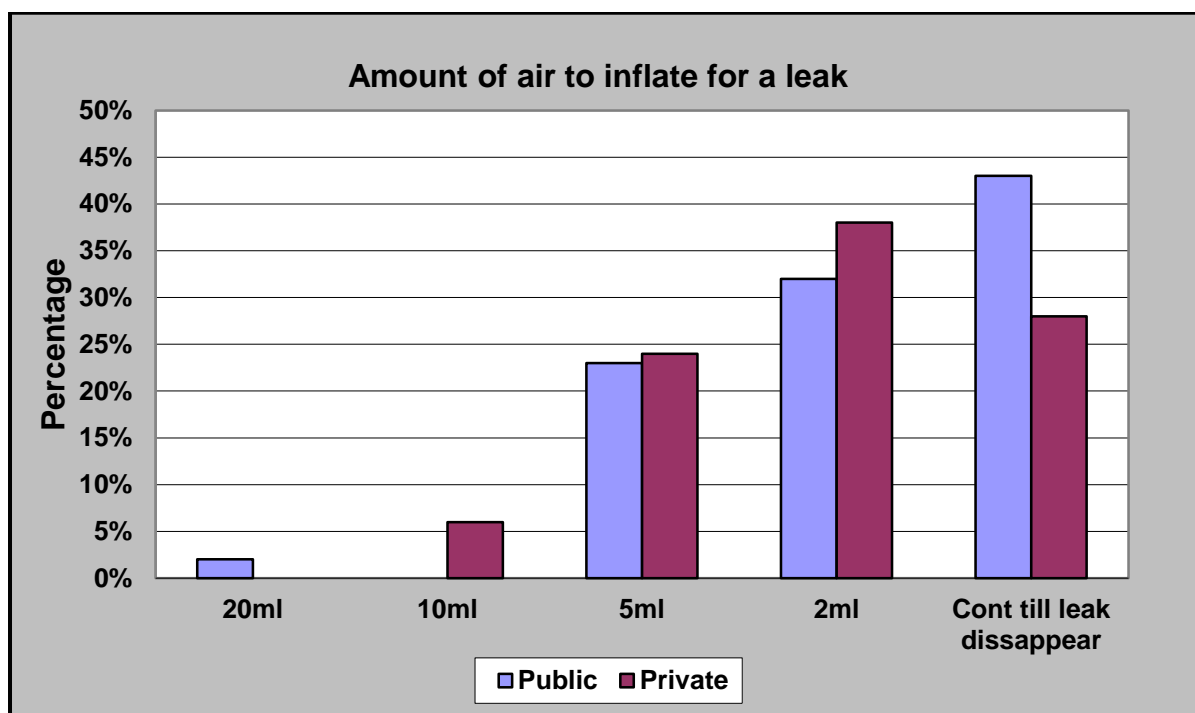


Figure 4.19 Amount of air to inflate for a leak

4.6.1.8 Consequences of under-inflation of the endotracheal tube cuff

Of the 100 participants, 72% [$n_1=28$ (70%); $n_2=44$ (73%)] indicated the correct response for the consequences related to under-inflation of the endotracheal tube cuff. The remaining 28% [$n_1=12$ (30%); $n_2=16$ (27%)] indicated the incorrect response as indicated in Table 4.7. No statistically significant difference was noted between the responses from the two health care sectors ($\text{Chi}^2(\text{d.f.}=3) = 3.411, p = .332$).

Table 4.7 Consequences of under-inflation of the endotracheal tube cuff			
Item	Public ($n_1=40$)	Private ($n_2=60$)	Total number of participants ($n=100$)
All of above	28 (70%)	44 (73%)	72
Aspiration of secretions into lower airway	10 (25%)	9 (15%)	19
Increasing the risk for VAP	2 (5%)	4 (7%)	6
None of above	0 (0%)	3 (5%)	3

4.6.1.9 Consequences of over-inflation of the endotracheal tube cuff

The majority of participants: 63%, [$n_1=22$ (55%); $n_2=41$ (68%)] indicated the correct response related to the consequences of over-inflating the endotracheal tube cuff: erosion, stenosis, rupture and innominate artery fistulas, while the remaining 37% [$n_1=18$ (45%); $n_2=19$ (32%)] indicated incorrect responses. No statistical difference was noted between the responses of professional nurses in the critical care units in the public and private sectors ($\text{Chi}^2(\text{d.f.}=5) = 13.78, p = .178$). The results are displayed in Table 4.8.

Table 4.8 Consequences of over-inflation of the endotracheal tube cuff			
Item	Public ($n_1=40$)	Private ($n_2=60$)	Total number of participants ($n=100$)
All of above	22 (55%)	41 (68%)	63
Trachael stenosis	15 (37%)	9 (15%)	24
Trachael erosion	0 (0%)	7 (11%)	7
Trachael rupture	1 (2%)	3 (5%)	4
Trachael innominate artery fistulas	1 (2%)	0 (0%)	1
None of above	1 (2%)	0 (0%)	1

4.6.1.10 Institutional guideline in place for endotracheal tube cuff pressure monitoring

Of the 100 participants, only 48% [$n_1=18$ (45%); $n_2=30$ (50%)] indicated that they have a guideline in place on endotracheal tube cuff pressure monitoring. The remaining 52% [$n_1=22$ (55%); $n_2=30$ (50%)] indicated the absence of a guideline in their respective critical care units. The difference in the responses from professional nurses in the public versus the private sectors was statistically insignificant ($\text{Chi}^2(\text{d.f.}=2) = 4.12, p = .420$). The results are graphically displayed in Figure 4.20.

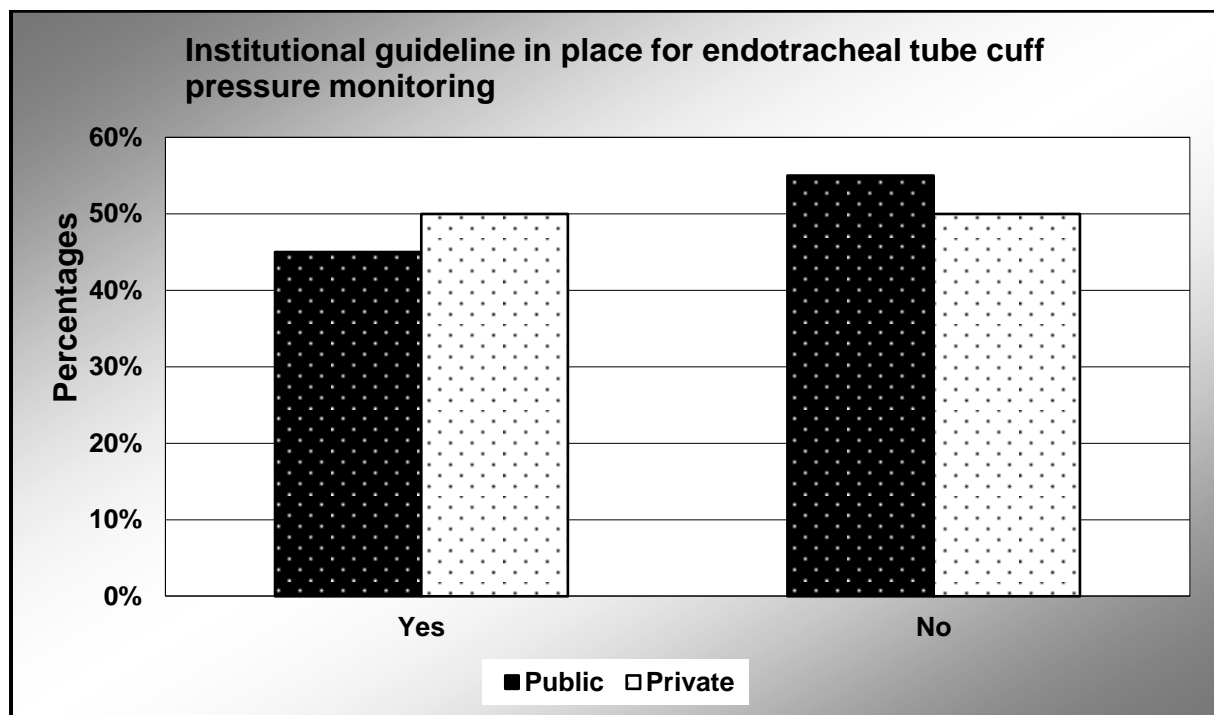


Figure 4.20 Institutional guideline in place for endotracheal tube cuff pressure monitoring

4.6.1.11 Who developed the guideline?

In questioning the participants on who developed the guideline, the majority of the responses were left blank and could thus not be statistically analysed. The minority of the responses that were completed revealed that individual unit managers developed these guidelines. When the guideline was requested from the various unit managers, none was available. However, only a procedural unit policy was available on endotracheal tube cuff pressure monitoring.

4.6.1.12 Frequency of use for the existing guideline

Of the 48% participants who indicated that they have a guideline available on endotracheal tube cuff pressures, 29% [$n_1=13$ (72%); $n_2=16$ (53%)] indicated that they use the guideline often, 16% [$n_1=5$ (28%); $n_2=11$ (37%)] that they seldom use the guideline and the remaining 3% [$n_1=0$ (0%); $n_2=3$ (10%)] that they never use it. No statistical significant difference was noted between the responses from professional nurses in the critical care units of the two health care sectors ($\text{Chi}^2(2) = 0.74$, $p = .692$). The results are displayed in Figure 4.21.

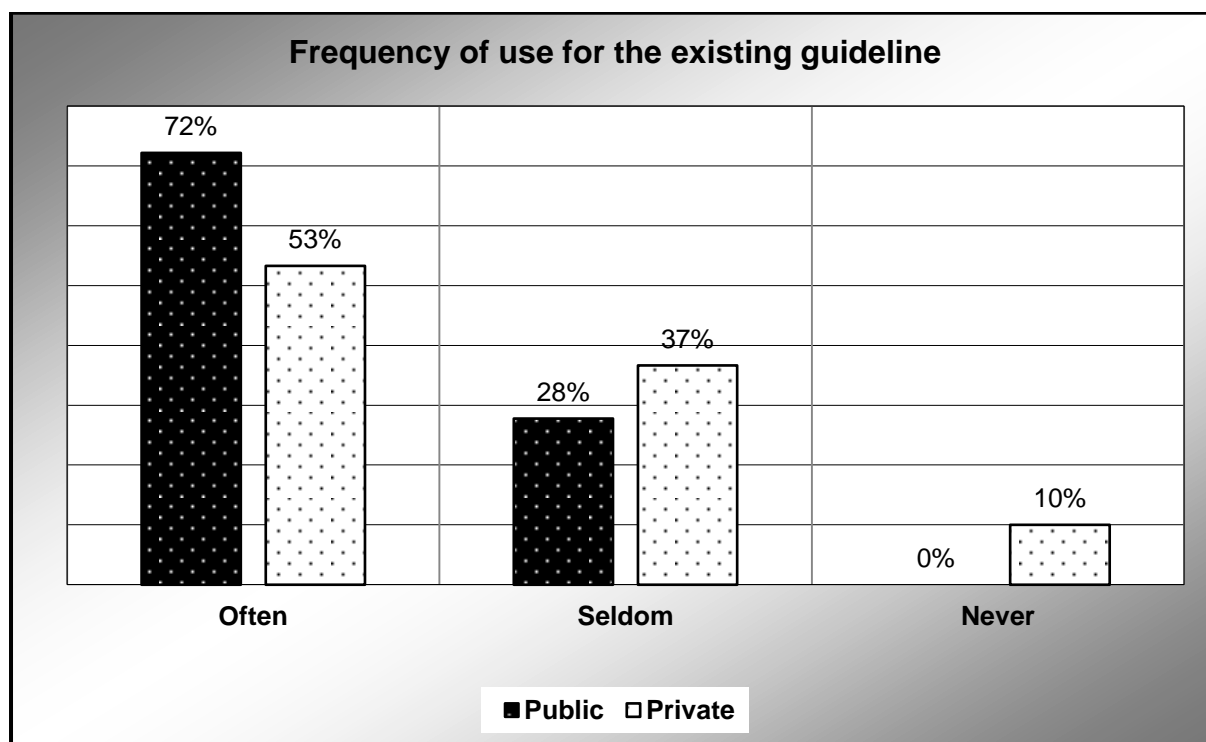


Figure 4.21 Frequency of use for the existing guideline

4.6.1.13 Decision-making choices

The response to this question followed if the participants indicated that they did not have an institutional guideline in place for endotracheal tube cuff pressure monitoring. Although 22 participants in the public sector indicated that they do not, 24 answered the question. In the private sector, 30 participants indicated that they do not have a clinical guideline in place, yet 41 answered the question. As this was a multi-response question and due to the fact that not all 100 participants answered the question, a total percentage could not be calculated for this question. Therefore, the individual percentages per response for both sectors are reported.

In the public sector, 17% ($n_1=4$) of participants indicated that they base their nursing care practices on own expertise, while 54% ($n_1=13$) indicated that they base their practices on what they have been taught in the unit. The remaining 29% ($n_1=7$) indicated that their nursing care practices related to endotracheal tube verification are based on the most recent literature. Results from the private sector reflected that 22% ($n_2=9$) base their practices on own expertise, 54% ($n_2=22$) on what they have been taught in the unit, while only 24% ($n_2=10$) on the most recent literature. Due to

the multiple responses, the Chi-square test could not be done for this question. The results are displayed in Figure 4.22.

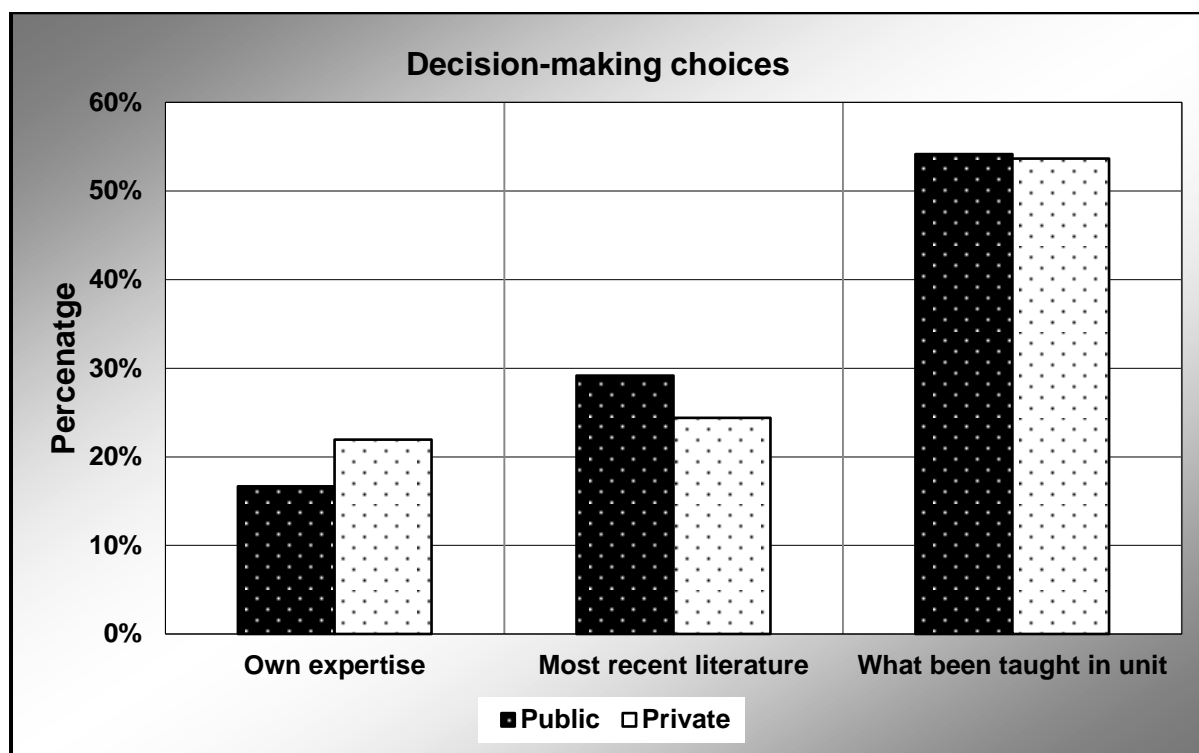


Figure 4.22 Decision-making choices

4.6.2 SUMMARY OF THE RESULTS FOR ENDOTRACHEAL TUBE CUFF PRESSURE MONITORING

The results for this section of the study are summarised in Tables 4.9 and 4.10. Table 4.9 depicts the summaries of the results pertaining to the nursing care practices on endotracheal tube cuff pressure monitoring. Table 4.10 displays the results pertaining to the existing institutional guideline, frequency for use and the choices on which professional nurses base their decision-making in caring for the intubated mechanically ventilated patient requiring endotracheal tube cuff pressure monitoring.

Table 4.9 Summary of the results on endotracheal tube cuff pressures		
Question	Correct or best recommended practice response	Incorrect or not best recommended practice response
Consequences of under-inflation	72%	28%
Deflation and re-inflation of the endotracheal tube cuff	69%	31%
Consequences of over-inflation	63%	37%
Frequency for measuring endotracheal tube cuff pressure	52%	48%
Management of an audible leak	44%	56%
Methods for endotracheal tube cuff pressure monitoring	34%	66%
Positioning of the patient	37%	73%
Normal range for endotracheal tube cuff pressure monitoring	22%	78%
Amount of air to inflate for a leak	6%	94%

The results for the summaries of the responses pertaining to the existing guideline on endotracheal tube cuff pressure monitoring and decision-making are displayed in Table 4.10.

Table 4.10 Summary of the existing guideline and decision-making			
The availability of an existing guideline	<u>Yes:</u> 48%	<u>No:</u> 52%	
The frequency of use for the existing guideline (n=48)	<u>Often:</u> 29%	<u>Seldom:</u> 16%	<u>Never:</u> 3%
Decision-making choices CCU in Public sector (n=24)	<u>Own expertise</u> 17%	<u>What have been taught in unit</u> 54%	<u>Most recent literature</u> 29%
Decision-making choices CCU in Private sector (n=41)	<u>Own expertise</u> 22%	<u>What have been taught in unit</u> 54%	<u>Most recent literature</u> 24%

4.6.3 DISCUSSION ON ENDOTRACHEAL TUBE CUFF PRESSURE MONITORING

Pierce (2007:93) and Urden *et al* (2006:667) recommend that endotracheal tube cuff pressures should be measured and monitored at least once per shift, or eight hourly as failure to monitor the cuff pressure may place the patient at an increased risk for aspiration and ventilator-associated pneumonia (VAP). Once per shift would refer be either 6 or 12-hour intervals in both the private and public sectors. A paucity of literature exists on the use of more frequent intervals, for instance, 2 or 4-hour intervals for measuring and recording of endotracheal tube cuff pressures. The study findings highlighted the fact that a variety of practices exists amongst professional nurse in the critical care units of both public and private sectors. Furthermore, it was found that 48% of the participants do not check the endotracheal tube cuff pressures according to best practice recommendations. The professional nurses in the public sector were more inclined to practice according to best practice recommendations.

According to Pierce (2007:91), it is recommended that the endotracheal tube cuff pressures be monitored by means of an aneroid cuff pressure manometer. The results of the study revealed that only 34% participants use the best recommended practice method for monitoring endotracheal tube cuff pressures. Routine deflation

and re-inflation of endotracheal tube cuffs is no longer recommended (Urden *et al*, 2006:667). Only 31% of the participants still perform this practice. Cuff pressure monitoring should be performed in the 30-45 degrees position, in order to avoid aspiration (Metheny *et al*, 2006:1010). It is concerning that 73% of the participants did not place the patient in the best recommended position when checking the endotracheal tube cuff pressures. No studies were available to compare the research findings.

The endotracheal tube cuff pressures should be maintained at 18 to 22 mmHg (25 to 30 cmH₂O) and maximal cuff pressures should not exceed 25 to 30 cmH₂O or 20 to 22 mmHg. Maintaining the pressures between 18 to 22 mmHg greatly reduces the risk of cuff site ischemia, injury and the risk of aspiration (Pierce, 2007:93). It is concerning that the majority participants (78%) within this research study did not know the normal range for maintaining correct cuff pressure measurements, thereby increasing the safety risk for the critically ill patient to develop complications related to over-inflation of the endotracheal tube.

Morton and Fontaine (2009:609) suggest that if more than 10 ml of air be injected for a cuff leak, the cause for the leak should be investigated. Notifying the physician regarding the leak is imperative as the cuff might be damaged, thus requiring re-intubation of the critically ill patient. Of the 100 participants in the study 56% of participants do not implemented the best recommended practice, which might compromise the safety of the mechanically ventilated patient. Furthermore only 4% of the participants indicated the best recommended amount of air to inflate for a leak.

Under-inflation of the endotracheal tube cuff is associated with inadequate delivery of prescribed tidal volume and aspiration of secretions. When the cuff pressures are maintained at less than 18 mmHg, the risk for aspiration and ventilator associated pneumonia are increased (Adam and Osborne, 2005:88). Professional nurses should thus not only maintain the normal endotracheal tube cuff pressures, but should be aware of the complications of under-inflation of the cuff. The findings from this study revealed that 28% of professional nurses in the critical care units in the

Nelson Mandela Metropole were not aware of the complications of under-inflation of the cuff.

Complications of over-inflation include nerve palsy, tracheosophageal fistula, tracheal wall damage, subglottic scarring or stenosis and hoarseness (Pierce, 2007:93). Due to the extensive damage that can occur through secondary to high endotracheal tube cuff pressures, the professional nurses in the critical care units should be aware of the complications secondary to over-inflation of the cuff. However, as reflected by the analysed data, only 63% of professional nurses in the critical care units of the private and public sectors knew the related complications, which might compromise the safety of the mechanically ventilated patient in the critical care unit.

Clinical guidelines make explicit recommendations, often on behalf of the health organization, with a definite intent to influence what clinicians do. Clinical guidelines are developed to assist the practitioner to make the appropriate practise decisions about health care for specific clinical circumstances. Furthermore, they are a way to minimise practice variances amongst nurses (Di Censoet *al*, 2005:156) and are thus essential. However, the study findings revealed that approximately half participants do not have a guideline on endotracheal tube cuff pressure monitoring available in their respective critical care units. However, when the guideline was requested none was available. In some units only procedural unit policies on endotracheal tube cuff pressures were available. Of those participants who indicated the availability of a clinical guideline, the frequency for use of the guideline varied significantly.

Evidence-based practice is an important concept in health care today. The phrases “That’s the way I’ve always done it” or “This is what I have been taught” are being replaced by “This practice is evidence-based”. Patients will receive improved care and outcomes and patient safety will be optimized by using an evidence-based approach to care (Munro, 2004:501). Although the findings in this section of the study showed an increased use of the most recent literature (compare Tables 4.5 & 4.10) to guide practice, there were still a large proportion of professional nurses in this study that base their decisions with regard to endotracheal tube cuff pressure

monitoring on own their expertise and what they have been taught in the unit and not on the most recent and available evidence.

4.7 ENDOTRACHEAL TUBE SUCTIONING

This section of the structured questionnaire comprised 26 questions, of which 22 questions aimed at exploring endotracheal tube suctioning. The remaining four questions explored the existing clinical guidelines, if any, in place and the decision-making choices that the professional nurses use in making practice decisions. A summary of the items for discussion in this section is given in Table 4.11.

Table 4.11 Items for discussion on endotracheal tube suctioning**4.7.1 RESULTS**

- 4.7.1.1 Frequency for performing endotracheal tube suctioning (ETT)
 - 4.7.1.2 Indications for endotracheal tube suctioning
 - 4.7.1.3 Suction catheter size
 - 4.7.1.4 Performing a respiratory assessment prior to suctioning
 - 4.7.1.5 Respiratory assessment findings
 - 4.7.1.6 Positioning of the patient when performing suctioning
 - 4.7.1.7 Suction pressures
 - 4.7.1.8 Hyperoxygenation
 - 4.7.1.9 Percentage of oxygen to use for hyperoxygenation
 - 4.7.1.10 Indications for hyperoxygenation
 - 4.7.1.11 Hyperinflation
 - 4.7.1.12 Methods for hyperinflation
 - 4.7.1.13 Indications for normal saline instillation
 - 4.7.1.14 Normal saline instillation
 - 4.7.1.15 Amount of normal saline instilled
 - 4.7.1.16 Adverse effects of normal saline instillation
 - 4.7.1.17 Hand hygiene
 - 4.7.1.18 Duration of suction procedure
 - 4.7.1.19 Depth of catheter insertion
 - 4.7.1.20 Complications of endotracheal tube suctioning
 - 4.7.1.21 Performing a respiratory assessment post suctioning
 - 4.7.1.22 Findings indicating effectiveness of endotracheal tube suctioning
 - 4.7.1.23 Institutional guideline in place for endotracheal tube suctioning
 - 4.7.1.24 Who developed the guideline?
 - 4.7.1.25 Decision-making choices
 - 4.7.1.26 In-service education required on endotracheal tube suctioning
- 4.7.2 SUMMARY OF RESULTS FOR ENDOTRACHEAL TUBE SUCTIONING**
- 4.7.3 DISCUSSION ON ENDOTRACHEAL TUBE SUCTIONING**

4.7.1 RESULTS

The results as derived and analysed from the structured questionnaire are presented in this section of the research study.

4.7.1.1 Frequency for performing endotracheal tube suctioning

The results for the 100 participants comprising 40 (n_1) professional nurses in the public sector and 60 (n_2) professional nurses in the private sector were as follow:

- 33% [$n_1=16$ (40%); $n_2=17$ (28%)] indicated that they would only suction the patient when necessary, which is the correct response;

The remaining participants indicated the following incorrect responses:

- 28% [$n_1=14$ (35%); $n_2=14$ (23%)] perform suctioning at 1 to 2-hour intervals;
- 36% [$n_1=9$ (23%); $n_2=27$ (45%)] every 4 hours;
- 3% [$n_1=1$ (3%); $n_2=2$ (3%)] every 6 hours.

With reference to Figure 4.23, it is evident that practice variations regarding the frequency for performing endotracheal tube suctioning exists amongst professional nurses in the critical care units of both the public and private sectors in the Nelson Mandela Metropole. However, the difference in the responses from the two health care sectors were not statistically significant ($\chi^2(d.f.=3) = 5.58, p = .133$).

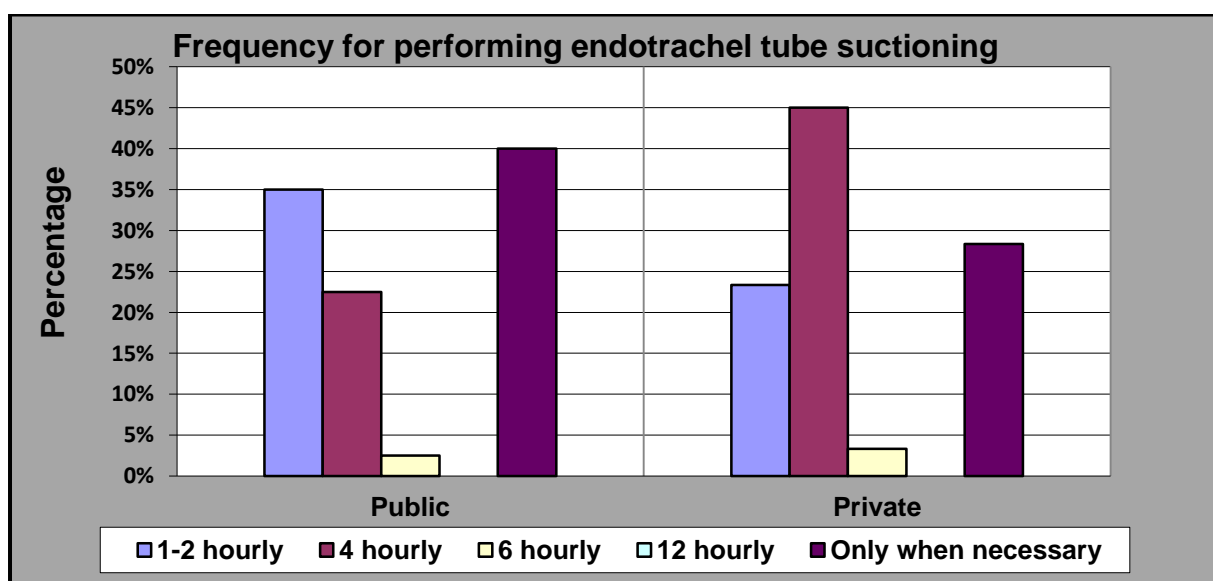


Figure 4.23 Frequency for performing endotracheal tube suctioning

4.7.1.2 Indications for endotracheal tube suctioning

From the data derived, as reflected in Figure 4.24, it is evident that the majority of participants: 83%, [$n_1=29$ (73%); $n_2=54$ (90%)] know the indications for performing endotracheal tube suctioning, which includes the patient coughing, visible or audible secretions, desaturation and increased airway pressure. The participants had to indicate all of the above in order to elicit a correct response. The remaining 17% [$n_1=11$ (27%); $n_2=6$ (10%)] indicated only one of the variables; therefore, the response was captured as incorrect. The results are presented graphically below. The difference between the responses from the professional nurses in the critical care units of the public and private sectors was not statistically significant ($\text{Chi}^2(\text{d.f.}=3) = 7.49, p = .057$).

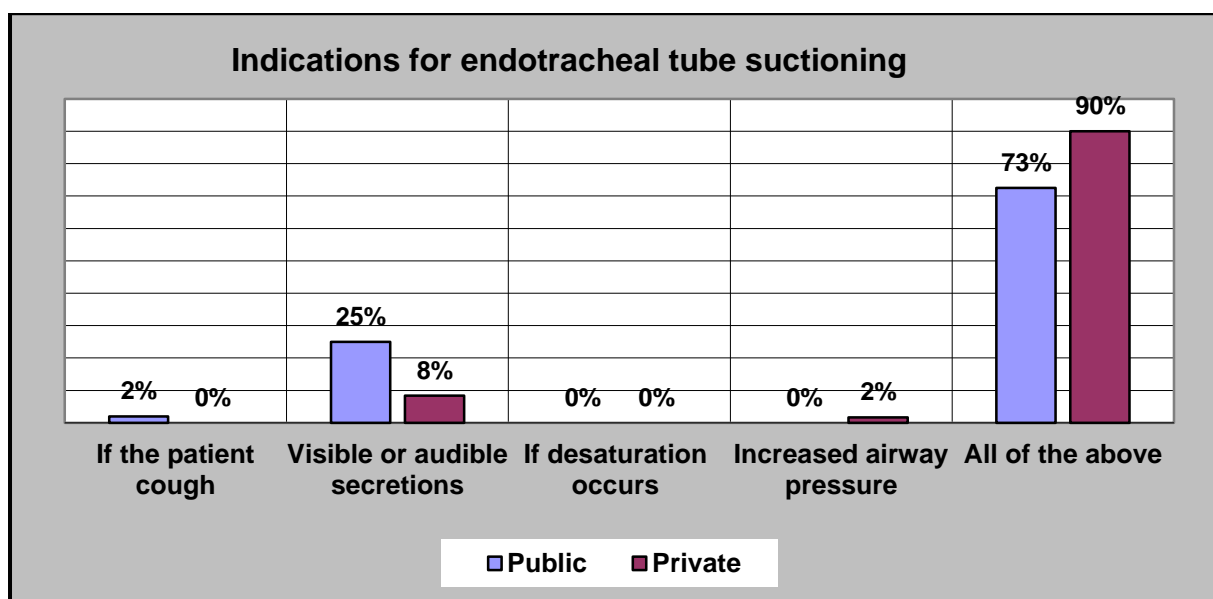


Figure 4.24 Indications for endotracheal tube suctioning

4.7.1.3 Suction catheter size

Of the 100 participants, 37% indicated the correct response in strongly agreeing [$n_1=19$ (48%); $n_2=18$ (30%)] or agreeing 42%; [$n_1=19$ (48%); $n_2=23$ (38%)] that they use a suction catheter with an external diameter that is less than half the size of the internal diameter of the endotracheal tube. The remaining participants indicated incorrect responses as reflected by answering by neither agreeing nor disagreeing: [11%; [$n_1=1$ (2%); $n_2=10$ (17%)] disagreeing [9%; [$n_1=1$ (2%); $n_2=8$ (13%)] and strongly disagreeing [1%; [$n_1=0$ (0%); $n_2=1$ (2%)]. The difference in the responses

between the professional nurses from the critical care units in the two health care sectors was statistically significant ($\chi^2(d.f.=4) = 10.64, p = .030, V = 0,33$). The difference was mainly due to incorrect responses as indicated by professional nurses in the critical care units in the private sector. It can thus be concluded that the nurses in the public health care sector are more inclined to use the incorrect suction catheter size when performing endotracheal tube suctioning. The results are graphically displayed in Figure 4.25.

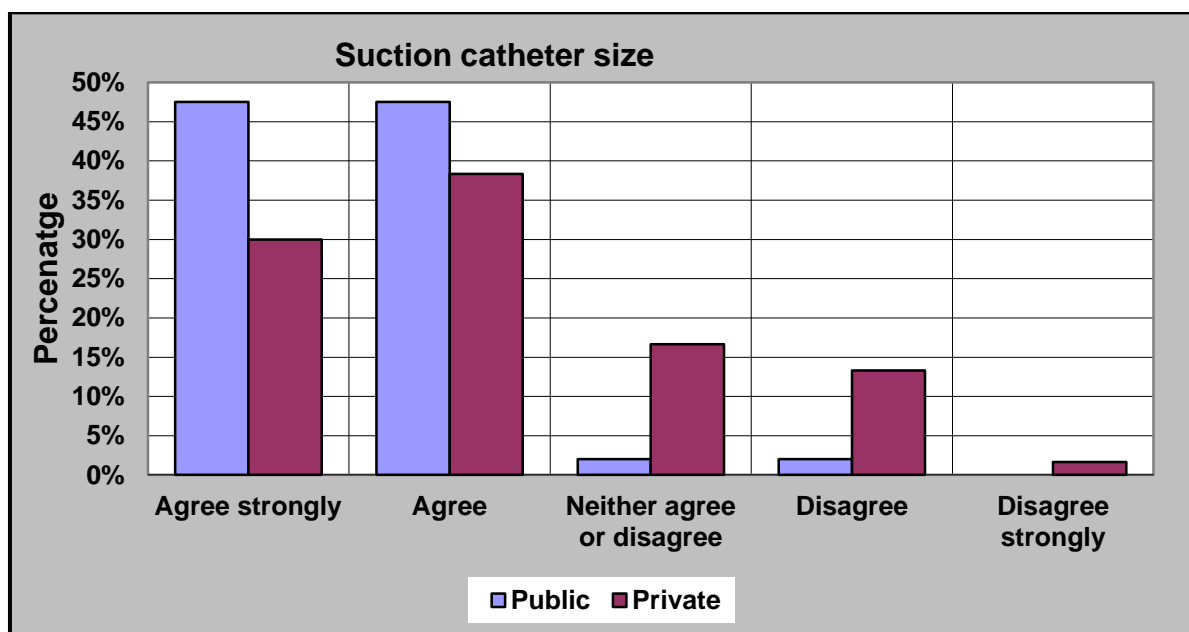


Figure 4.25 Suction catheter size

4.7.1.4 Performing a patient assessment prior to suctioning

The majority of participants in the critical care units of both health care sectors [75%; $n_1=28$ (70%); $n_2=46$ (78%)] indicated that they would perform a patient assessment prior to suctioning the mechanically ventilated patient which is recommended best practice. However, the remaining participants [25 %; $n_1=12$ (30%); $n_2=13$ (22%)] indicated that they would not. No statistically significant difference was noted between the responses from the professional nurses in the two health care sectors ($\chi^2(d.f.=3) = 5.58, p = .133$). The results are displayed in Figure 4.26.

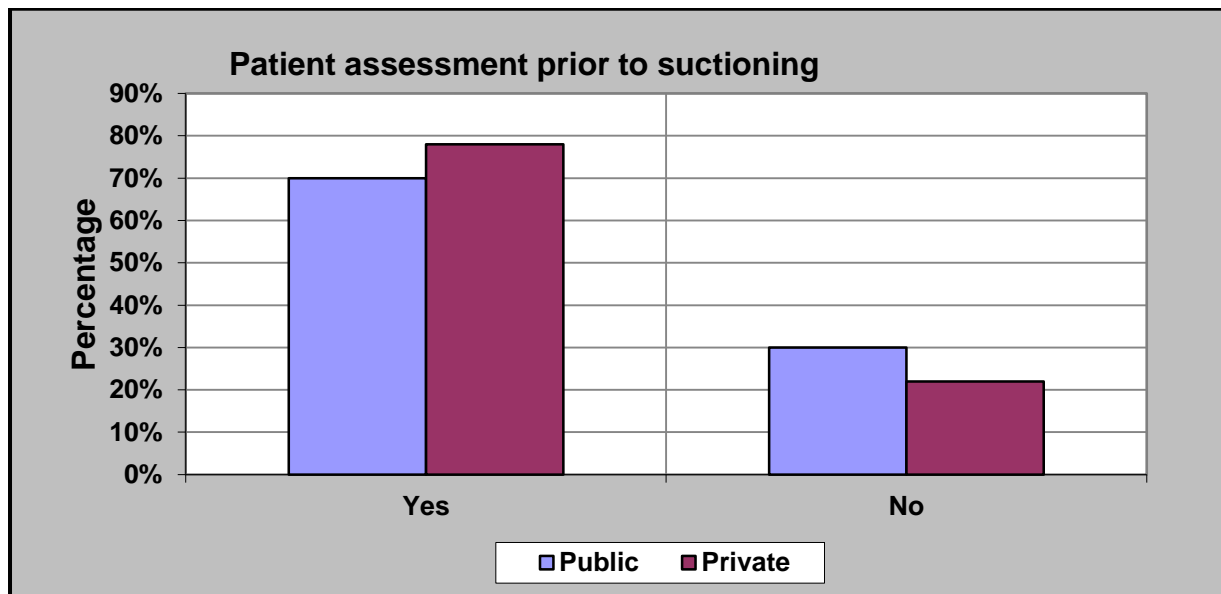


Figure 4.26 Performing a patient assessment prior to suctioning

4.7.1.5 Respiratory assessment findings

The majority of participants correctly indicated rhonchi [31%; $n_1=10$ (36%), $n_2=21$ (44%)] and crackles [37%; $n_1=14$ (50%), $n_2=23$ (48%)] as the appropriate patient assessment findings indicating that the patient requires endotracheal tube suctioning. The minority of participants indicated the following incorrect responses: wheezes [6%; $n_1=3$ (11%), $n_2=3$ (6%)], normal breath sounds [2%; $n_1=1$ (3%), $n_2=1$ (2%)]. The difference between the responses from the participants in the two groups was not statistically significant ($\text{Chi}^2(\text{d.f.}=3) = 0.89, p = .827$). The results are illustrated in Figure 4.27.

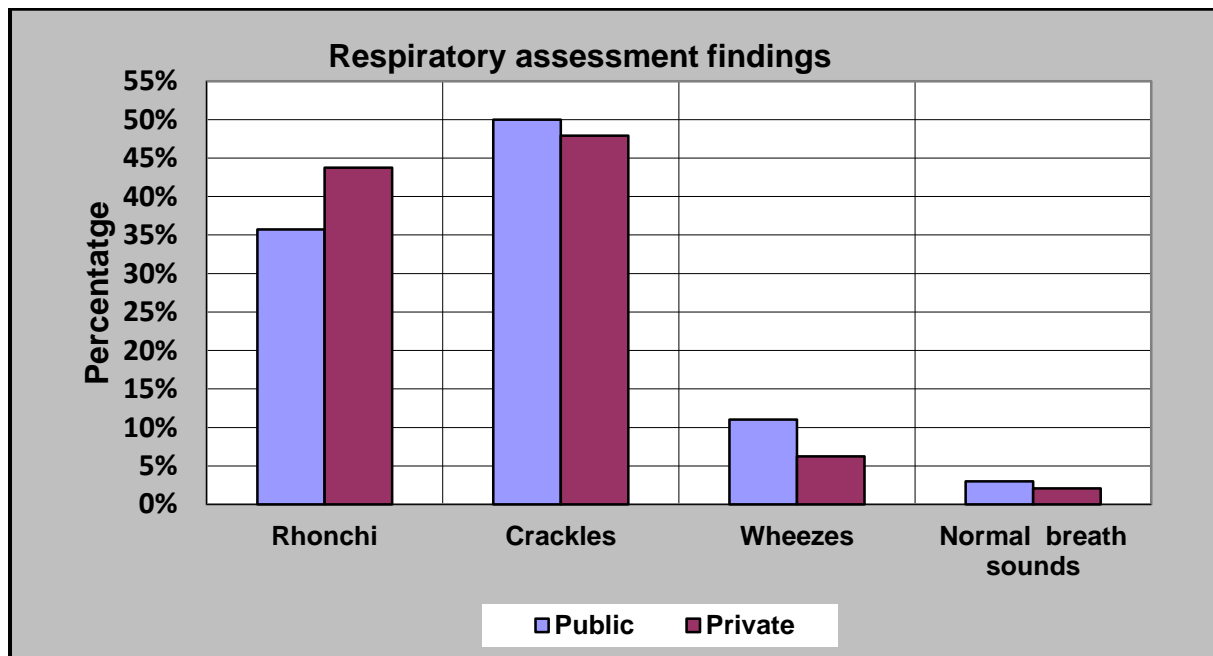


Figure 4.27 Respiratory assessment findings

4.7.1.6 Positioning of the patient when performing suctioning

In questioning the participants on how they would position the patient when performing suctioning, the majority [84%; $n_1=33$ (83%), $n_2=51$ (86%)] indicated the best recommended position, which is semi-fowlers positioning. The remaining participants indicated the following incorrect responses: supine position [14% [$n_1=7$ (17%); $n_2=7$ (12%)] and high-fowlers position [1% [$n_1=0$ (0%); $n_2=1$ (2%)]. No statistically significant difference was found in the responses from the professional nurses in the two health groups ($\text{Chi}^2(\text{d.f.}=1) = 0.29$, $p = .592$). The results are graphically displayed in Figure 4.28.

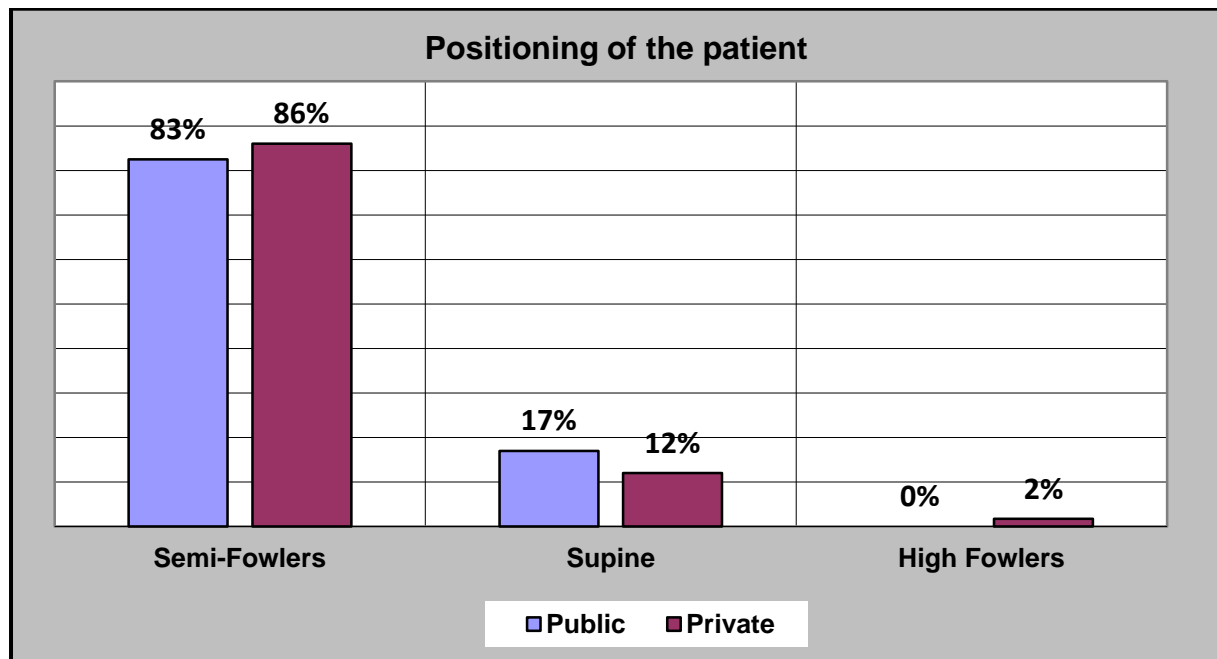


Figure 4.28 Positioning of the patient when performing suctioning

4.7.1.7 Suction pressures

With regard to the suction pressures used when performing suctioning, only 26% [$n_1=8$ (20%); $n_2=18$ (30%)] indicated the correct response, which is 80 to 120 mmHg. The following incorrect responses were noted: 150 to 180 mmHg [22%; $n_1=11$ (28%), $n_2=11$ (18%)], 200 mmHg [33%; $n_1=17$ (42%), $n_2=16$ (27%)], 250 mmHg [7%; $n_1=4$ (10%); $n_2=3$ (5%)], 300 mmHg (12%; $n_1=0$ (0%), $n_2=12$ (20%)). A significant difference was noted between the responses from the professional nurses in the critical care units of the two health groups ($\text{Chi}^2(\text{d.f.}=4) = 12.52, p = .014, V = 0.36$). Although a small percentage (30%) of nurses in the private sector were more inclined to maintain best recommended suction pressures when performing endotracheal tube suctioning, the majority maintained incorrect suction pressures. Professional nurses in the critical care units in the private sector were more inclined to use high suction pressures (>200 mmHg) than the professional nurses in the public sector (25% versus 10%). Practice variations amongst professional nurses in the critical care units of both health care sectors are noted. The results are displayed in Figure 4.29.

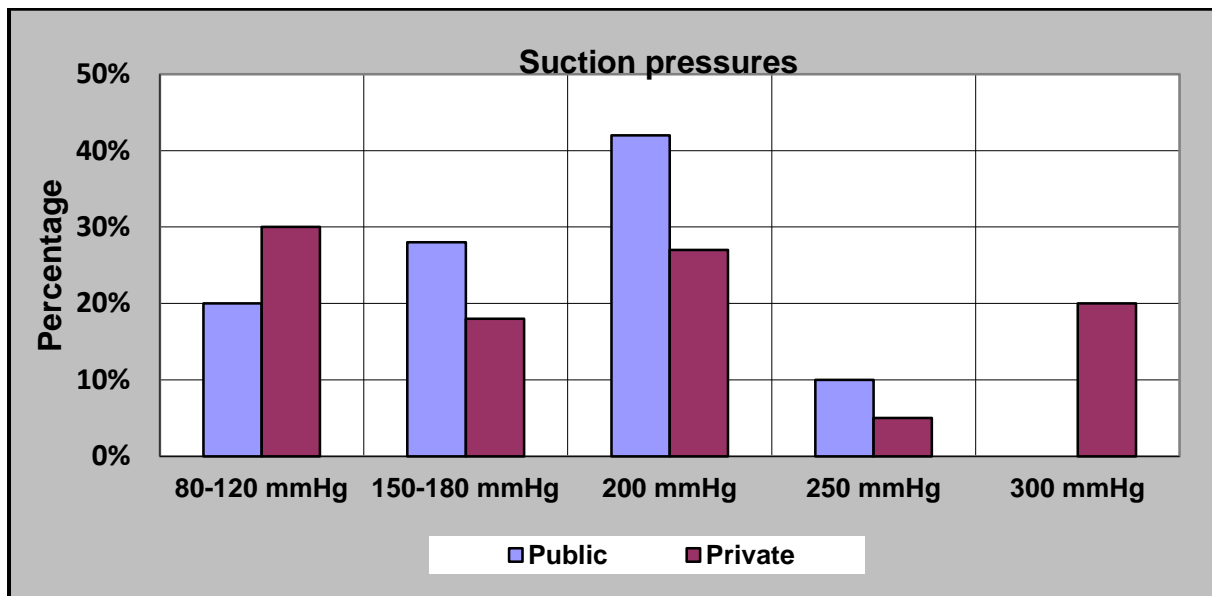


Figure 4.29 Suction pressures

4.7.1.8 Hyperoxygenation

The majority of participants [97%; $n_1=39$ (98%), $n_2=58$ (97%)] indicated that they would hyper-oxygenate the patient prior to endotracheal suctioning, which is best recommended practice. The remaining 3% [$n_1=1$ (2%), $n_2=2$ (3%)] indicated that would not. The difference in the responses from professional nurses in the critical care units of two health sectors, as reflected in Figure 4.30, was not statistically significant ($\chi^2(d.f.=1) = 0.57, p = .810$).

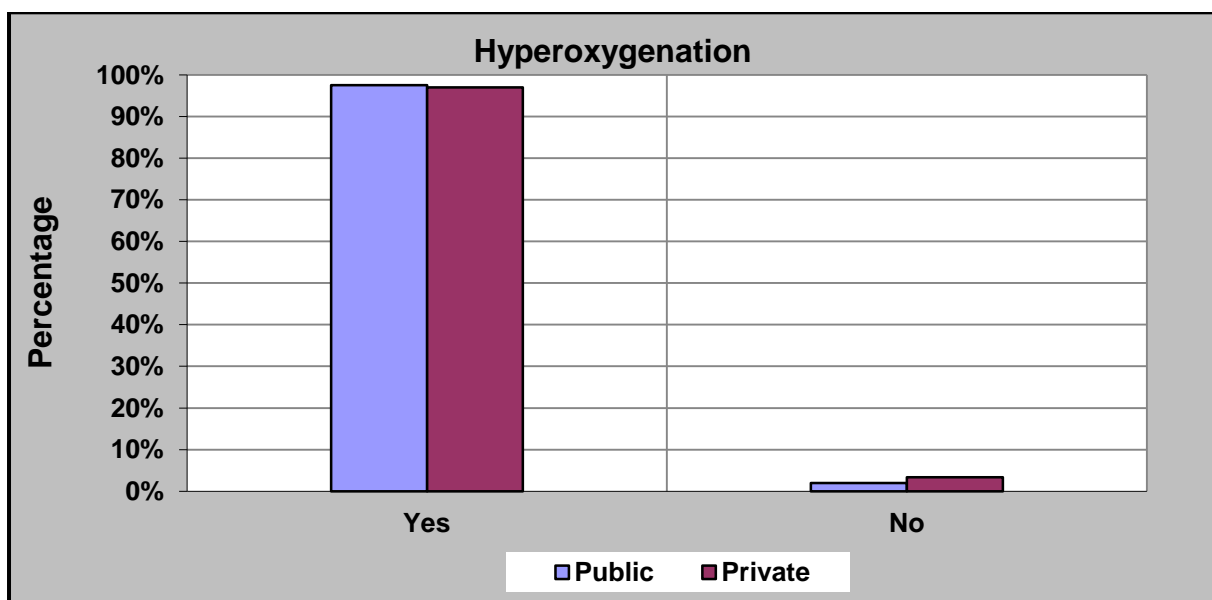


Figure 4.30 Hyperoxygenation

4.7.1.9 Percentage of oxygen to use for hyperoxygenation

Of the 100 participants, 96% [$n_1=36$ (90%), $n_2=58$ (97%)] indicated that they would use 100% oxygen for at least 30 seconds prior to suctioning, which is the correct response. The remaining 4% [$n_1=4$ (10%), $n_2=2$ (3%)] indicated an incorrect response stating that they would use 60% oxygen at least for 30 seconds prior to suctioning. None of the participants indicated the other two incorrect responses, namely to use 50% oxygen for at least 30 seconds prior to suctioning or to use 55% oxygen for at least 30 seconds prior to suctioning. The difference in responses from the professional nurses in the critical care units of the public and private sectors was not statistically significant ($\text{Chi}^2(\text{d.f.}=1)= 1.63, p = .202$). No graphic representation was deemed necessary for this question.

4.7.1.10 Indications for hyperoxygenation

Of the 100 participants, 99% [$n_1=40$ (100%), $n_2=59$ (98%)] correctly stated the indications for pre-oxygenating the patient prior to suctioning in agreeing or strongly agreeing to this question. The remaining respondent neither agreed nor disagreed. None of the participants disagreed or strongly disagreed. No statistical significance was noted in the difference in responses from professional nurses in the public and private sectors ($\text{Chi}^2(\text{d.f.}=1) = 0.59, p = .746$). Due to the high percentage of correct responses, no graphical presentation was deemed necessary for this question.

4.7.1.11 Hyperinflation

In response to the question as to whether hyperinflation is practised, which is the correct and best recommended practice prior to performing suctioning, it was found that only 11% [$n_1=6$ (15%), $n_2=5$ (8%)] of participants answered affirmatively. The remaining 89% [$n_1=34$ (85%), $n_2=55$ (92%)] indicated that they do not. The difference in the responses from professional nurses in the critical care unit in the public and private sector is not statistically significant ($\text{Chi}^2(\text{d.f.}=1) = 1.12, p = .290$). The results are graphically displayed in Figure 4.31.

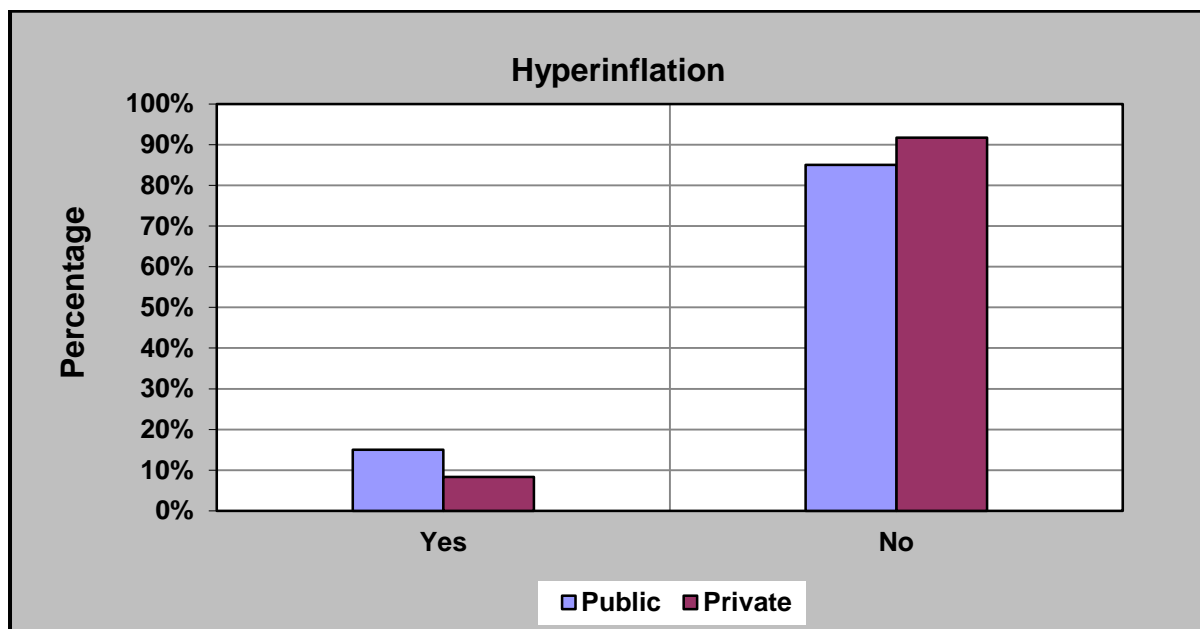


Figure 4.31 Hyperinflation

4.7.1.12 Methods for hyperinflation

Although 11 participants answered affirmatively to the question as to whether they practice hyperinflation, 23 participants answered the filter question regarding the methods used. Of these 10% [$n_1=0$ (0%), $n_2=10$ (59%)] indicated the correct response, namely that they would perform hyperinflation by means of a ventilator, while the remaining 13% [$n_1=6$ (100%), $n_2=7$ (41%)] indicated that they would use an ambubag, which is an incorrect response. The difference in responses from professional nurses in the critical care units of the two health care sectors was not statistically significant ($\text{Chi}^2(\text{d.f.}=1) = 3.16, p = .076$). The results are graphically reflected in Figure 4.32.

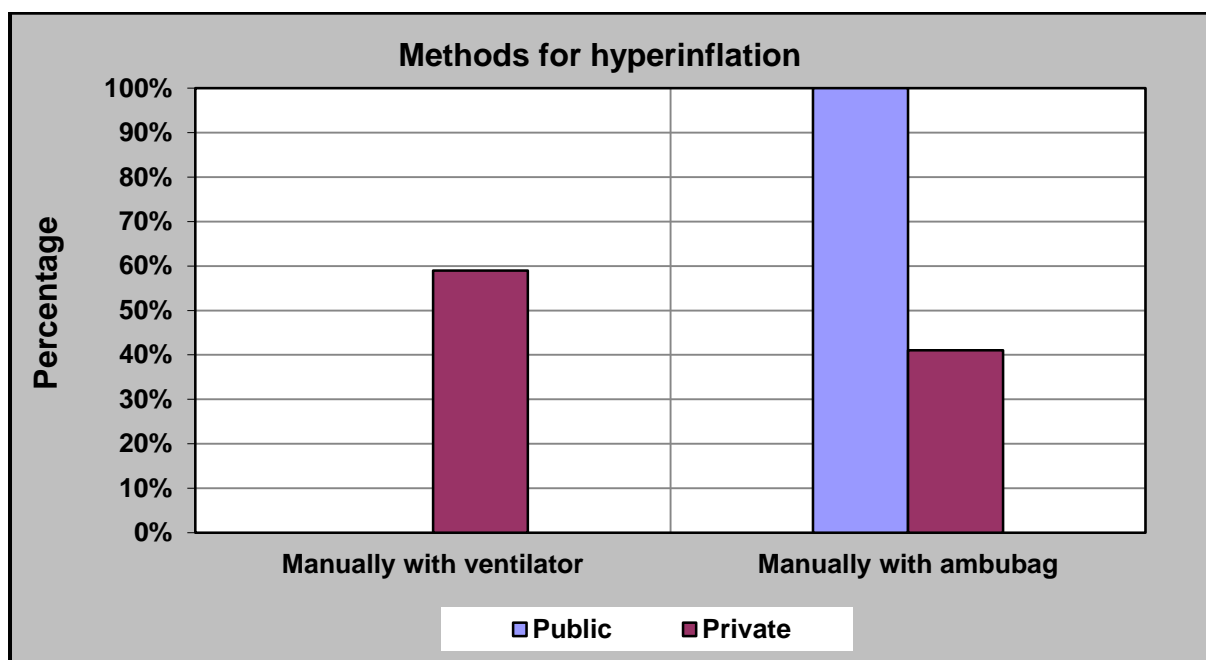


Figure 4.32 Methods for hyperinflation

4.7.1.13 Indications for normal saline instillation

From the responses, as reflected in Figure 4.33, it can be concluded that the majority of professional nurses in both sectors still depart from the premise that normal saline thins secretions. Of the 100 participants, only 9% indicated the correct response, which included the strongly disagree option [2% [$n_1=1$ (2%), $n_2=1$ (2%)] and the disagree option [7% [$n_1=2$ (5%), $n_2=5$ (8%)]. The remaining participants indicated the incorrect responses which include agreeing strongly [44% [$n_1=18$ (45%), $n_2=26$ (43%)] or agreeing [35% [$n_1=13$ (32%), $n_2=22$ (37%)] to the fact that normal saline instillation loosens the secretions prior to suctioning. Furthermore, 12% [$n_1=6$ (15%), $n_2=6$ (10%)] of participants neither agree nor disagree with the question. The difference in the responses from the professional nurses in the critical care units of the two health care sectors was not statistically significant ($\chi^2(d.f.=4) = 0.89, p = .926$).

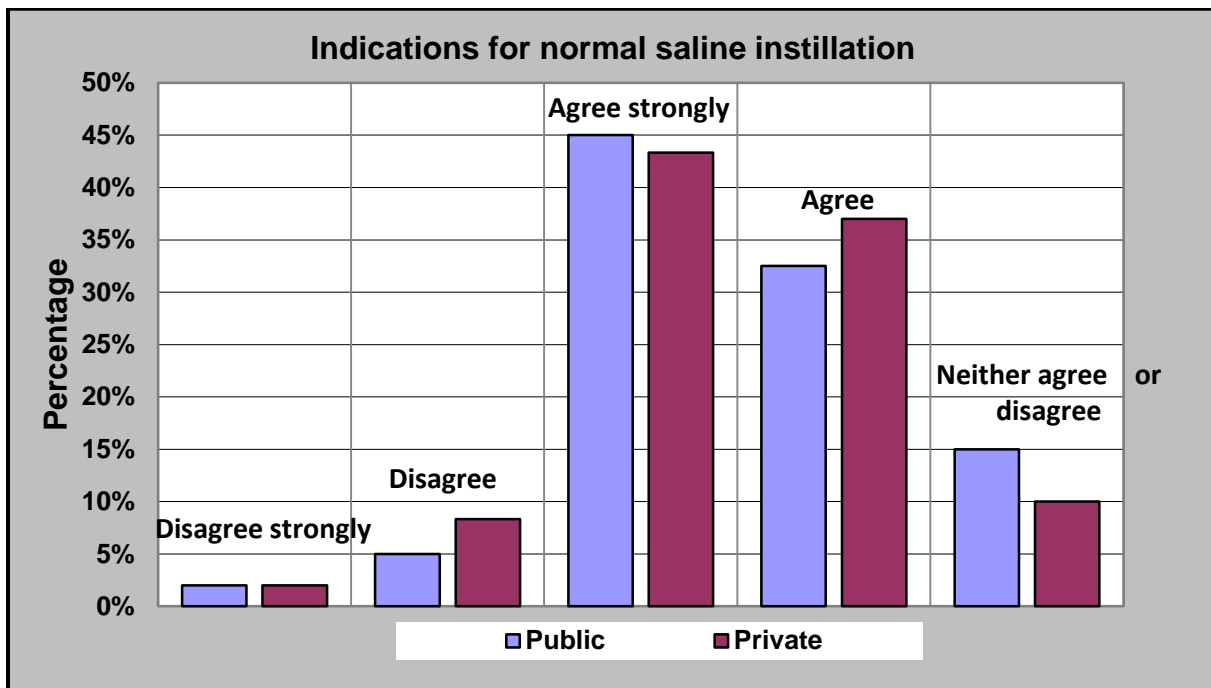


Figure 4.33 Indications for normal saline instillation

4.7.1.14 Normal saline instillation

Of the 100 participants, only 17% [$n_1=3$ (7%), $n_2=14$ (23%)] indicated the omission of normal saline (in answering no to the question) when performing endotracheal tube suctioning, which is the best recommended practice. The remaining 83% [$n_1=37$ (93%), $n_2=46$ (77%)] indicated the use of normal saline (in answering yes to the question), which is not best recommended practice. The difference between the responses from professional nurses in the public and the private sector was not statistically significant ($\chi^2(d.f.=2) = 1.09, p = .890$). The results are displayed graphically in Figure 4.34.

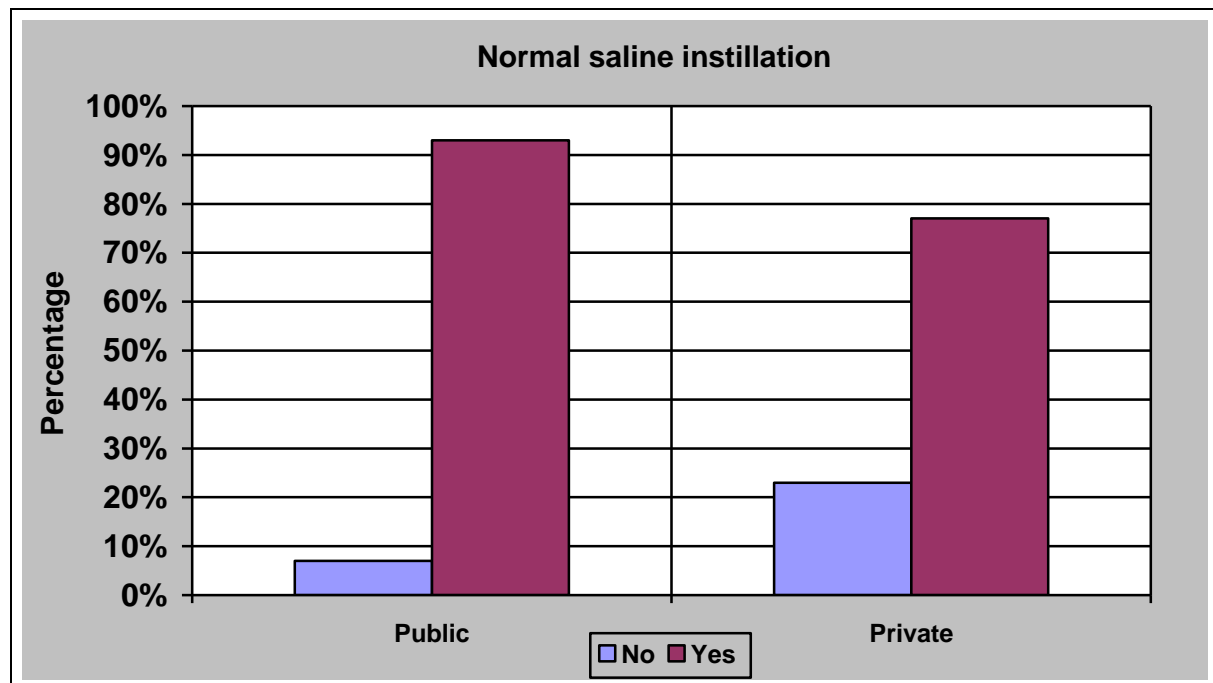


Figure 4.34 Normal saline instillation

4.7.1.15 Amount of normal saline instilled

This open-ended question aimed at exploring the amount of normal saline that professional nurses use when performing endotracheal tube suctioning. Instillation of normal saline is not a recommended best practice. Yet, the participants indicated a variety of answers, which were categorised and are depicted in Figure 4.35. Of the 83 participants who indicated in the preceding question, that they would use normal saline when performing endotracheal tube suctioning, 32% [$n_1=14$ (38%), $n_2=18$ (40%)] indicated the use of 1 to 2 ml of normal saline, while 9% [$n_1=3$ (8%), $n_2=6$ (13%)] the use of 3 to 4 ml normal saline, 31% [$n_1=15$ (42%), $n_2=16$ (35%)] indicated the use of 5 ml normal saline and the remaining 11% [$n_1=5$ (12%), $n_2=6$ (12%)] indicated the use of ten ml of normal saline. The difference in the responses from the professional nurses in the critical care units of the two health sectors was not statistically significant ($\text{Chi}^2(\text{d.f.}=2) = 3.14, p = .791$).

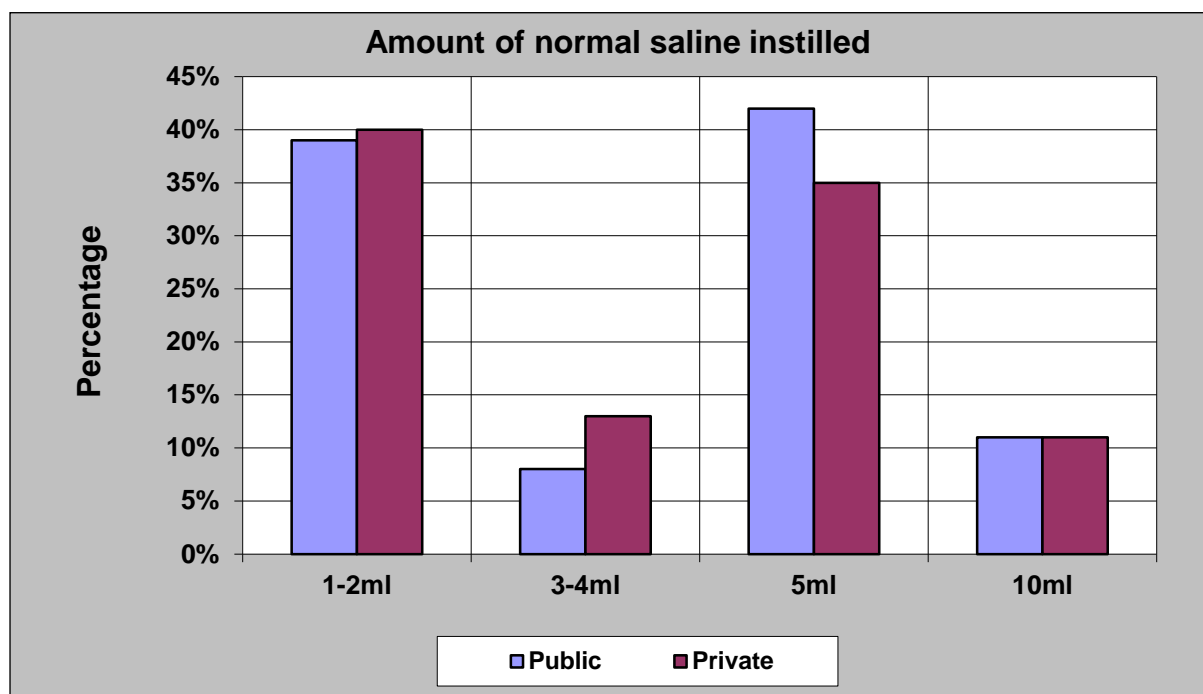


Figure 4.35 Amount of normal saline instilled

4.7.1.16 Adverse effects of normal saline instillation

Of the 100 participants in this study, only 33% [$n_1=12$ (30%), $n_2=21$ (35%)] indicated correctly that normal saline instillation has adverse effects, for instance bronchoconstriction, decreased saturation and excessive fluid volume in the mechanically ventilated patient. The response was correctly indicated by stating true to the question. The remaining 67% [$n_1=28$ (70%), $n_2=39$ (65%)] did not know the adverse effects. The difference in the responses between the participants from the professional nurses in the critical care units of the two health care sectors was not statistically significant ($\text{Chi}^2(\text{d.f.}=1) = 0.27$, $p = .602$). The results are graphically displayed in Figure 4.36.

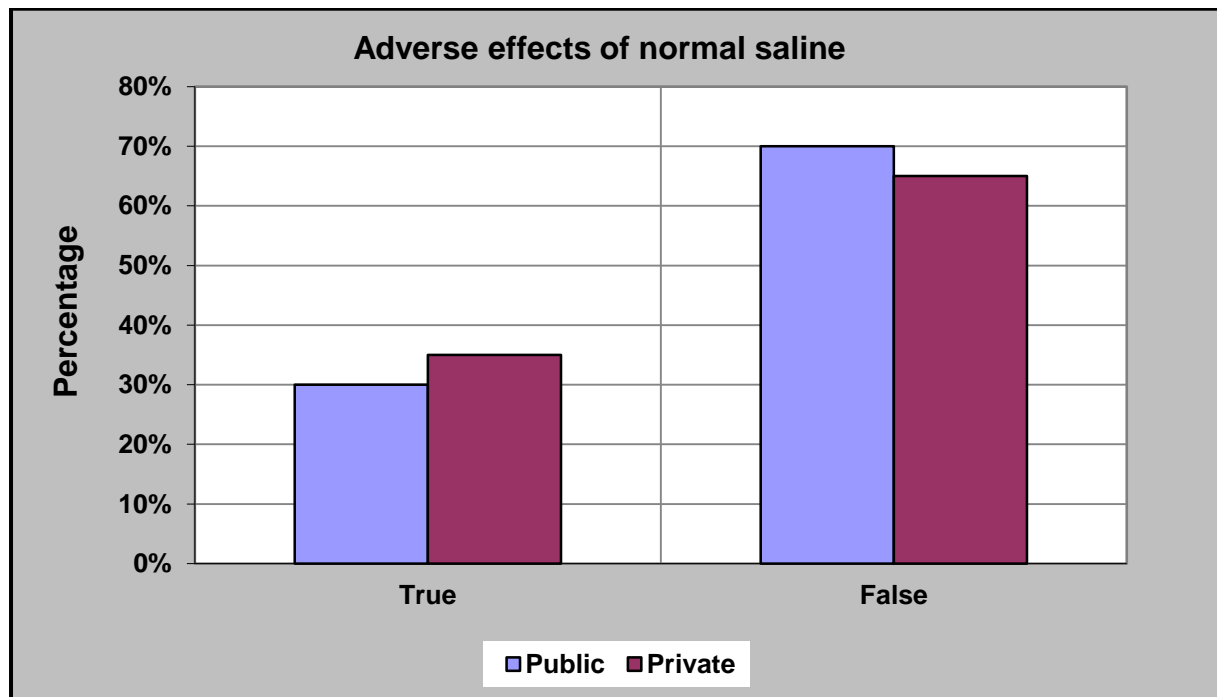


Figure 4.36 Adverse effects of normal saline instillation

4.7.1.17 Hand hygiene

In exploring hand-hygiene practices when performing endotracheal tube suctioning, 96% of participants [$n_1=39$ (98%), $n_2=57$ (95%)] indicated the best recommended practice, namely to wash or to spray hands before and after endotracheal tube suctioning. The remaining participants [4%; $n_1=1$ (2%), $n_2=3$ (5%)] indicated that they would perform hand hygiene prior to suctioning. None of the participants indicated the other incorrect responses, namely performing of hand hygiene after suctioning or not performing hand hygiene at all. The difference in responses from professional nurses in the critical care units of both health care sectors was not statistically significant ($\text{Chi}^2(\text{d.f.}=1) = 0.01, p = .923$). The results are graphically displayed in Figure 4.37.

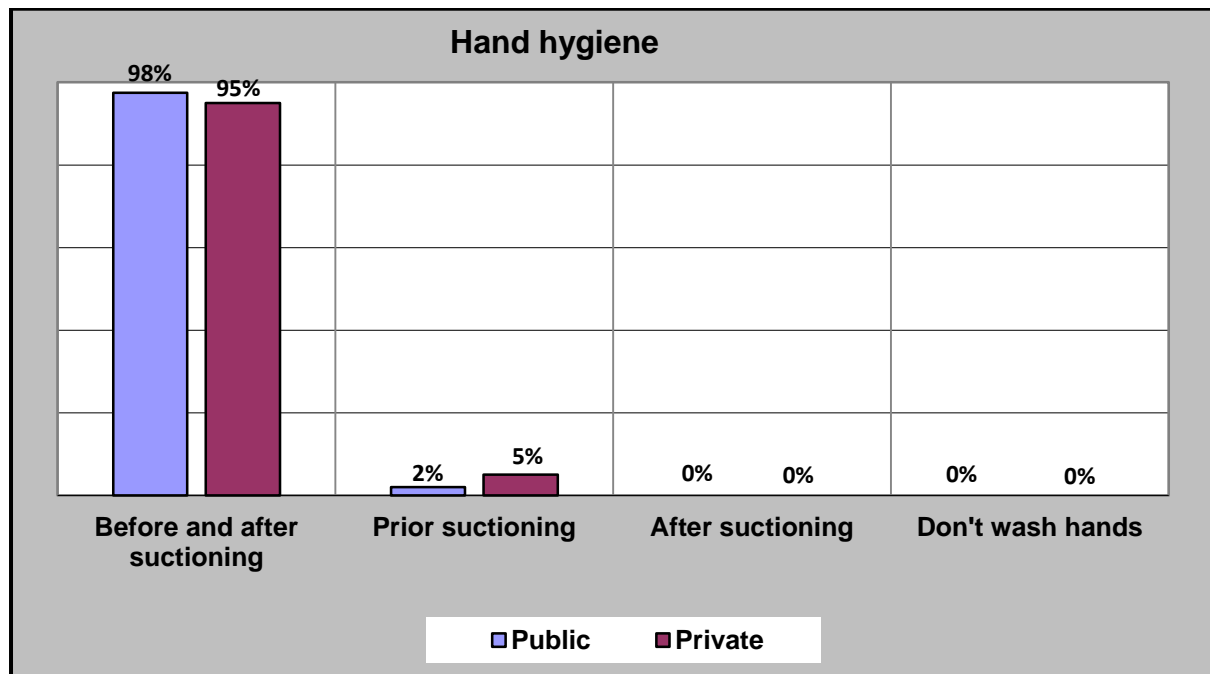


Figure 4.37 Hand hygiene

4.7.1.18 Duration of suction procedure

In response to this question, the majority of the professional nurses [77%; $n_1=28$ (70%), $n_2=49$ (82%)] indicated the correct response, namely that the duration of the suction procedure should be ten seconds. The remaining 23% participants indicated the following incorrect responses: 18 seconds [6%; $n_1=5$ (12%), $n_2=1$ (2%)]; 20 seconds [15%; $n_1=7$ (18%), $n_2=8$ (13%)] and 25 seconds [2%; $n_1=0$ (0%), $n_2=2$ (3%)]. No statistically significant difference was noted between the responses from professional nurses in the critical care units of the public and private sector ($\chi^2(d.f.=3) = 6.72, p = .081$). The results are reflected in Figure 4.38.

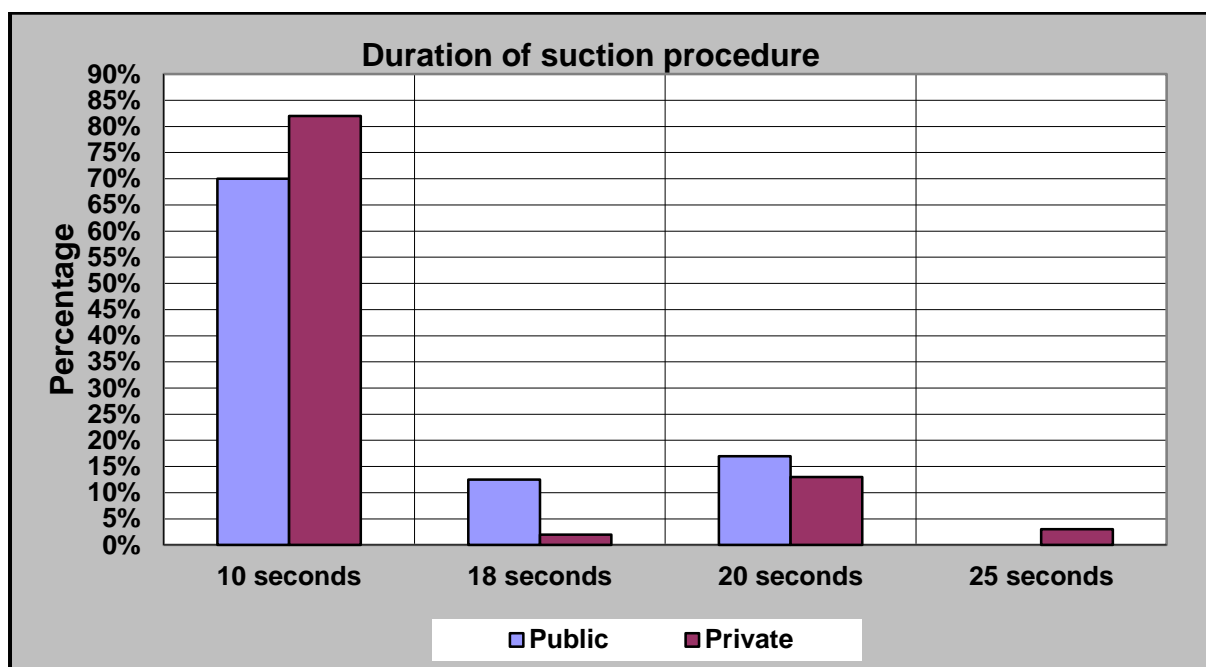


Figure 4.38 Duration of suction procedure

4.7.1.19 Depth of catheter insertion

In questioning the participants on how far they would insert the suction catheter when performing endotracheal suctioning, the majority of participants indicated the correct responses, which included any of the following: to the carina [24% [$n_1=12$ (30%), $n_2=12$ (20%)], until resistance is felt [24% [$n_1=14$ (35%), $n_2=10$ (17%)] and/or until the patient coughs [16% [$n_1=3$ (7%), $n_2=13$ (21%)]. The remaining 36% [$n_1=11$ (28%), $n_2=25$ (42%)] indicated the incorrect response, namely to insert the suction catheter pass the length of the endotracheal tube. The difference in responses from the professional nurses in the critical care units of the two health care sectors was statistically significant ($\text{Chi}^2(\text{d.f.}=3) = 8.71, p = .033, V = 0.30$). Derived from the results, it can be concluded that professional nurses in the critical care units in the public sector are more inclined to practice according to best recommended practices with regard to catheter depth insertion. A definite variance in practices is noted amongst professional nurses in both health sectors, which is indicative of nursing care practices that are not standardised in caring for the mechanically ventilated patient. The results are graphically displayed in Figure 4.39.

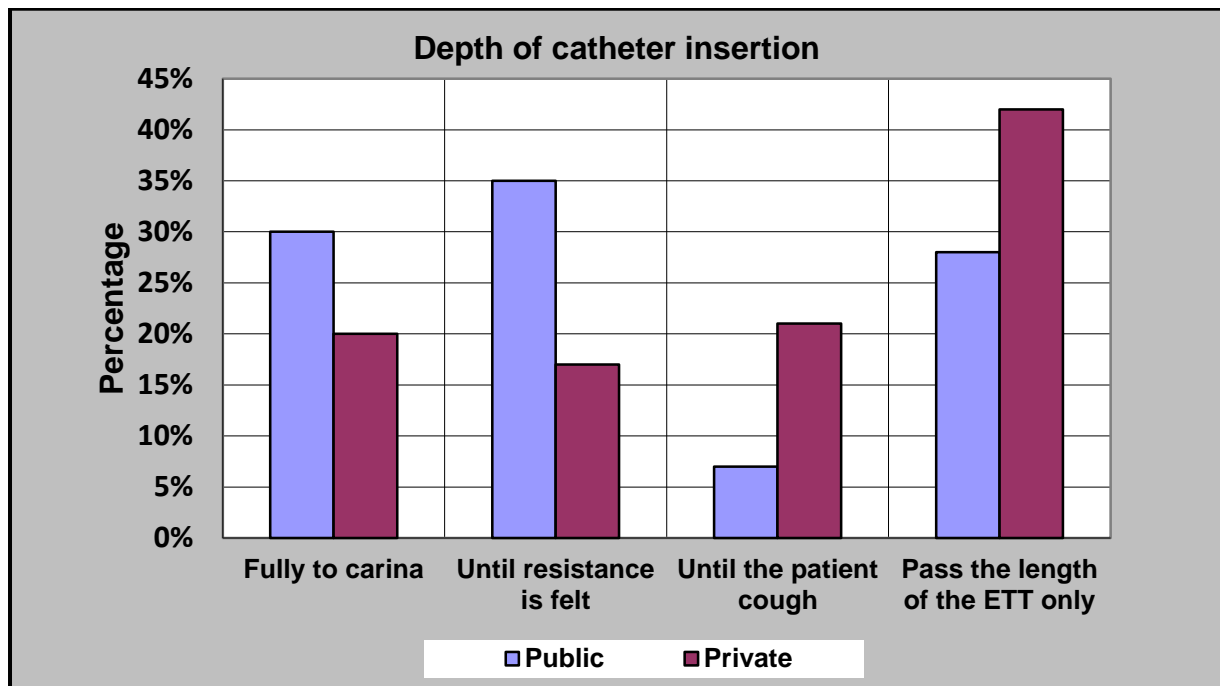


Figure 4.39 Depth of catheter insertion

4.7.1.20 Complications of endotracheal tube suctioning

The majority of participants [82%; $n_1=30$ (75%), $n_2=52$ (87%)] were aware of the complications associated with endotracheal tube suctioning. In order to elicit a correct response, the participants had to indicate the “all of the above” option, which included hypoxia, infection, bradycardia and tracheal bleeding. The remaining 18% [$n_1=10$ (25%), $n_2=8$ (13%)] indicated the incorrect responses as reflected in Figure 4.40. No statistically significant difference was noted between the responses from professional nurses in the critical care units in the public and private sectors ($\text{Chi}^2(\text{d.f.}=4) = 6.46, p = .167$).

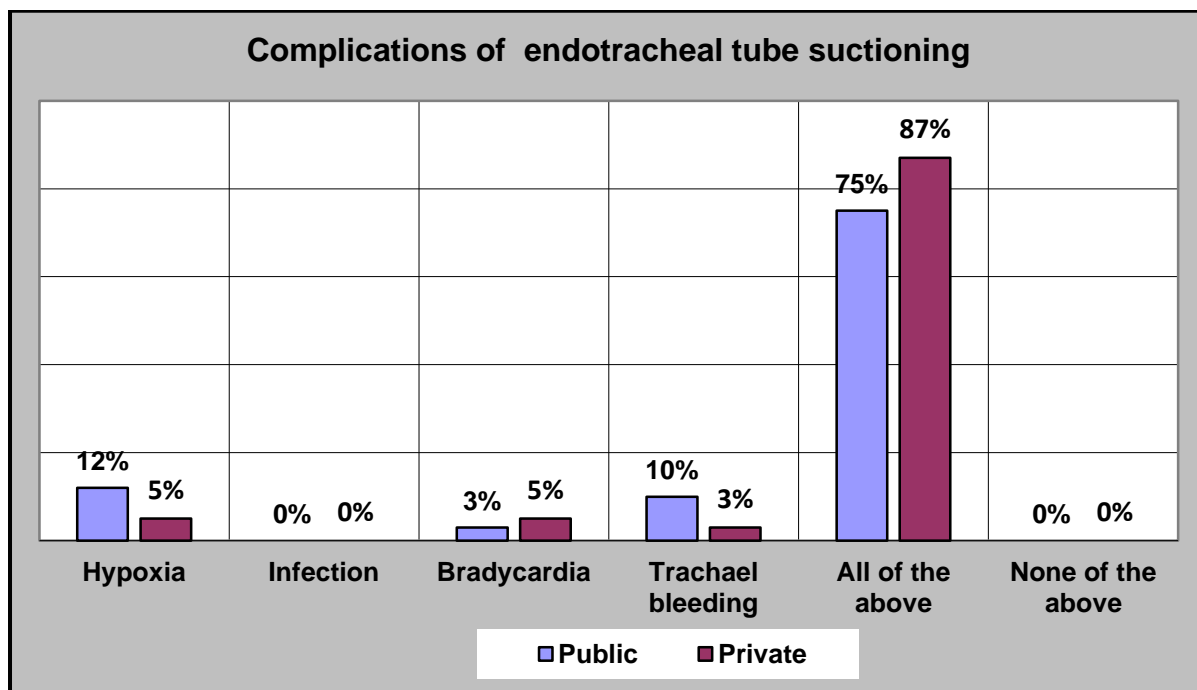


Figure 4.40 Complications of endotracheal tube suctioning

4.7.1.21 Performing a respiratory assessment post-suctioning

Of the 100 participants, 82% [$n_1=35$ (88%), $n_2=47$ (78%)] indicated that they would perform a respiratory assessment comprising of a lung auscultation post endotracheal tube suctioning, which is the best recommended practice. The remaining participants [18%; $n_1=5$ (12%), $n_2=13$ (22%)] indicated the incorrect response, namely that they would not perform a respiratory assessment after performing endotracheal tube suctioning. No statistical significant difference was noted in the responses from the professional nurses in the critical care unit of the public and private sectors respectively ($\text{Chi}^2(\text{d.f.}=2) = 1.37, p = .242$). The results are graphically displayed in Figure 4.41.

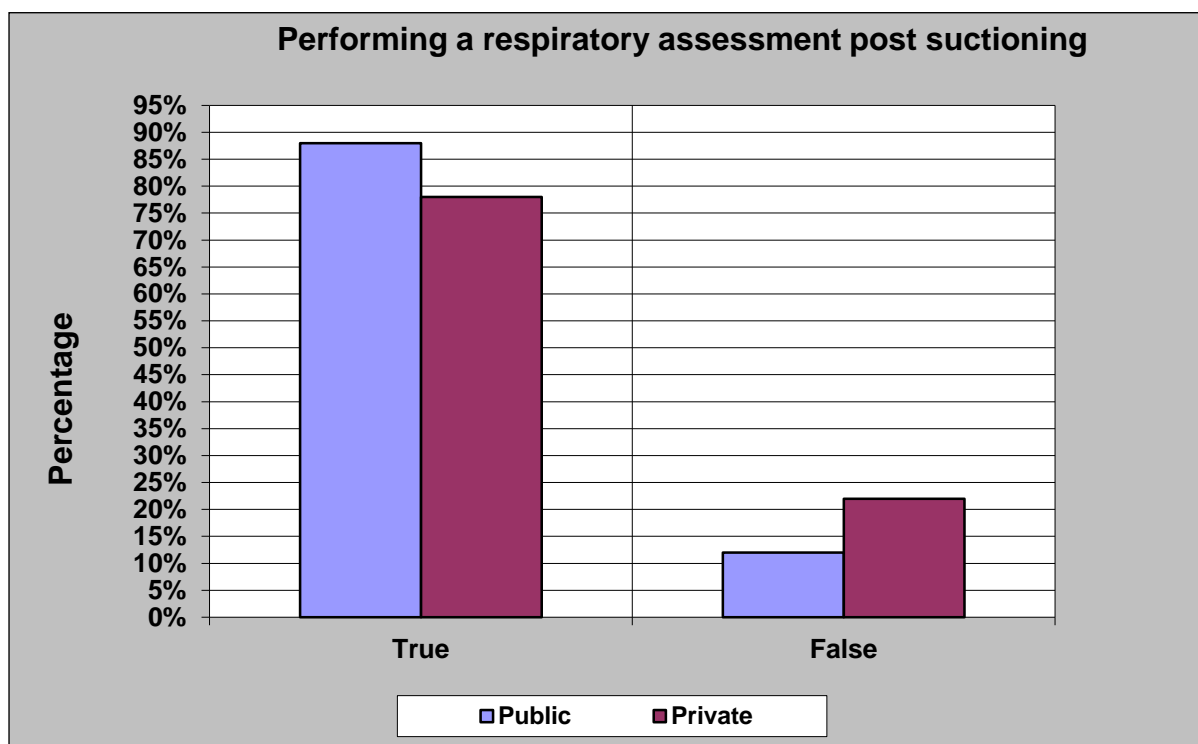


Figure 4.41 Performing a respiratory assessment post-suctioning

4.7.1.22 Findings indicating the effectiveness of endotracheal tube (ETT) suctioning

The findings revealed that 83% of participants [$n_1=28$ (70%), $n_2=55$ (92%)] stated the correct assessment findings, namely that all of the above options, which include increased oxygen saturation, decreased rhonchi on auscultation, decreased peak inspiratory pressure and decreased secretions, indicate the effectiveness of endotracheal tube suctioning performed. The remaining participants indicated the incorrect assessment findings, namely increased oxygen saturation [4%; $n_1=1$ (2%), $n_2=3$ (5%)] and decreased secretions [13%; $n_1=11$ (28%), $n_2=2$ (3%)]. None of the participants indicated decreased peak inspiratory pressure (PIP) or decreased rhonchi on auscultation as assessment findings on the effectiveness of endotracheal tube suctioning. The difference in responses from professional nurses in the critical care units of the public and private sectors respectively was not statistically significant ($\text{Chi}^2(\text{d.f.}=4) = 9.14, p = .058$). The results are reflected in Figure 4.42.

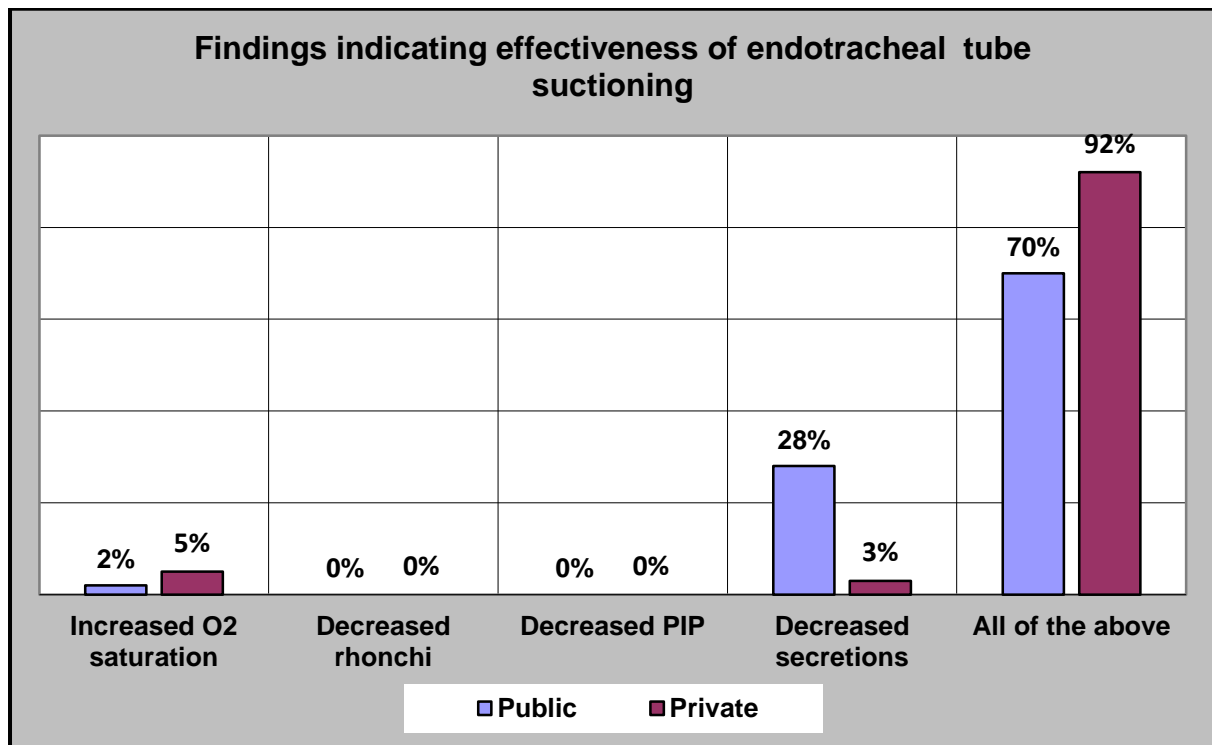


Figure 4.42 Findings indicating the effectiveness of ETT suctioning

4.7.1.23 Institutional guideline in place for endotracheal tube suctioning

Of the 100 participants in the study, 66% [$n_1=30$ (75%), $n_2=36$ (60%)] indicated the availability of a guideline on endotracheal tube suctioning in their respective critical care units. The remaining participants [34%; $n_1=10$ (25%) $n_2=24$ (40%)] indicated the absence of a guideline. No statistical significant differences were noted in the responses from the professional nurses in the critical care units of the two different health care sectors ($\text{Chi}^2(\text{d.f.}=1) = 2.41, p = .121$). The results are graphically displayed in Figure 4.43.

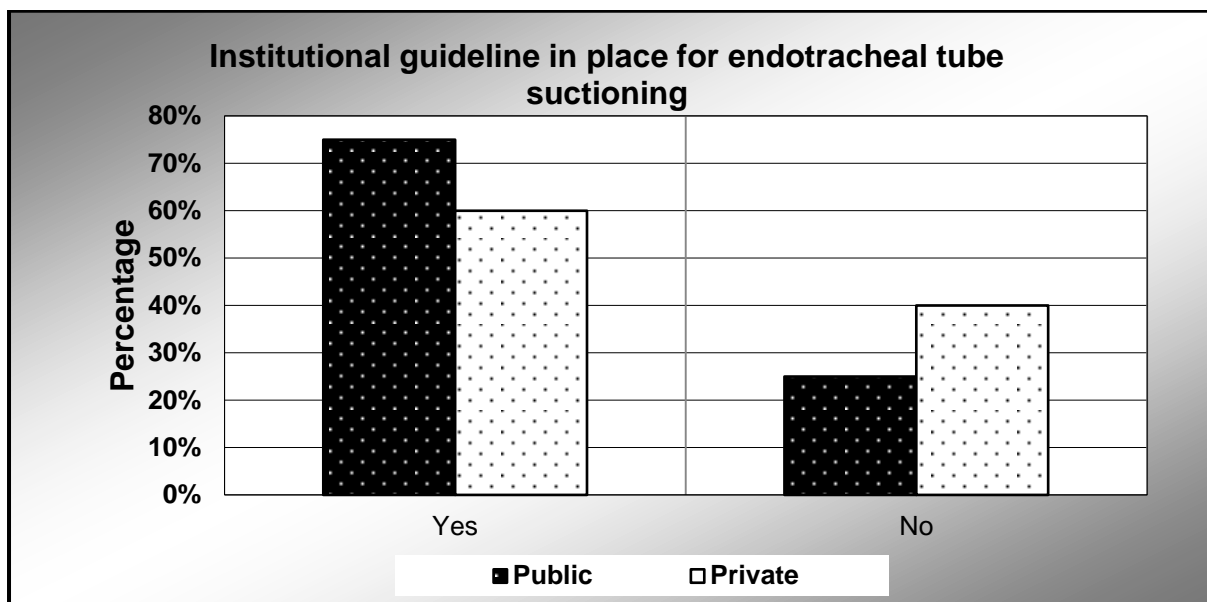


Figure 4.43 Institutional guideline in place for endotracheal tube suctioning

4.7.1.24 Who developed the guideline?

Approximately 30 of the participants completed the open-ended question by stating that the unit manager, shift leader or the company's head office developed the guideline on endotracheal tube suctioning. The remaining participants left the response blank thus not allowing statistical analysis of the question.

4.7.1.25 Decision-making choices

Although only ten participants in the critical care units of the public sector indicated that they did not have a guideline available, 19 participants answered the filter question. Of the 19 participants, 37% ($n_1=7$) indicated that they base their decision-making on own expertise, while 42% ($n_1=8$) indicated they practice according to what they have been taught in the unit, while only 21% ($n_1=4$) indicated the use of the most recent literature to guide their decision-making on patient care.

In the critical care units of the private sector, 24 participants indicated the absence of a guideline, yet 32 participants answered the filter question. Of the 32 participants, 19% ($n_2=6$) indicated the use of own expertise to guide their clinical decision-making, while 63% ($n_2=20$) indicated they do according to what they have been taught in the unit. The remaining 19% ($n_2=6$) indicated that they use the most recent literature when making decisions related to endotracheal tube suctioning in caring for the

mechanically ventilated patient. Due to the fact that this was a multi-response question, the Chi-square test could not be performed. The results are graphically displayed in Figure 4.44.

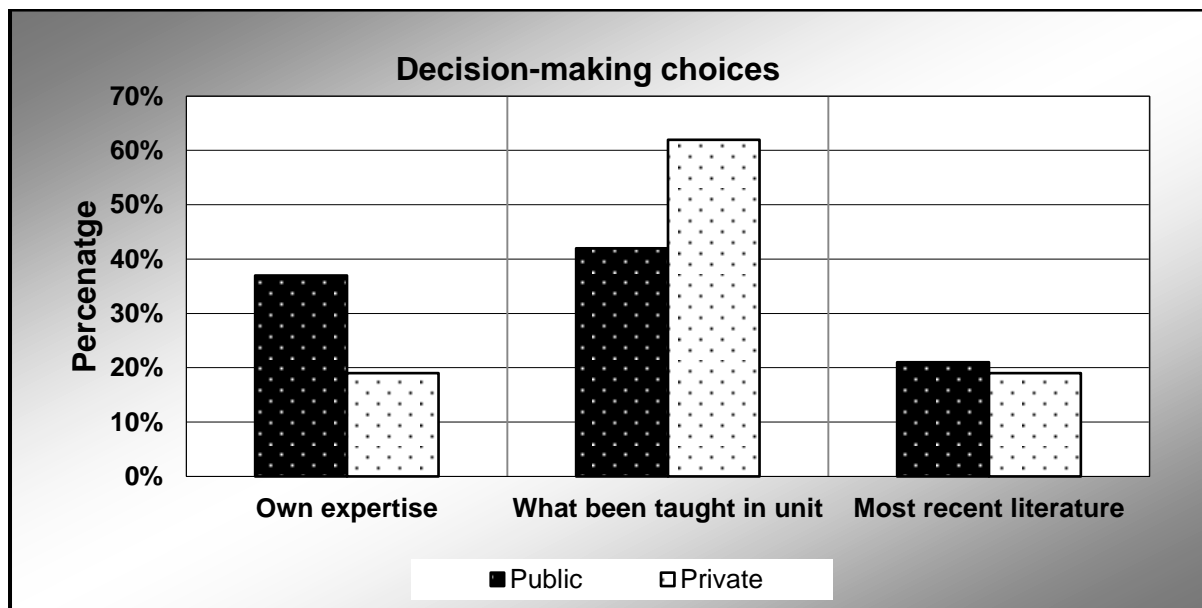


Figure 4.44 Decision-making choices

4.7.1.26 In-service education required on endotracheal tube suctioning

Despite the fact that professional nurses in both health care sectors indicated that they do have a clinical guideline in place, a large percentage [73%; $n_1=25$ (63%), $n_2=48$ (80%)] indicated that they would require in-service education on endotracheal tube suctioning. The remaining participants [37%; $n_1=15$ (37%) $n_2=12$ (20%)] indicated that they do not need in-service education on the topic. The difference between the responses from the professional nurses in the critical care units of the public and private sectors was not statistically significant ($\text{Chi}^2(1) = 2.41, p = .121$). No graphical presentation was deemed necessary for this question.

4.7.2 SUMMARY OF RESULTS FOR ENDOTRACHEAL TUBE SUCTIONING

The results for this section is summarised in the following two tables (Tables 4.12 & 4.13). Table 4.12 depicts the results for the nursing care practices on endotracheal tube suctioning.

Table 4.12 Summary of the results on endotracheal tube suctioning		
Question	Correct or best recommended practice response	Incorrect or not best recommended practice response
Indications for hyperoxygenation	99%	1%
Performing hyperoxygenation	97%	3%
Percentage of oxygen to use for hyperoxygenation	96%	4%
Hand hygiene	96%	4%
Positioning of the patient	84%	16%
Indications for ETT suctioning	83%	17%
Post-suctioning assessment findings	83%	17%
Post-suctioning assessment	82%	18%
Complications of ETT suctioning	82%	18%
Suction catheter size	79%	21%
Duration of suction procedure	77%	23%
Performing a patient assessment prior to suctioning	75%	25%
Assessment findings prior to suctioning	68%	32%
Depth of catheter insertion	64%	36%
Frequency for performing endotracheal tube suctioning	33%	67%
Adverse effects of normal saline instillation	33%	67%
Suction pressures	26%	74%
Normal saline instillation	17%	83%
Hyperinflation	11%	89%
Methods for hyperinflation (n=23)	10%	13%
Indications for normal saline instillation	9%	91%
Amount of normal saline instillation	0%	100%

The results for the summaries of the responses to the existing guideline, frequency for use and choices for decision-making are displayed in Table 4.13.

Table 4.13 Summary of the existing guideline and decision-making			
The availability of an existing guideline	<u>Yes</u> 66%		<u>No</u> 34%
Decision-making choices CCU in Public sector (n=19)	<u>Own expertise</u> 37%	<u>What have been taught in unit</u> 42%	<u>Most recent literature</u> 21%
Decision-making choices CCU in Private sector (n=32)	<u>Own expertise</u> 19%	<u>What have been taught in unit</u> 63%	<u>Most recent literature</u> 19%
In-service education required on endotracheal tube suctioning	<u>Yes</u> 73%		<u>No</u> 37%

4.7.3 DISCUSSION ON ENDOTRACHEAL TUBE SUCTIONING

The findings of this study revealed that practice variations occur amongst professional nurses. The majority (67%) of the professional nurses in the critical care units, as included in the study, in the Nelson Mandela Metropole did not perform endotracheal tube suctioning according to the best recommended practice frequencies. From the data derived, it was noted that professional nurses in the critical care units of the public sector were more inclined to suction the mechanically ventilated patient according to best recommended practice frequencies. According to Adam and Osborne (2005:103); Elliot *et al* (2007:280) and Morton and Fontaine (2009:578) endotracheal tube suctioning should be done once a physical assessment has been done indicating the need for suctioning as required. Endotracheal tube suctioning that is not clinically indicated may cause unnecessary anxiety and stress and provoke life-threatening suctioning related complications (Day *et al*, 2001:685).

Suctioning is indicated whenever a patient is unable to clear secretions independently. The patient should be suctioned if visible or audible secretions are present, when desaturation occurs, if the patient coughs or if the airway pressure is increased on the ventilator (Urden *et al*, 2006:668). Other indications for suctioning include preparation for extubation, assessment of airway patency, cough-reflex stimulation and sputum collection (Schell and Puntillo, 2001:140). With reference to the question exploring the indications for endotracheal tube suctioning, the participants had to include all the correct indications in order to elicit a correct response. The study findings revealed that the majority (83%) of the professional nurses in the critical care units in the Nelson Mandela Metropole stated the indications for suctioning the mechanically ventilated patient correctly.

Selection of an appropriately sized suction catheter for a given tube inner lumen is important to avoid complications, such as bleeding and atelectasis, during the suctioning procedure. The external diameter of the suction catheter should be less than half the internal diameter of the endotracheal tube. Choosing the incorrect size catheters might be detrimental to the critically ill patients and could jeopardize their safety (Odell, Alder, Bayne, Everett, Scott and Still, 1993:274-278; McKelvie, 1998:244-248; Day *et al*, 2001:682; Urden *et al*, 2006:667). The study findings revealed that 21% of the professional nurses did not choose the correct suction catheter size and might, therefore, compromise the safety of the mechanically ventilated patient. Derived from the data, it was evident that professional nurses in the critical care units of the public sector were more inclined to choose the best recommended suction catheter size when suctioning the mechanically ventilated patient. Day *et al* (2001:697) indicated similar findings when only 7 out of the 28 participants in their study indicated the correct catheter size selection.

Best practice recommendations suggest that when performing a respiratory assessment, nurse should auscultate the chest to verify the need for endotracheal tube suctioning (Griggs, 1998:50; Pierce, 2007:159). Auscultation findings, such as crackles and rhonchi, are indicative of the need to implement suctioning in the mechanically ventilated patient. The study findings show that approximately 25% of the professional nurses in the critical care units in the Nelson Mandela Metropole did

not practice this. However, the majority participants (75%) indicated the correct response. Day *et al* (2001:686) reported similar findings in a study of acute and high dependency unit nurses. Their findings showed that only two nurses were observed to have performed chest auscultation prior to performing endotracheal tube suctioning.

According to Pierce (2007:160) who suggest that the patient should be positioned in a semi-fowlers position unless otherwise contra-indicated, as this position is beneficial in performing endotracheal suctioning as it promotes gas exchange. The supine position should be avoided as it increases the risk for aspiration and the development of ventilator-associated pneumonia in the critically ill patient. Although a small percentage (16%) indicated that they would place the patient in a supine or high-fowlers position in performing suctioning, this needs to be addressed in order to ensure consistent, standardised practice amongst the professional nurses in the critical care units in the Nelson Mandela Metropole.

The lowest possible suction pressure, namely 80 to 120 mmHg, is recommended to reduce the risk of atelectasis, hypoxia and damage to the tracheal mucosa (Pierce, 2007:163; Oh and Seo, 2003:915). The study findings showed that the current practices with regard to endotracheal suction pressures as performed by professional nurses in the critical care units in the Nelson Mandela Metropole are proven to be unsafe and are not based on the best recommended practices. The majority of participants (74%) indicated the incorrect suction pressures. Kelleher and Andrews (2008:366) reported similar findings in their study where the majority of the participants in their study failed to use the recommended suction pressure of 80-120mmHg.

Hyperoxygenation by delivery of 100% oxygen for at least 30 seconds prior to and after the suctioning procedure is recommended. Hyperoxygenation is recommended to prevent or minimize decrease in oxygen saturation and effects of hypoxia (Pierce, 2007:164). As the majority of participants (96%) indicated the best recommended practice, it will not be further addressed.

Hyperinflation should be used after an individual patient's assessment has been done as it can be detrimental for some patient populations. The procedure is assumed to improve the patient's oxygenation capacity by recruiting pulmonary volume and loosening secretions. Hyperinflation should be performed manually by means of a ventilator (Day, 2000:14; Pierce, 2007:165). The study findings revealed that the majority (89%) of professional nurses in the critical care units in the Nelson Mandela Metropole do not practice hyperinflation. However, the ones who do practice it did not use the best recommended practice method, namely the by means of a ventilator and might thus compromise the safety of the mechanically ventilated patient.

Several authors indicated that normal saline does not thin or loosen secretions and may have significant adverse effects on the patient (Schwenker, Ferrin and Gift, 1998:258; Mims *et al*, 2004:39; Morton and Fontaine, 2009:578). According to the data derived from the participants, it is evident that the majority of professional nurses (91%) in the critical care units in the Nelson Mandela Metropole could not state the correct indications for using normal saline when performing endotracheal tube suctioning.

The findings of this study are congruent with other studies. Sole, Byers, Judy and Ostrow (2002:365) reported in a descriptive study that most institutions include the instillation of normal saline as a treatment for thick secretions in their institutional policies. Blackwood (1999:930) reported similar findings when it was reported that 67% of health care practitioners, including respiratory technicians, instil normal saline prior to and during endotracheal suctioning. However, as indicated by Sole *et al* (2002:365) the instillation of normal saline prior to suctioning is not best recommended practice. The current practices related to normal saline instillation as performed by professional nurses in the critical care units of the Nelson Mandela Metropole proved not to be based on the best recommended practice. The study findings revealed that professional nurses instil up to 10ml of normal saline prior to and during performing endotracheal tube suctioning. The study findings are similar with findings reported by Day *et al* (2001:685), where 27 out of 28 participants believed that it was acceptable to instil 5 ml or more normal saline prior to suctioning.

Hand hygiene is an important aspect when performing endotracheal tube suctioning. Health care practitioners should, at all times, minimise the risk of infection in the already compromised patient (Odell *et al*, 1993:274; Dean, 1997:93; Parker, 1999:720). No other questions were explored on infection-control practices related to suctioning; therefore, no other conclusion could be made regarding infection-control principles related to suctioning practices amongst professional nurses in the critical care units in the Nelson Mandela Metropole.

According to Urden *et al* (2006:668), suctioning should be performed for a maximum duration of ten seconds. Longer durations are associated with an increased risk of mucosal damage and hypoxemia. A small percentage of participants (23%) indicated that the duration should not be more than ten seconds. The study finding is similar to the study conducted by Day *et al* (2001:682), where it was found that only 10 out of 28 participants in their study were aware of the recommended duration of suctioning.

It has been recommended that the suction catheter be advanced fully until it reaches the carina, felt by resistance and/or the patient coughing. Advancing the suction catheter further than the recommended depth may cause a greater negative pressure applied to the lungs. Bradycardia might result due to the occlusion of more than half the lumen of the bronchial branch (Dean, 1997:94; Day *et al*, 2001:683). The study findings showed that 36% of professional nurses in the critical care units in the public and private sectors of the Nelson Mandela Metropole do not insert the suction catheter to the recommended depth. The professional nurses in the critical care units of the public sector were more inclined to base their practices on the best recommendation.

As stated in the literature (Urden *et al*, 2006:668; Pierce, 2007:165), there are numerous complications associated with performing endotracheal tube suctioning. The professional nurse has to be knowledgeable regarding these complications in order to ensure patient safety when performing endotracheal tube suctioning. The study findings revealed that 82% of the participants indicated the complications related to endotracheal tube suctioning correctly. The majority of the participants

(82%) indicated that they would perform a respiratory assessment, including a chest auscultation on completion of the suctioning procedure.

Clinical guidelines are systematically developed statements to assist practitioner decisions about appropriate health care for specific clinical circumstances. Clinical guidelines help to reduce variations in practice (Craig and Smyth, 2007:238). Although the 66% participants in this study indicated the availability of a guideline on endotracheal tube suctioning, a wide variety in the responses amongst professional nurses still exists in the critical care units in the Nelson Mandela Metropole. It is concerning that when the guideline was requested from the unit managers, none was available. However, procedural unit policies on endotracheal tube suctioning were available, suggesting that professional nurses might not have a clear understanding of the difference between a clinical guideline, procedural guideline and/or unit policies. Further exploration is required in order to explain the rationale for this discussion.

Health professionals are expected to work as part of a multi-disciplinary team in order to provide appropriate care to their patients. This requires the ability to examine evidence related to a proposed course of treatment and the ability to apply that evidence in their practice. Own expertise and tradition, when making clinical decisions, are thus regarded as approaches that are inappropriate in an age of rapidly changing knowledge (Pearson *et al*, 2007:3). The study findings showed that the majority of the professional nurses in the critical care units in the Nelson Mandela Metropole still base their decisions regarding endotracheal tube suctioning on their own expertise and tradition, which are regarded as inappropriate and that might compromise the quality of care and the safety of the mechanically ventilated patient.

4.8 MECHANICAL VENTILATOR SETTINGS

The data derived from this section of the questionnaire aimed at exploring the nursing care practices related to the mechanical ventilator settings and alarm monitoring practices that have been proven to be the best recommended for critically ill patients to reduce complications related to ventilator-induced lung injury. A summary of the items for discussion in this section is displayed in Table 4.14.

Table 4.14 Items for discussion on mechanical ventilator settings

4.8.1	RESULTS
4.8.1.1	Ventilator modes
4.8.1.2	Complications of Volume Controlled-Continuous Mandatory Ventilation VC-CMV
4.8.1.3	Pressure support ventilation
4.8.1.4	Recommended tidal volumes
4.8.1.5	Peak airway pressure
4.8.1.6	Complications of high tidal volumes and high airway pressures
4.8.1.7	Positive-end expiratory levels(PEEP)
4.8.1.8	Complications of PEEP
4.8.1.9	Oxygen administration
4.8.1.10	Oxygen toxicity
4.8.1.11	Hypo-ventilation
4.8.1.12	Hyper-ventilation
4.8.1.13	Flow rate
4.8.1.14	Frequency of monitoring ventilator alarms
4.8.1.15	Peak pressure ventilator alarms limits
4.8.1.16	Respiratory rate alarm limits
4.8.1.17	Minute ventilation alarm limits
4.8.1.18	Institutional guideline in place for mechanical ventilator settings
4.8.1.19	Who developed the guideline?
4.8.1.20	Decision-making choices
4.8.2	SUMMARY OF RESULTS FOR MECHANICAL VENTILATOR SETTINGS
4.8.3	DISCUSSION ON MECHANICAL VENTILATOR SETTINGS

4.8.1 RESULTS

The section comprised of 20 questions, of which 17 aimed at exploring mechanical ventilator settings. The remaining three questions explored the existing guidelines, if any in place, and the decision-making choices of professional nurses guiding their nursing-care practices.

4.8.1.1 Ventilator modes

In answering this question, the participants had to indicate what ventilator modes would be the safest to use in order to reduce the incidence of ventilator-induced lung injury in the mechanically ventilated patient. Only 10% [$n_1=2$ (5%), $n_2=8$ (13%)] of participants indicated the correct response, namely the use of airway pressure release ventilation (APRV). The following incorrect responses were indicated: volume-assured pressure support ventilation (VAPSV) [3%; $n_1=2$ (5%), $n_2=1$ (2%)] and pressure support ventilation (PSV) [9%; $n_1=4$ (10%), $n_2=5$ (8%)]. The majority of participants [78%; $n_1=32$ (80%), $n_2=46$ (77%)] indicated that they would use synchronized intermittent mandatory ventilation (SIMV) as the safest mode to minimise ventilator-induced lung injury. However, this is not the correct response. No statistically significant difference was noted between the responses from professional nurses in the critical care units of the public and private health sectors ($\chi^2(d.f.=3) = 2.66, p = .446$). The results are reflected in Figure 4.45.

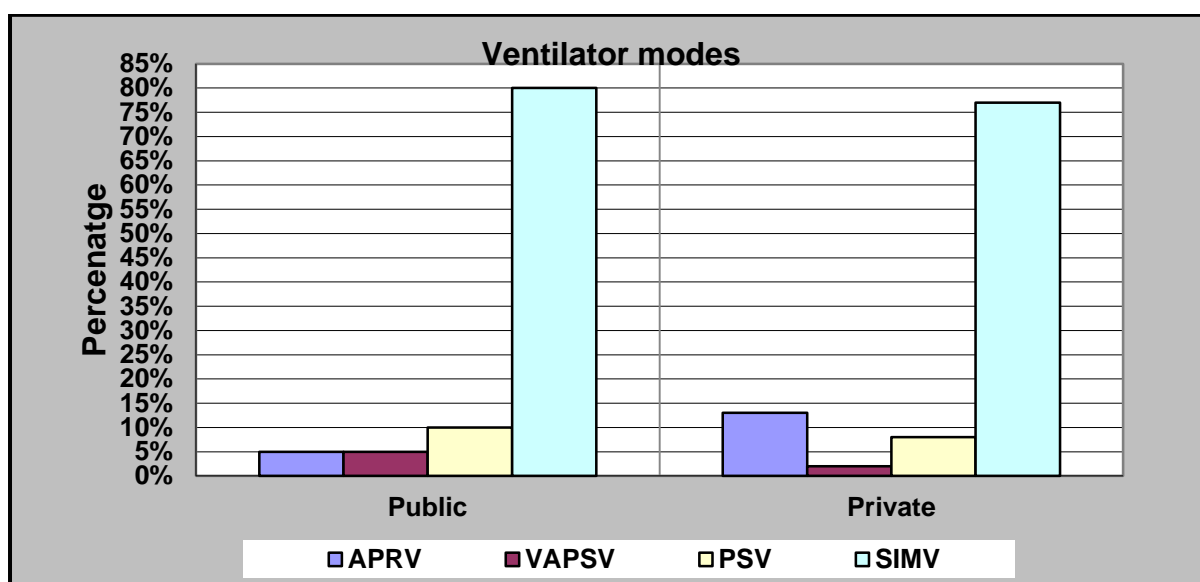


Figure 4.45 Ventilator modes

4.8.1.2 Complications of Volume Controlled-Continuous Mandatory Ventilation (VC-CMV)

This question aimed at exploring the complications related to the use of VC-CMV as a ventilator mode in the care of the critically ill patient. Of the 100 participants, only 21% [$n_1=12$ (30%), $n_2=9$ (15%)] indicated the correct response, namely volutrauma

as a complication of VC-CMV. The remaining 79% indicated the following incorrect responses: 13% [$n_1=2$ (5%), $n_2=11$ (18%)] indicated atelectrauma, while 1% [$n_1=1$ (3%), $n_2=0$ (0%)] indicated biotrauma. The remaining 65% [$n_1=25$ (62%), $n_2=40$ (67%)] indicated barotrauma. No statistical significant difference was noted between the responses from the professional nurses in the critical care units of the two health care sectors ($\text{Chi}^2(\text{d.f.}=2) = 5.93, p = .051$). The results are graphically displayed in Figure 4.46.

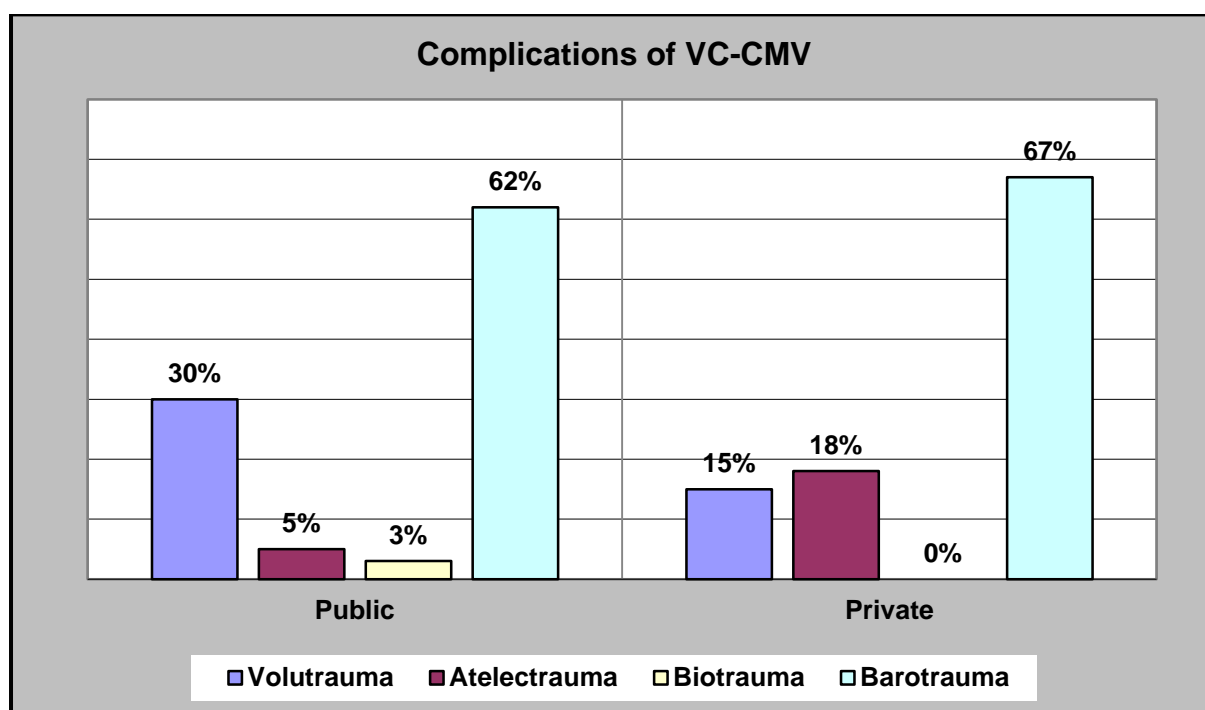


Figure 4.46 Complications of VC-CMV

4.8.1.3 Pressure-support ventilation

The majority of participants [66%; $n_1=23$ (58%), $n_2=43$ (72%)] indicated that the use of pressure-support ventilation would limit barotrauma, which is correct response (indicated by stating true as an answer to the response). The remaining participants [34%; $n_1=17$ (42%), $n_2=17$ (28%)] indicated the incorrect response, which is indicated by the false answer. No statistically significant difference was found between the responses from professional nurses in the two health care sectors ($\text{Chi}^2(\text{d.f.}=1) = 2.15, p = .143$). The results are depicted in Figure 4.47.

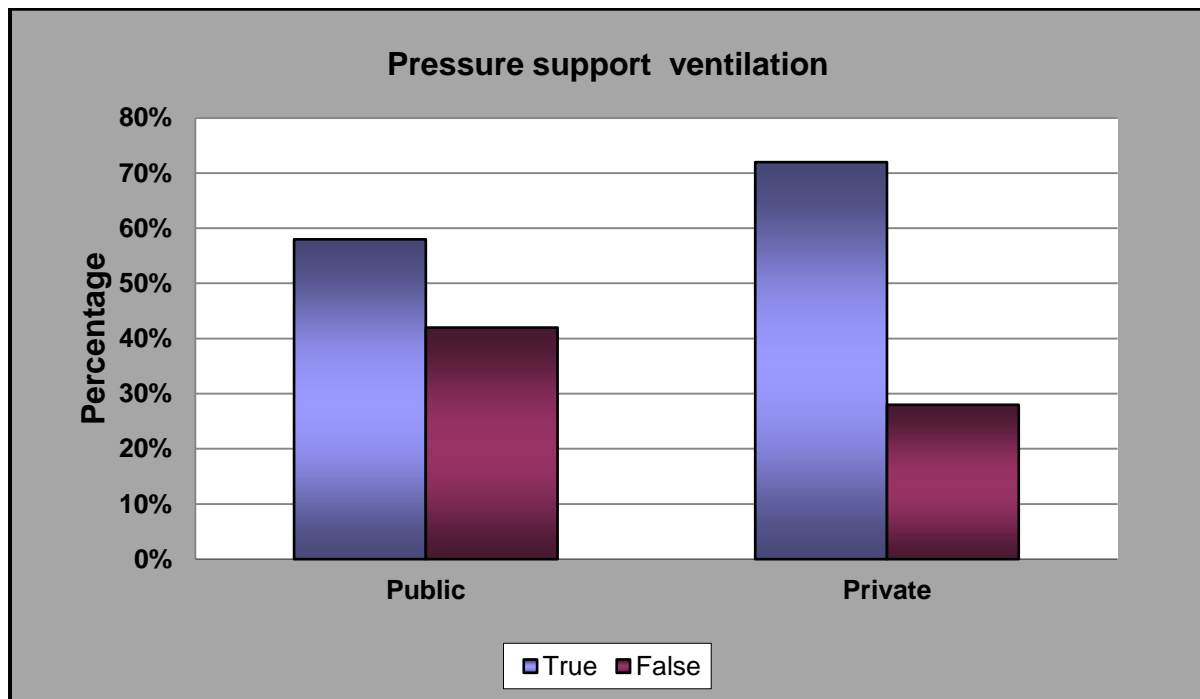


Figure 4.47 Pressure-support ventilation

4.8.1.4 Recommended tidal volumes

This question aimed at exploring the best recommended tidal volumes that professional nurses use while caring for the mechanically ventilated patient. Of the 100 participants, only 55% [$n_1=24$ (60%), $n_2=31$ (52%)] indicated the correct and best recommended tidal volumes, namely 6 to 8 ml/kg. The remaining 45% indicated the following incorrect responses: 4 to 6 ml/kg [17%; $n_1=5$ (12%), $n_2=12$ (20%)], 8 to 10 ml/kg [27%; $n_1=11$ (28%), $n_2=16$ (26%)] and 10 to 12 ml/kg [1%; $n_1=0$ (0%), $n_2=1$ (2%)]. No statistical significant difference was noted between the responses from the professional nurses in the critical care units of the two health care sectors ($\text{Chi}^2(\text{d.f.}=2) = 1.09, p = .579$). The results are reflected in Figure 4.48.

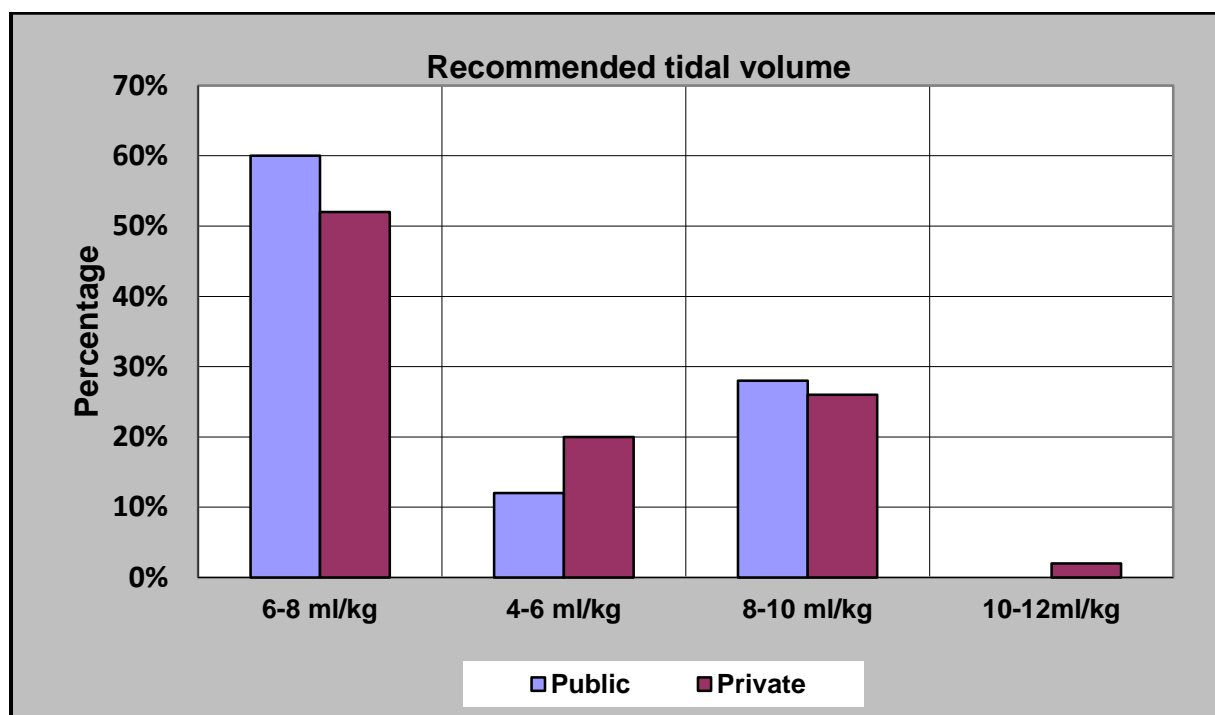


Figure 4.48 Recommended tidal volumes

4.8.1.5 Peak airway pressure

This question aimed at exploring the use of the best recommended peak airway pressures necessary to minimise the incidence of ventilator-induced lung injury in the mechanically ventilated patient. Of the 100 participants, only 13% [$n_1=7$ (17%), $n_2=6$ (10%)] indicated the best recommended peak airway pressures, namely maintaining peak airway pressures at 30 cmH₂O. The remaining participants indicated the following incorrect responses, which are not regarded as best recommended practices: 43% [$n_1=15$ (38%), $n_2=28$ (46%)] indicated that they would maintain the peak airway pressures at levels less than 35 cmH₂O, while 43% [$n_1=18$ (45%), $n_2=25$ (42%)] indicated the use of peak airway pressures at levels less than 45 cmH₂O. The remaining 1% [$n_1=0$ (0%), $n_2=1$ (2%)] indicated the use of peak airway pressure of 50 to 55 cmH₂O. No statistical significance was noted between the responses from professional nurses in the critical care units in the public and private health care sectors ($\text{Chi}^2(\text{d.f.}=3) = 1.44, p = .697$). The results are depicted in Figure 4.49.

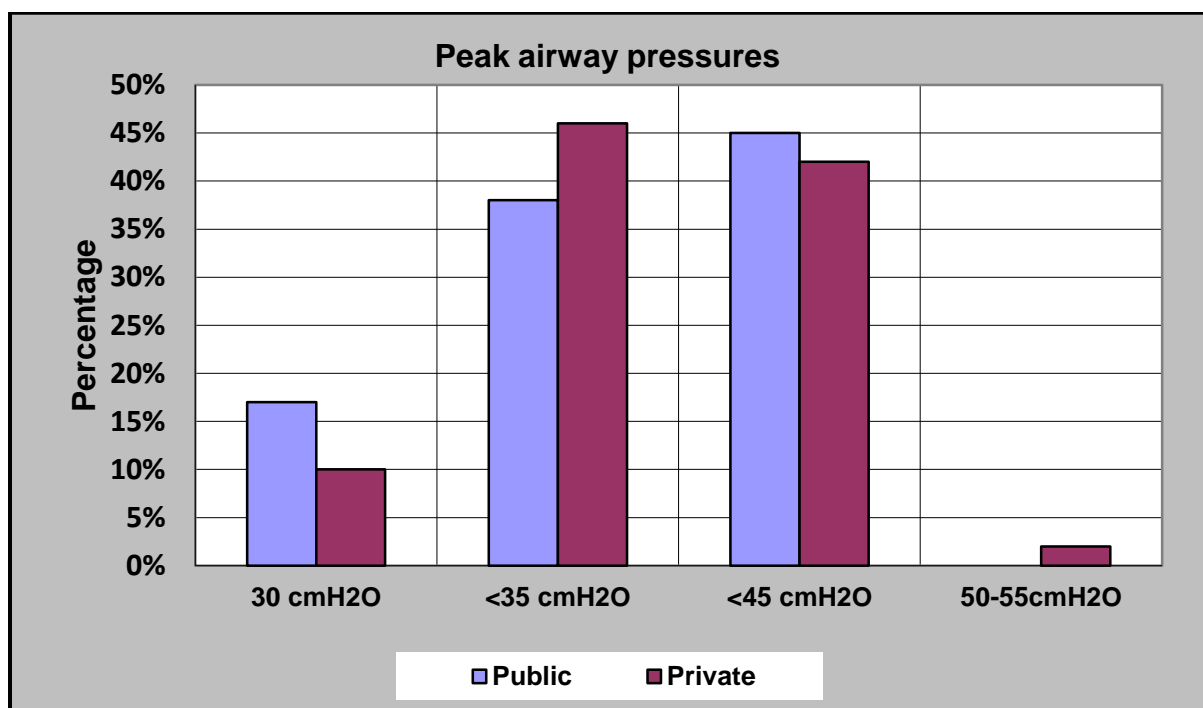


Figure 4.49 Peak airway pressure

4.8.1.6 Complications of high tidal volumes and high airway pressures

All participants (100%) stated the correct response to this question indicating that they are aware that high tidal volumes and high airway pressures can cause a syndrome of ventilator-induced lung injury in the mechanically ventilated patient. Due to the high correct response rate, no graphic presentation is deemed necessary for the results.

4.8.1.7 Positive-end expiratory pressure (PEEP) levels

The majority of participants [69%; $n_1=29$ (72%), $n_2=40$ (66%)] indicated the best recommended level of positive-end expiratory pressure (PEEP) levels, namely 0 to 5 cmH₂O. The remaining participants indicated the following incorrect responses: 26% [$n_1=11$ (28%), $n_2=15$ (25%)] that they would use 6 to 8 cmH₂O of PEEP, while 4% [$n_1=0$ (0%), $n_2=4$ (7%)] that they would use PEEP levels of 9 to 10cmH₂O, and the remaining 1% [$n_1=0$ (0%), $n_2=1$ (2%)] the use of PEEP levels of 11 to 15 cmH₂O. The differences in responses between professional nurses in the critical care units of the two health care sectors are statistically not significant ($\text{Chi}^2(\text{d.f.}=3) = 0.47$, $p = .926$). The results are displayed in Figure 4.50.

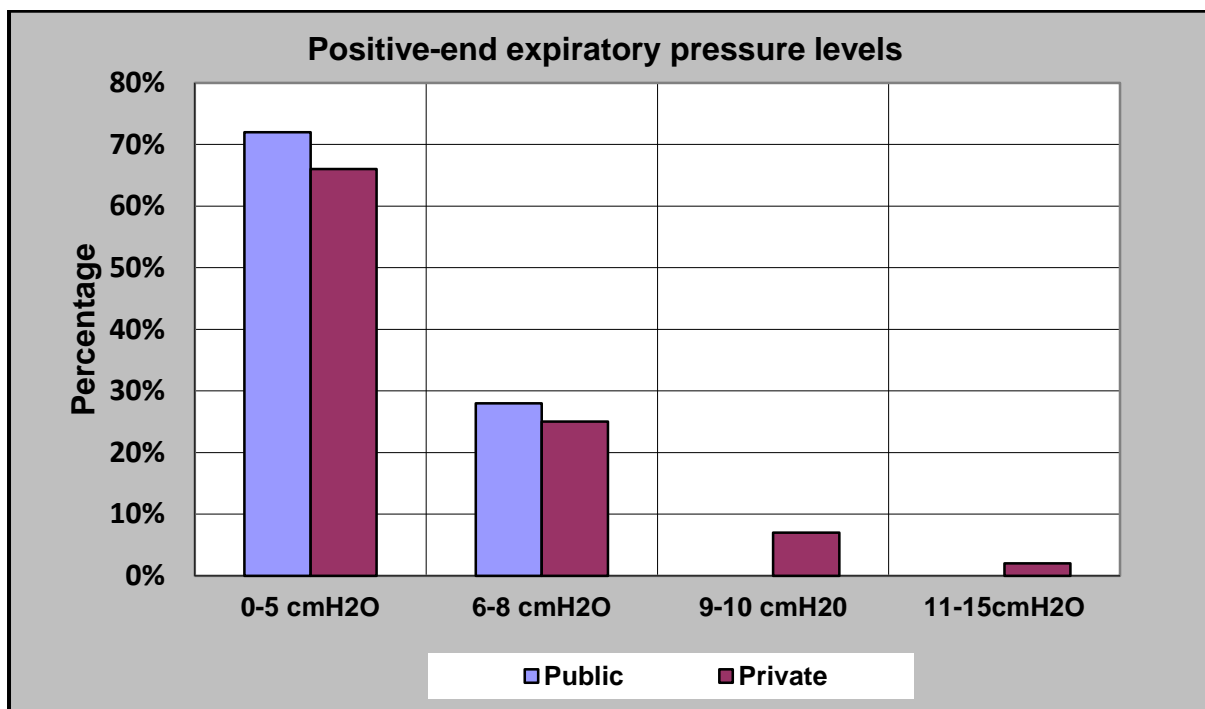


Figure 4.50 Positive-end expiratory pressure levels

4.8.1.8 Complications of positive-end expiratory pressure

In response to this question, aimed at exploring the complications of positive-end expiratory pressure (PEEP), it was revealed that only 28% [$n_1=6$ (15%), $n_2=22$ (37%)] of participants indicated correctly that high levels of PEEP would cause atelectrauma in the mechanically ventilated patient. The remaining participants indicated the following incorrect responses: 11% [$n_1=3$ (7%), $n_2=8$ (13%)] indicated increased cardiac output, 22% [$n_1=12$ (30%), $n_2=10$ (17%)] volutrauma, while 39% [$n_1=19$ (48%), $n_2=20$ (33%)] decreased afterload as a complication of PEEP. A statistically significant difference was noted between the responses from professional nurses in the critical care units of the two health care sectors ($\text{Chi}^2(\text{d.f.}=3) = 7.94$, $p = .047$, $V = 0.28$). Although practice variations are noted amongst professional nurses in the critical care units of the public and private sector, data reveals that professional nurses in the critical care units in the private sector are more inclined to indicate the best recommended response. The professional nurses in the critical care units in the public sector were more inclined to indicate the incorrect responses. The results are displayed in Figure 4.51.

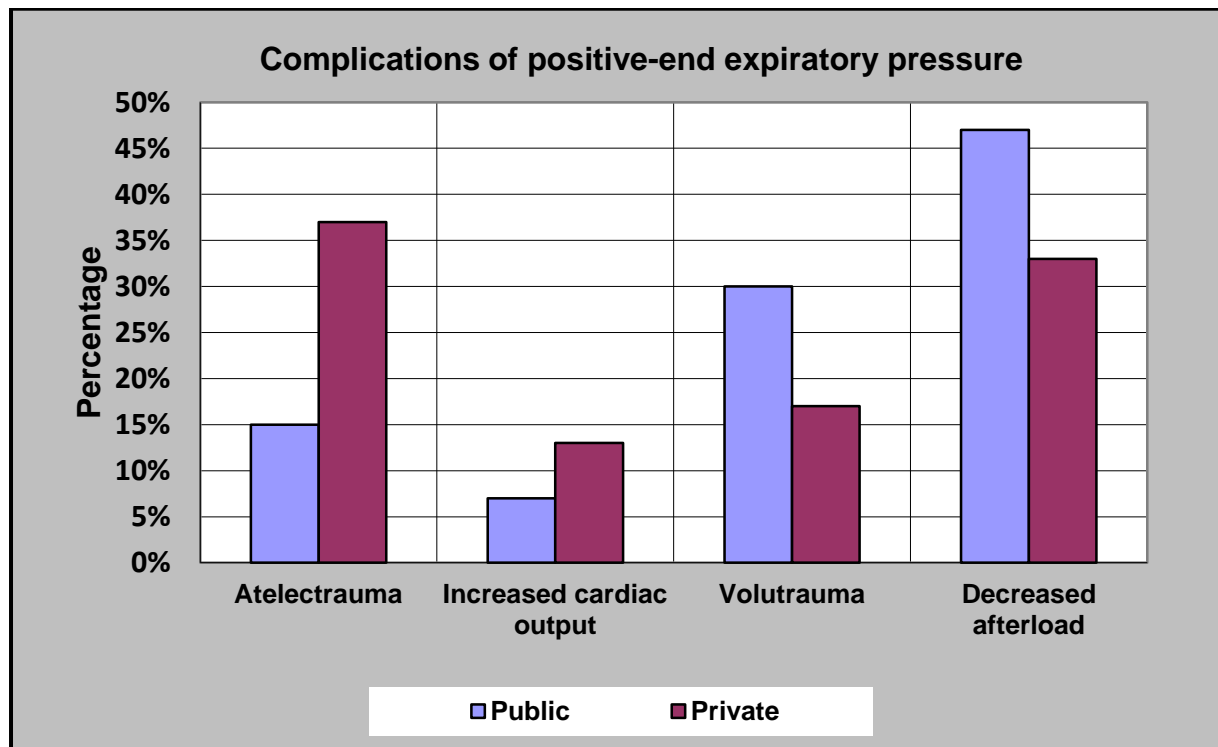


Figure 4.51 Complications of positive-end expiratory pressure

4.8.1.9 Oxygen administration

Of the 100 participants, 64% [$n_1=24$ (60%), $n_2=40$ (67%)] indicated the best recommended practice response, which is enough oxygen to keep the saturation above 90% and the PO_2 more than 60mmHg. The remaining participants (36%) indicated the following incorrect responses: 31% [$n_1=13$ (32%), $n_2=18$ (30%)] indicated the use of 0.4% oxygen, while 5% [$n_1=3$ (8%), $n_2=2$ (3%)] the use of 0.6% oxygen. None of the participants indicated that they would use 100% (0.1%) oxygen in setting the mechanical ventilator. No statistically significant difference was noted between the responses from professional nurses in the critical care units in the two health care sectors ($\chi^2(d.f.=2) = 1.04$, $p = .592$). The results are displayed in Figure 4.52.

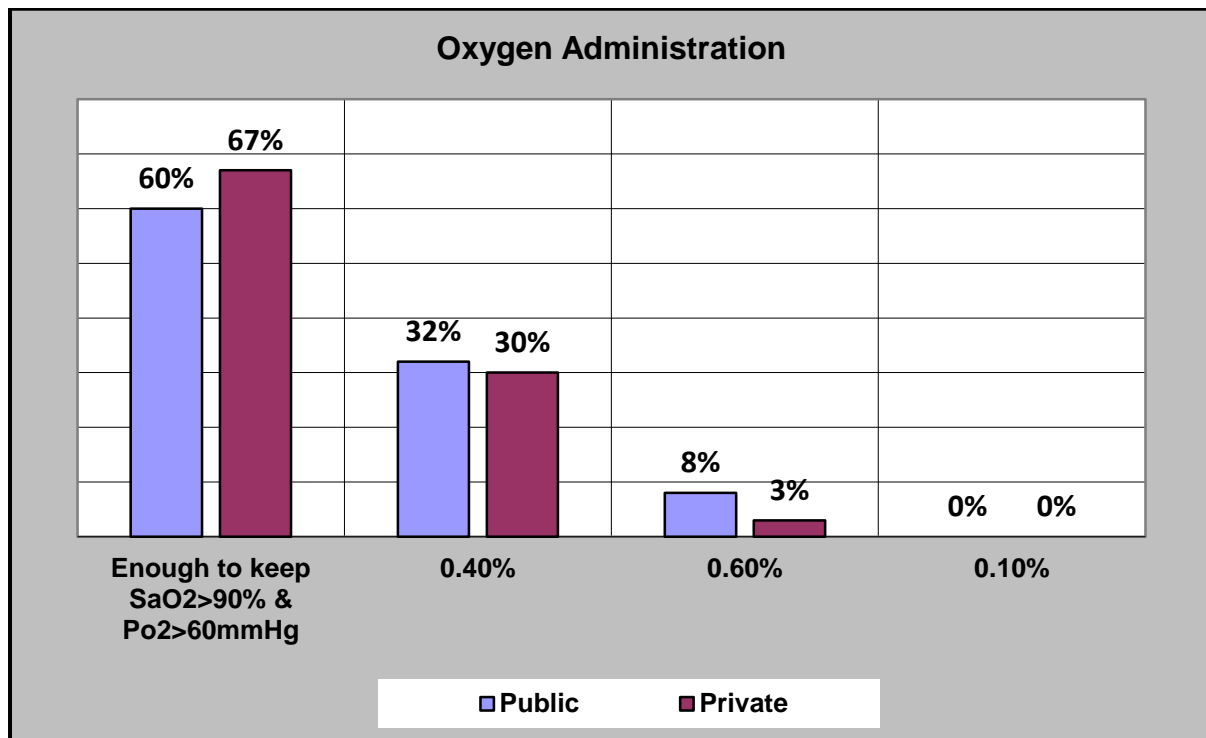


Figure 4.52 Oxygen administration

4.8.1.10 Oxygen toxicity

Of the 100 participants, only 54% [$n_1=28$ (70%), $n_2=26$ (43%)] of participants indicated correctly that oxygen toxicity might result in acute lung injury in the mechanically ventilated patient. The remaining participants indicated the following incorrect responses: 8% [$n_1=4$ (10%), $n_2=4$ (7%)] that excessive oxygen administration might cause a pneumothorax, 15% [$n_1=3$ (7%), $n_2=12$ (20%)] indicated pulmonary edema as a complication of oxygen toxicity, while 23% [$n_1=5$ (13%), $n_2=18$ (30%)] indicated barotrauma as a complication of excessive oxygen administration. No statistical significant difference was noted between the responses from professional nurses in the critical care units of the two health care sectors ($\chi^2(d.f.=3) = 7.36, p = .061$). The results are reflected in Figure 4.53.

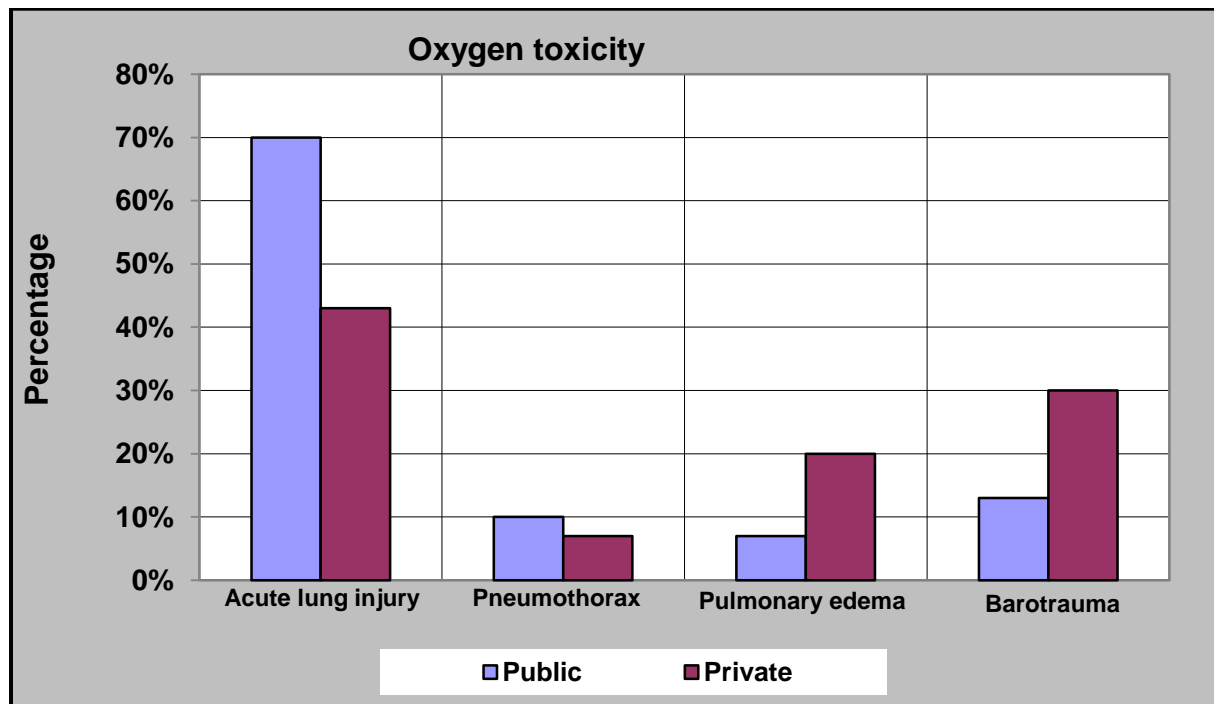


Figure 4.53 Oxygen toxicity

4.8.1.11 Hypo-ventilation

This question aimed at exploring the effects of setting a low respiratory rate (hypo-ventilation) on the mechanical ventilator. Of the 100 participants 86% [$n_1=36$ (90%), $n_2=50$ (83%)] indicated the correct response, namely that hypo-ventilation might cause acidosis in the mechanically ventilated patient. The remaining (14%) participants indicated the following incorrect responses: 13% [$n_1=4$ (10%), $n_2=9$ (15%)] indicated alkalosis, while 1% [$n_1=0$ (0%), $n_2=1$ (2%)] indicated barotrauma. None of the participants indicated volutrauma as a complication in setting the ventilator rate too low. No statistical significant difference was noted between the responses from the professional nurses in the critical care units of the two health care sectors ($\text{Chi}^2(\text{d.f.}=3) = 0.38, p = .944$). The results are displayed in Figure 4.54.

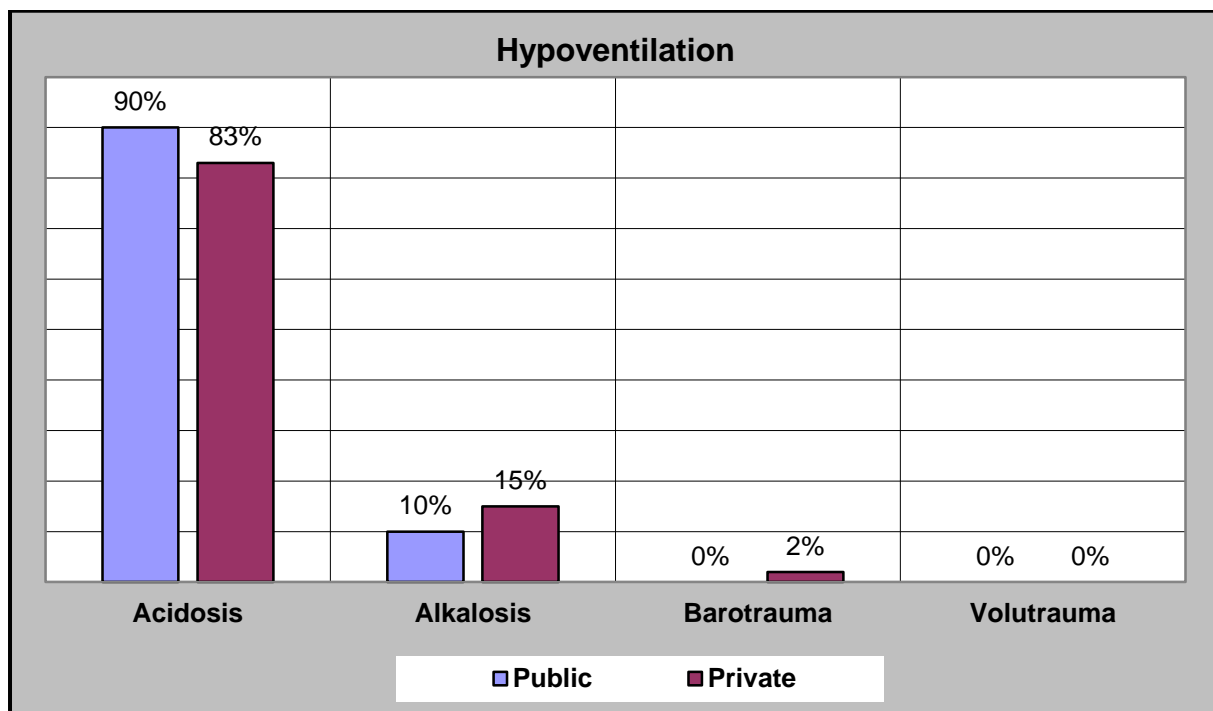


Figure 4.54 Hypo-ventilation

4.8.1.12 Hyper-ventilation

In assessing the effects of setting a respiratory rate on the mechanical ventilator that is too high (hyper-ventilation), 83% [$n_1=34$ (85%), $n_2=49$ (82%)] of participants indicated the correct response, namely alkalosis. The remaining 17% indicated the following incorrect responses: 14% [$n_1=5$ (13%), $n_2=9$ (15%)] indicated that acidosis will be an effect of hyper-ventilation, while 3% [$n_1=1$ (2%), $n_2=2$ (3%)] indicated barotrauma. None of the participants indicated volutrauma as an effect of hyperventilation. No statistical significant difference were noted between the responses from the professional nurses in the critical care units in the public and private health care sectors ($\chi^2(d.f.=2) = 0.05$, $p = .975$). The results are graphically displayed in Figure 4.55.

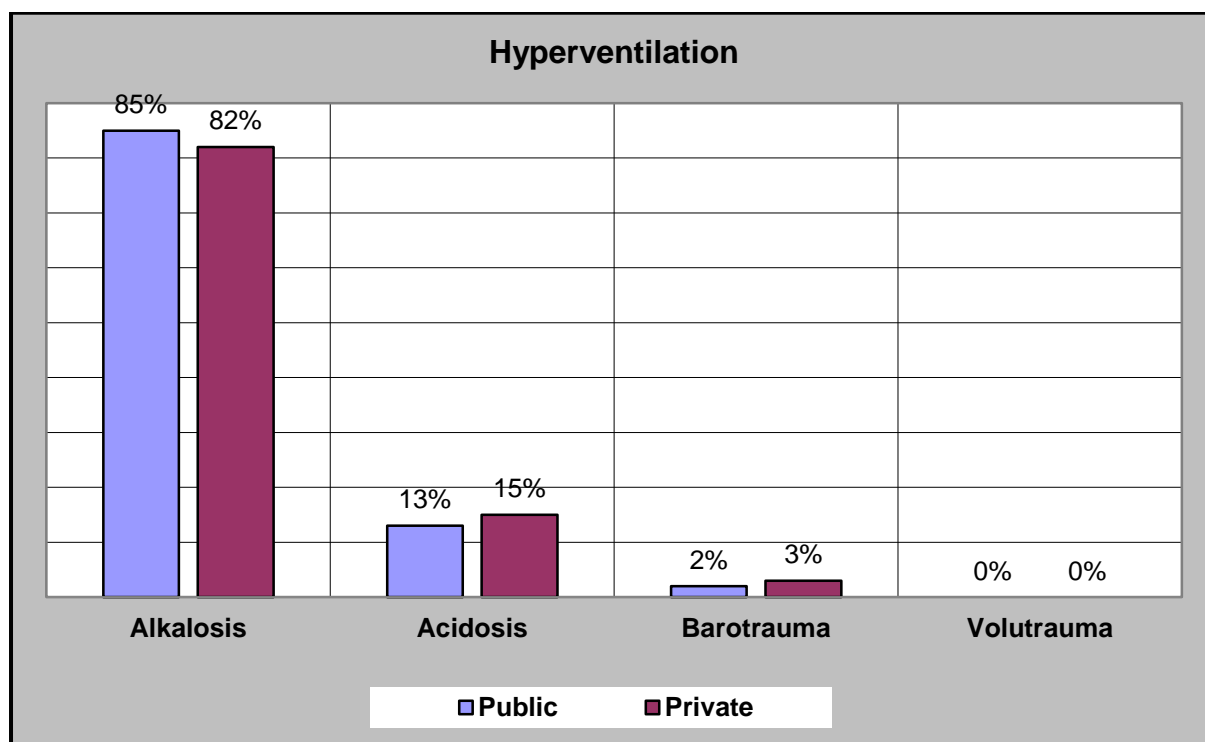


Figure 4.55 Hyper-ventilation

4.8.1.13 Flow rate

This question aimed at exploring the best recommended flow rate used by professional nurses, which is needed to minimise ventilator-induced lung injury in the mechanically ventilated patient in the critical care unit. Of the 100 participants, only 46% [$n_1=14$ (35%), $n_2=32$ (53%)] indicated the best recommended response, namely 40 to 60 L/min. The remaining 54% indicated the following incorrect responses: 40% [$n_1=20$ (50%), $n_2=20$ (34%)] 20 to 39 L/min as the best recommended flow rates, while 13% [$n_1=5$ (13%), $n_2=8$ (13%)] 61 to 80 L/min and the remaining 1% [$n_1=1$ (2%), $n_2=0$ (0%)] 81 to 100 L/min. ($\chi^2(d.f.=3) = 3.59, p = .309$). No statistical significant difference was noted between the responses from the professional nurses in the critical care units in the public and private sectors ($\chi^2(d.f.=3) = 3.59, p = .309$). The results are reflected in Figure 4.56.

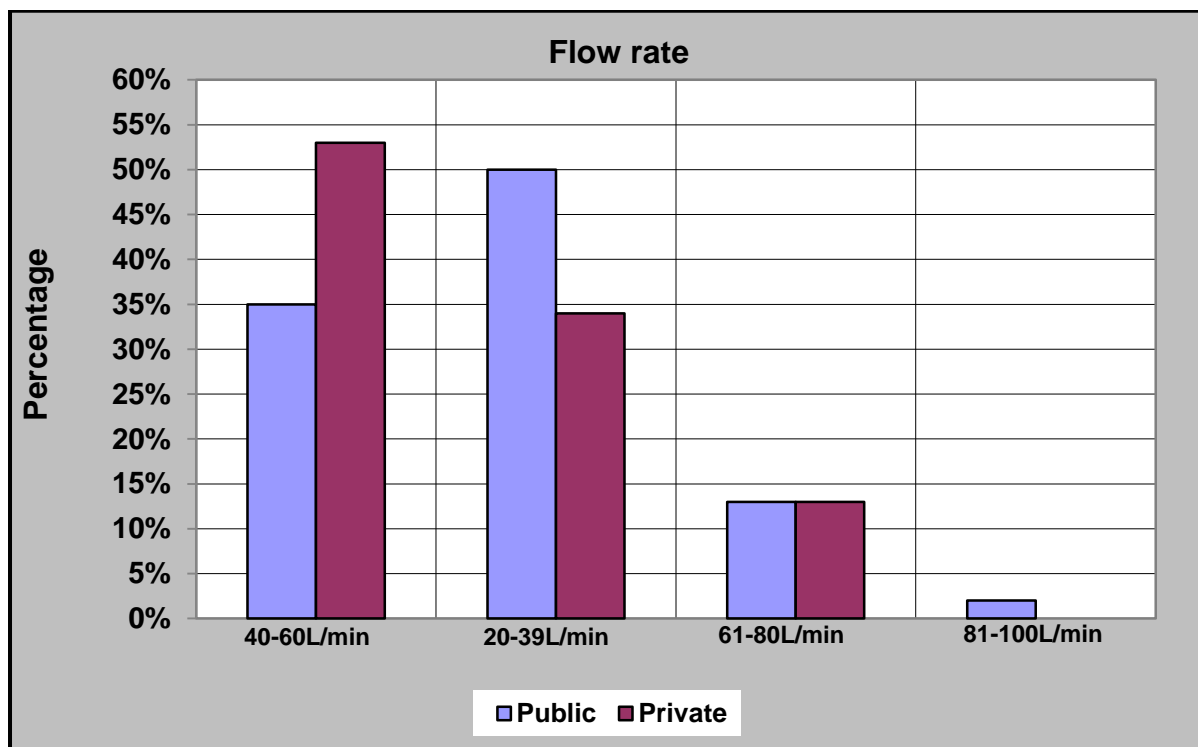


Figure 4.56 Flow rate

4.8.1.14 Frequency of monitoring ventilator alarms

This question aimed to elicit how frequently professional nurses monitor the ventilator alarm parameters. The best recommended frequency would be once per working shift, which can either be every 6 or 12 hours depending on the shift worked at the particular health care institution. Of the 100 participants, 68% indicated the best recommended response, namely to monitor the ventilator alarms either at six [13% [$n_1=5$ (12%), $n_2=8$ (13%)] or 12-hour intervals [55% [$n_1=26$ (65%), $n_2=29$ (48%)]. The remaining 26% [$n_1=7$ (18%), $n_2=19$ (32%)] indicated that they would check the ventilator alarms at 2-hour intervals, while 4% [$n_1=0$ (0%), $n_2=4$ (7%)] at 4-hour intervals and 2% [$n_1=2$ (5%), $n_2=0$ (0%)] never check the ventilator alarms, all of which are incorrect and not best recommended practice. No statistical significant difference was noted between the responses from the professional nurses in the critical care units of the two health care sectors ($\text{Chi}^2(\text{d.f.}=4) = 3.76, p = .440$). The results are displayed in Figure 4.57.

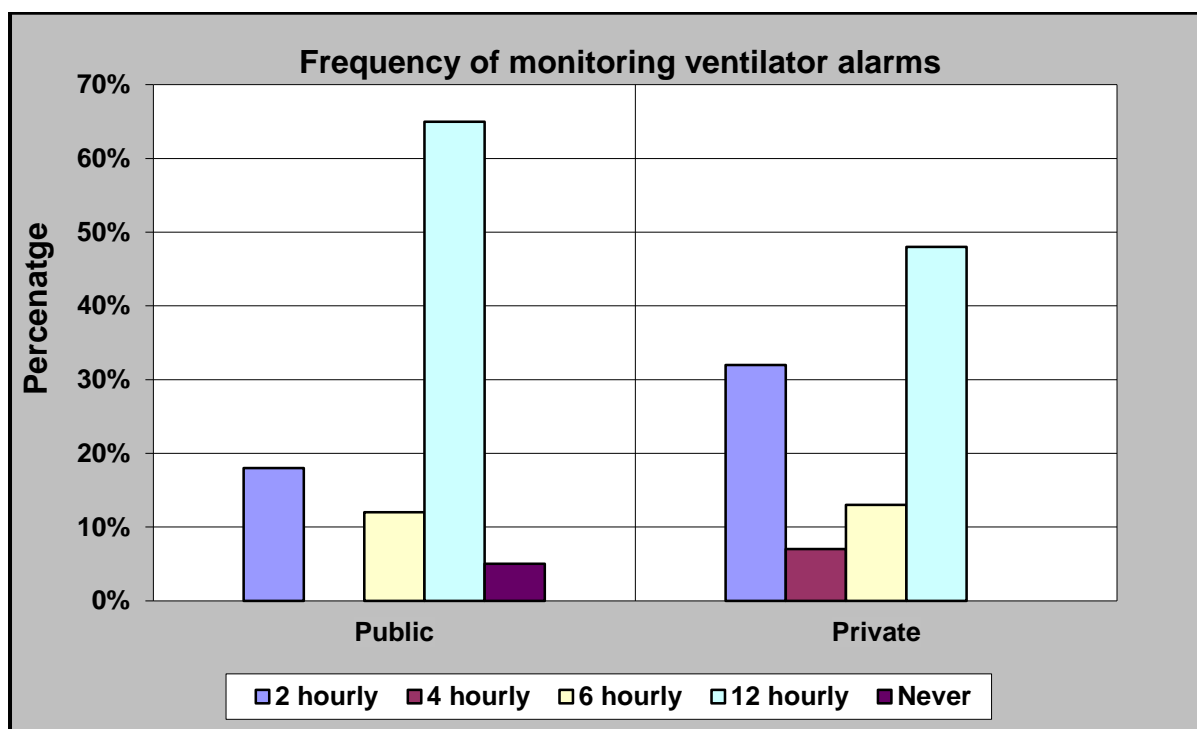


Figure 4.57 Frequency of monitoring ventilator alarms

4.8.1.15 Peak pressure alarms limits

Of the 100 participants, only 28% [$n_1=11$ (27%), $n_2=17$ (28%)] indicated the best recommended response, namely 10 to 20 cmH₂O above peak inspiratory pressure. The remaining participants indicated the following incorrect responses: 56% [$n_1=19$ (48%), $n_2=37$ (62%)] indicated peak pressure alarms of 5 to 10 cmH₂O above the peak inspiratory pressure limit, 8% [$n_1=6$ (15%), $n_2=2$ (3%)] more than 21 to 30 cmH₂O above the limit, while the remaining 8% [$n_1=4$ (10%), $n_2=4$ (7%)] indicated 31 to 35 cmH₂O. No statistical significant difference was noted in the responses from the professional nurses in the critical care units in the two health care sectors ($\chi^2(d.f.=3) = 4.31, p = .230$). The results are depicted in Figure 4.58.

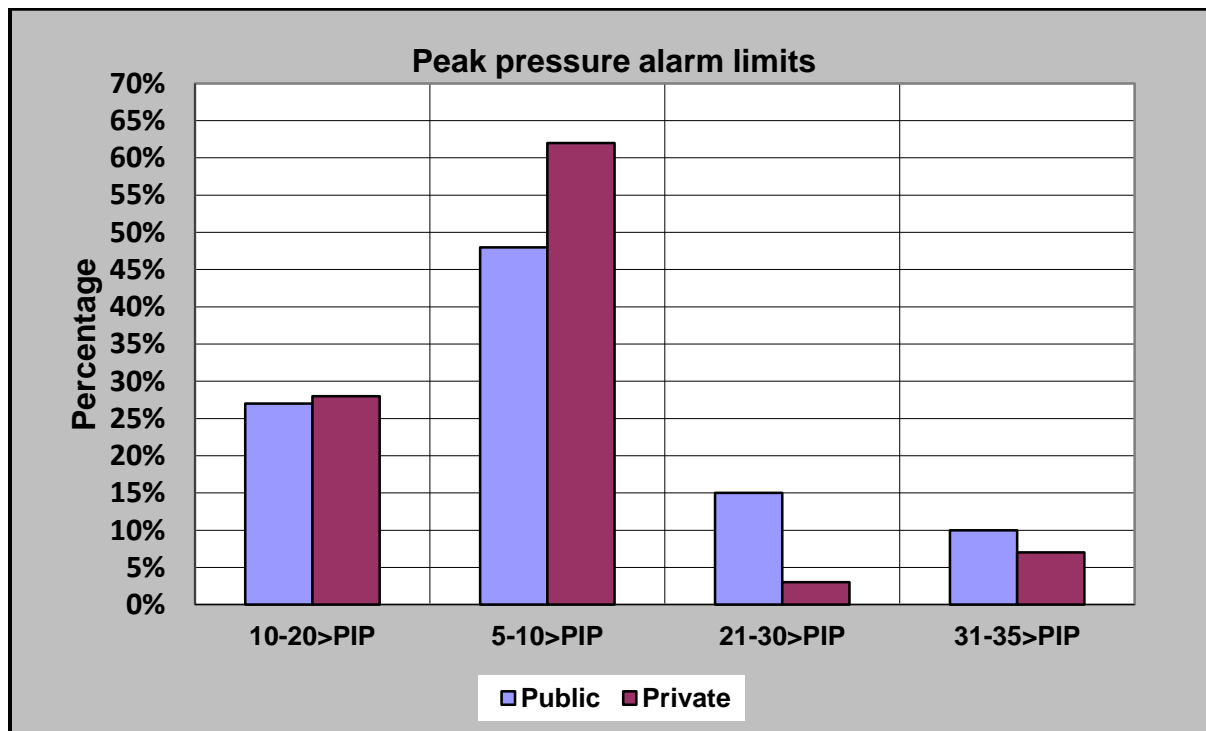


Figure 4.58 Peak pressure alarm limits

4.8.1.16 Respiratory rate alarm limits

Only 26% [$n_1=9$ (22%), $n_2=17$ (28%)] indicated the best recommended response, namely setting the respiratory rate alarm limit at a upper limit of 30 breaths per minute (bpm) and at a lower limit of 12 bpm. The remaining participants (74%; $n_1=31$, $n_2=43$) indicated the incorrect responses for setting accurate respiratory rate alarm limits as indicated in Table 4.15 below. No statistical significant difference was noted between the responses from the professional nurses in the critical care units in the public and private health sectors respectively ($\text{Chi}^2(\text{d.f.}=6) = 1.27$, $p = .973$).

Item	Public sector n(%)	Private sector n(%)	Total (n=100)
A. Upper alarm limit of 30bpm	1(3%)	3(5%)	4%
B. Upper alarm limit of 40bpm	0(0%)	1(2%)	1%
C. Lower alarm limit of 12bpm	0(0%)	2(3%)	2%
D. Lower alarm limit of 8bpm	0(0%)	0(0%)	0%
A & C	9(22%)	17(28%)	26%
A & D	28(70%)	33(55%)	61%
B & C	2(5%)	1(2%)	3%
B & D	0(0%)	3(5%)	3%

4.8.1.17 Minute ventilation alarm limits

Of the 100 participants, only 12% [$n_1=5$ (13%), $n_2=7$ (12%)] indicated the best recommended response, namely setting the minute ventilation alarm limits at an upper alarm limit of 15 and at a lower alarm limit of 3. The remaining 88% ($n_1=35$, $n_2=53$) indicated the incorrect responses as shown in Table 4.16. No statistical significant difference was noted between the responses from the professional nurses in the critical care units in the public and private health sectors respectively ($\chi^2(d.f.=7) = 6.70$, $p = .460$).

Item	Public sector n(%)	Private sector n(%)	Total (n=100)
A. Upper alarm limits of 10	0(0%)	2(3%)	2%
B. Upper alarm limit of 15	1(2%)	3(5%)	4%
C. Lower alarm limit of 2	0(0%)	4(7%)	4%
D. Lower alarm limit of 3	1(2%)	1(2%)	2%
A & C	6(15%)	20(33%)	26%
A & D	25(63%)	18(30%)	43%
B & C	2(5%)	5(8%)	7%
B & D	5(13%)	7(12%)	12%

4.8.1.18 Institutional guideline in place for mechanical ventilator settings

As reflected in Figure 4.59, of the 100 participants, only 20% [$n_1=7$ (18%), $n_2=13$ (21%)] indicated the availability of a clinical guideline on mechanical ventilator settings in the critical care unit where they work. The remaining participants (80%; $n_1=33$ (82%), $n_2=47$ (79%)] indicated that they do not have a guideline. No statistical significant difference was noted between the responses from the professional nurses in the critical care units in the public and private health sectors ($\text{Chi}^2(\text{d.f.}=1) = 0.26, p = .610$).

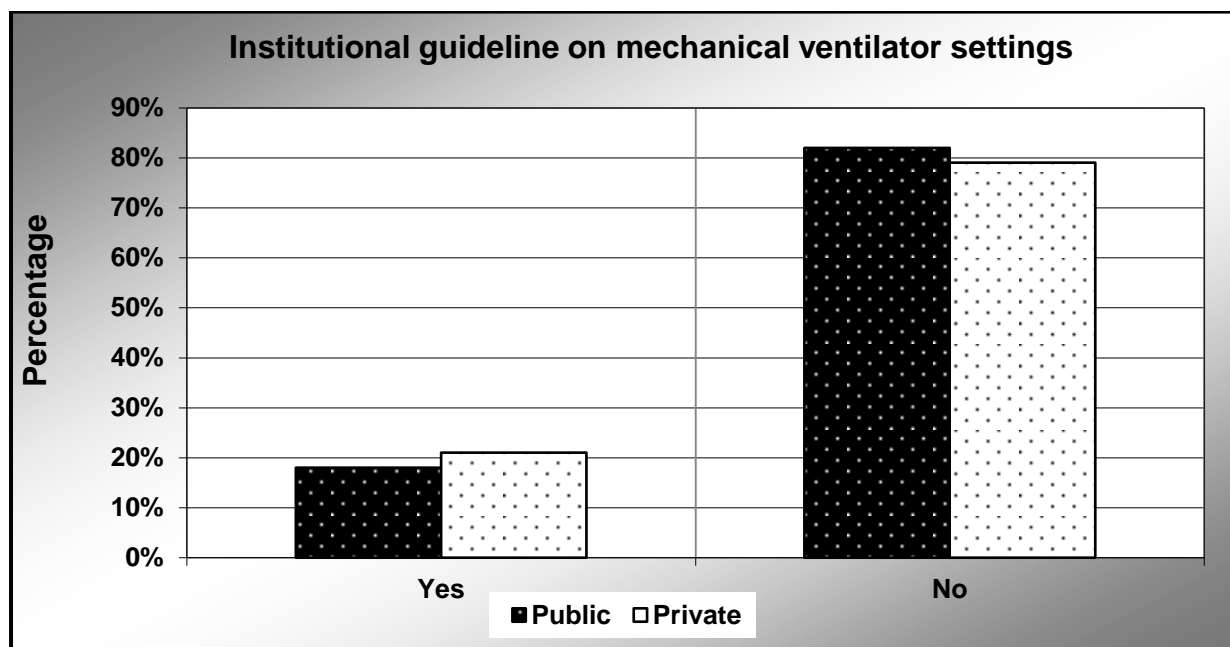


Figure 4.59 Institutional guideline on mechanical ventilator settings

4.8.1.19 Who developed the guideline?

The response to this question was left blank in the majority of the questionnaires and could, therefore, not be statistically analysed. Approximately 70% of the participants did not complete the response. The remaining 30% of the participants indicated that the unit manager, shift leader or the company's head office developed the existing clinical guideline on mechanical ventilator settings. Some of the participants stated that they were unsure of who had developed the guideline.

4.8.1.20 Decision-making choices

In the critical care units of the public sector, 36% ($n_1=13$) indicated that they base their decision-making on own expertise and 47% ($n_1=17$) on what they have been taught in the unit. Only 17% ($n_1=6$) participants use the most recent literature to guide their practice decisions.

Within the critical care units of the private sector, 22% ($n_2=11$) participants indicated that they base their decision-making on own expertise and 64% ($n_2=32$) on what they have been taught in the unit. Only 14% ($n_2=7$) participants use the most recent literature to guide their practice decisions. Due to the multi-responses for this question, the Chi-square test could not be performed. The results are displayed in Figure 4.60.

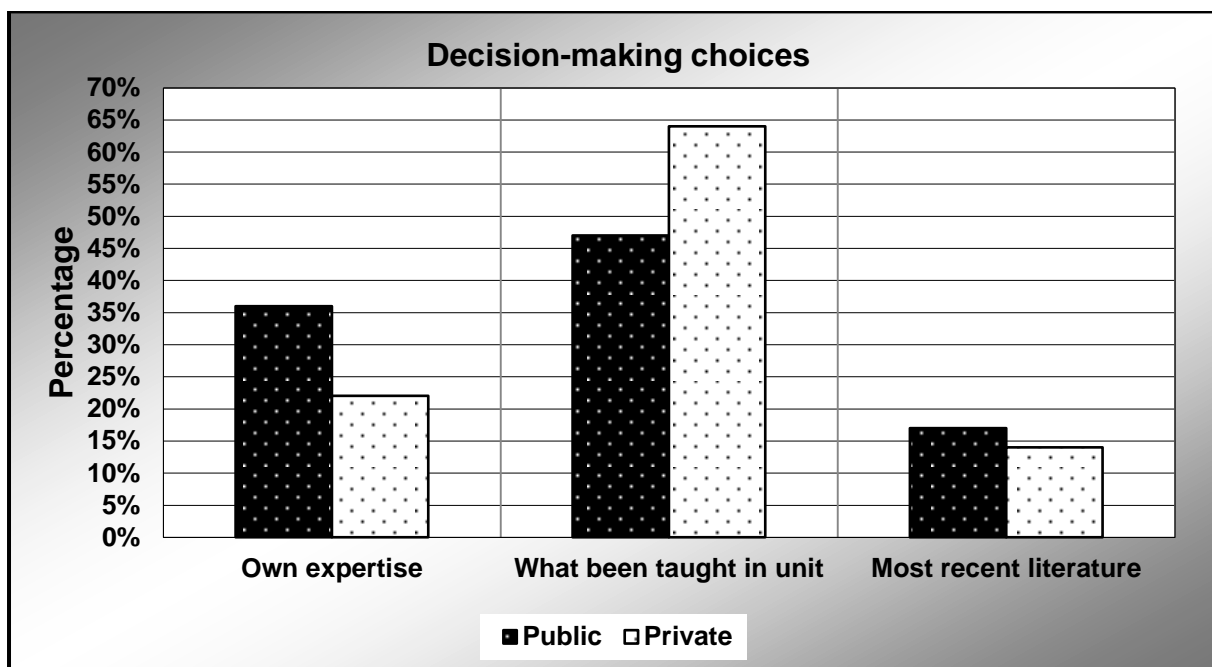


Figure 4.60 Decision-making choices

4.8.2 SUMMARY OF RESULTS FOR MECHANICAL VENTILATOR SETTINGS

Data derived and analysed from this section revealed the results reflected in Table 4.17.

Table 4.17 Summary of the results on mechanical ventilator settings		
Question	Correct or best recommended practice response	Incorrect or not best recommended practice response
Complications of high tidal volumes and high airway pressures	100%	0%
Respiratory Rate		
Hypo-ventilation	86%	14%
Hyper-ventilation	83%	17%
PEEP	69%	31%
Frequency of monitoring ventilator alarms	68%	32%
Pressure support ventilation	66%	34%
Oxygen administration	64%	36%
Recommended tidal volumes	55%	45%
Oxygen toxicity	54%	46%
Flow rate	46%	54%
Complications of PEEP	28%	72%
Peak pressure ventilator alarms	28%	72%
Respiratory rate alarm limits	26%	74%
Complications of VC-CMV	21%	79%
Peak airway pressure	13%	87%
Minute ventilation alarm limits	12%	88%
Ventilator modes	10%	90%

The results for the summaries of the responses with regard to the existing guideline, frequency for use and choices for decision-making are displayed in Table 4.18.

Table 4.18 Summary of the existing guideline and decision-making			
The availability of an existing guideline	<u>Yes</u> 20%	<u>No</u> 80%	
Decision-making choices CCU in Public sector (n=19)	<u>Own expertise</u> 36%	<u>What have been taught in unit</u> 47%	<u>Most recent literature</u> 17%
Decision-making choices CCU in Private sector (n=32)	<u>Own expertise</u> 22%	<u>What have been taught in unit</u> 64%	<u>Most recent literature</u> 14%

4.8.3 DISCUSSION ON MECHANICAL VENTILATOR SETTINGS

Although there are various modes available to mechanically ventilate the critically ill patient, is it important to choose an optimal mode that would minimise the risk of acute lung injury. Airway pressure release ventilation (APRV) has been recommended as the ventilator mode that is the most beneficial in minimising this risk as it is known to decrease lung compliance and functional residual volume. It is proven that APRV is safer to use than other ventilator modes, including SIMV the in the reduction of incidences of acute lung injury (Kaplan *et al*, 2001:222; Pierce, 2007:243). The study findings revealed that only 10% of the professional nurses in the critical care units in the Nelson Mandela Metropole would use APRV as the best recommended mode. The majority (78%) of the participants in this study stated that SIMV is still the best recommended mode of ventilation.

Delivered breath is volume-controlled by a set volume on the ventilator. The controller decides upon a volume to be set, usually according to the individual patient. The disadvantage and risk in using volume-controlled ventilation is that an increased delivered volume of air might cause stretching and sheer forces on the alveolar wall, thus contributing to the development of volutrauma (Petrucci and Lacoveli, 2004:193). The study findings revealed that 21% of participants in the study were aware of the fact that using volume-controlled ventilation might put the critically ill patient at this risk.

Pressure support ventilation has been proposed in limiting acute lung injury. It is recommended as a ventilator mode which has been used to limit barotrauma and to reduce the patient's work of breathing (Petrucci and Lacoveli, 2004:193; Hamed *et al*, 2006:79). Although the majority of participants indicated the best recommended response, 34% indicated the incorrect response, which might compromise the safety of their nursing care practices.

Historically, conventional mechanical ventilation was applied by setting tidal volumes of ten to 12 ml/kg. Evidence indicates however that large tidal volumes can cause acute lung injury and/or are associated with ventilator-induced lung injury. Secondary effects of settings high tidal volumes include increased ventilator days, length of stay and mortality in the critically ill patient. It is currently best recommended practice that a tidal volume of 6 to 8 ml/kg ideal body weight be used when ventilating the patient mechanically. Using lower tidal volumes will avoid over distension of the lung and minimise the risk for developing acute lung injury (Hamed *et al*, 2006:81; Pierce, 2007:192). The findings in this study revealed that approximately half of the participants (55%) use tidal volumes of 6 to 8 ml/kg when setting the mechanical ventilator of a critically ill patient. Although a small portion (17%) of the participants use lower than recommended tidal volumes (4 to 6 ml/kg), 28% still use tidal volumes of higher than 8 ml/kg.

It is recommended that the peak airway pressures be kept at less than 30 cmH₂O in mechanically ventilating the critically ill patient, as this avoids the risk for developing ventilator-induced lung injury, perivascular edema, pulmonary edema or severe hypoxia (Fenstermacher and Hong, 2004:280; Tremblay and Slutsky, 2006:25; Pierce, 2007:192). Within the research study it was found that only 13% of participants indicated that they would maintain peak airway pressures at the recommended safety level of less than 30 cmH₂O.

The relationship between PEEP and ventilator-induced lung injury (VILI) has been explored in several studies showing that excessive lung distension and injury occurs with high levels of PEEP. Literature is not clear on what level of PEEP should be maintained. However, the lowest level of PEEP should be maintained, as high levels

lead to atelectrauma (Fenstermacher and Hong, 2004:279; Trembly and Slutsky, 2006:26). Safe levels of PEEP are to be kept between 0 to 5 cmH₂O, which was indicated by the majority (69%) participants.

Professional nurses should be able to identify and be knowledgeable regarding the complications of PEEP in order to minimise ventilator-induced lung injury and thereby ensure the safety of the mechanically ventilated patient (Pierce, 2007:193). The study findings showed that only 28% participants indicated the complications of PEEP correctly, thereby increasing the risks for adverse events related to mechanical ventilation. A statistical significance in the responses from professional nurses in the critical care units of the public and private health sectors indicated that the professional nurses in the private sector obtained a higher correct response than those in the critical care units in the public health care sector.

Manno (2005:40) recommend that in order to prevent oxygen toxicity, the lowest FiO₂ should be set to keep the SAO₂ greater than 90% and PO₂ greater than 60mmHg. From the study findings, it can be concluded that the majority (64%) of the professional nurses' care practices in the adult critical care units in the Nelson Mandela Metropole used in the study are congruent with the best recommended practice related to oxygen administration. Urden *et al* (2006:658) state that the administration of high levels of oxygen might result in the initiation of acute lung injury. Although the majority participants (54%) indicated the best recommended practice, the safety of the mechanically ventilated patient might be compromised if nursing care practices are not consistent amongst all the professional nurses in the units.

Setting of the respiratory rate on the mechanical ventilators is dependent on various variables, for instance, the tidal volume, minute ventilation, disease disorder, work of breathing and comfort of the patient, ventilator mode used and maintaining an adequate acid-base status. Hypo-ventilation results in the development of acidosis. Hyper-ventilation causes acids to be blown off and results in respiratory alkalosis (Pierce, 2007:55,193). Professional nurses should be aware of the complications related to setting the respiratory rate settings higher or lower than the recommended

10 to 12 breaths per minute on the mechanical ventilator, thereby exposing the patient to metabolic alterations. The study findings showed that the majority of professional nurses in the critical care units in the Nelson Mandela Metropole are aware of the complications related to hypo- and hyper-ventilating the mechanically ventilated patient.

Setting an adequate flow must be adjusted for each patient on the basis of the desired Inspiration: Expiration (I:E) ratio, the tidal volume, the respiratory rate and the disease conditions. However, it is recommended that the flow rate of 40 to 60 L/min should be set on the mechanical ventilator. Setting the flow rate higher than the recommended value may increase peak inspiratory pressures, while setting the flow rate lower may reduce peak inspiratory pressures (Pierce, 2007:194). The study findings revealed that 46% of the participants use the correct and best recommended flow rate. The remaining participants use flow rates that are either lower (40%) or higher (14%) than the recommended rates.

Alarms warn the health care practitioners of events that require their attention or action. Although alarms systems on ventilators play an important role, they serve a purpose only if set properly. It is recommended that alarms be set correctly at the beginning of each shift and if the patient's status and ventilator settings change. Furthermore, they should be monitored at least once per shift (Pierce, 2007:312). The study findings revealed that although majority of the professional nurses (68%) check the ventilator alarms at the recommended frequency intervals, a definite lack of best recommended practice was present with regard to the alarm limits to be set. With reference to Table 4.17, it is evident that the participants do not set the peak pressure, respiratory rate and minute ventilation alarms according to the best recommended practice.

Clinical guidelines are recommendations that assist practitioners in making decisions about patient care and have been developed to assist in narrowing the gap between practice and research. They aim to reduce practice variations and improve the quality of patient care rendered (LoBiondo-Wood and Haber, 2010:25). It is, therefore, imperative that nurses have a clinical guideline in place to guide their

nursing practices. The majority (80%) of professional nurses indicated the absence of a guideline on mechanical ventilator settings, which might impact on safety and the nursing care rendered to the critically ill patient.

Evidence-based practice is the collection, interpretation and integration of valid research evidence to inform clinical decision-making. Nurses are constantly challenged to stay abreast of new information to provide the highest quality of patient care. Nurses are challenged to expand their “comfort zone” where relying on own expertise and what they have been taught should be replaced by creative approaches to health problems. The challenge can be met by integrating the best available literature or evidence into the care of patients entrusted to them (LoBiondo-Wood and Haber, 2010:6). The study findings have shown that a minority ($n_1=17\%$, $n_2=14\%$) of professional nurses in the critical care units in the Nelson Mandela Metropole use the most recent literature to guide their decision-making.

The study findings highlighted the nursing care practices related to mechanical ventilator settings that were done according to the best recommended practice. However, the practices that were not done according to best practice recommendations were also highlighted. Except for the statistical significant difference in the complications of PEEP, the remaining nursing care practices related to mechanical ventilator settings were the same amongst the professional nurses in the critical care units in both health care sectors.

The next section of the study will discuss the findings of the four identified nursing care practices, as well as a summary of the combined nursing care practices.

4.9 THE FINDINGS AS RELATED TO THE FOUR IDENTIFIED NURSING CARE PRACTICES

Following the analysis of data, as illustrated in the latter part of the study, further statistical analysis was done as described in Chapter 3. The analysis not only allowed for a comparison of the nursing care practices of professional nurses in the critical care units of the public and private sectors respectively, but it also aided in

exploring which nursing care practices were done according to the best recommended practices.

A rating scale ranging from low, average and high was created as discussed in Chapter 3 of this study. A rating in the high category constituted adherence to best recommended practices. A rating in the average category indicated practices that are marginally acceptable but not necessarily as best recommended practice. The rating in the low category indicated non-adherence to recommended best practice. The higher the nursing care practice score, the closer the adherence to best practice recommendations. Similarly, the lower the score, the less likely was the adherence to best practice recommendations. The findings related to the four nursing care practices as well as the overall scoring are discussed below.

4.9.1 Endotracheal tube verification

The results for this section are reflected in Figure 4.61. Of the 100 participants, only 41% [$n_1=16$ (40%), $n_2=25$ (42%)] obtained a rating in the high-score category indicating that endotracheal tube verification were done according to best recommended practices. Of the remaining participants, 50% [$n_1=21$ (53%), $n_2=29$ (48%)] obtained an rating in the average-score category, which indicates that their practices were suitably done, but not according to best recommended practice, while 9% [$n_1=3$ (8%), $n_2=6$ (10%)] obtained a rating in the low-score category. The difference between the responses from professional nurses in the critical care units of the public and private health care sectors in the Nelson Mandela Metropole was not statistically significant ($\text{Chi}^2(\text{d.f.}=2) = 0.27, p = .875$).

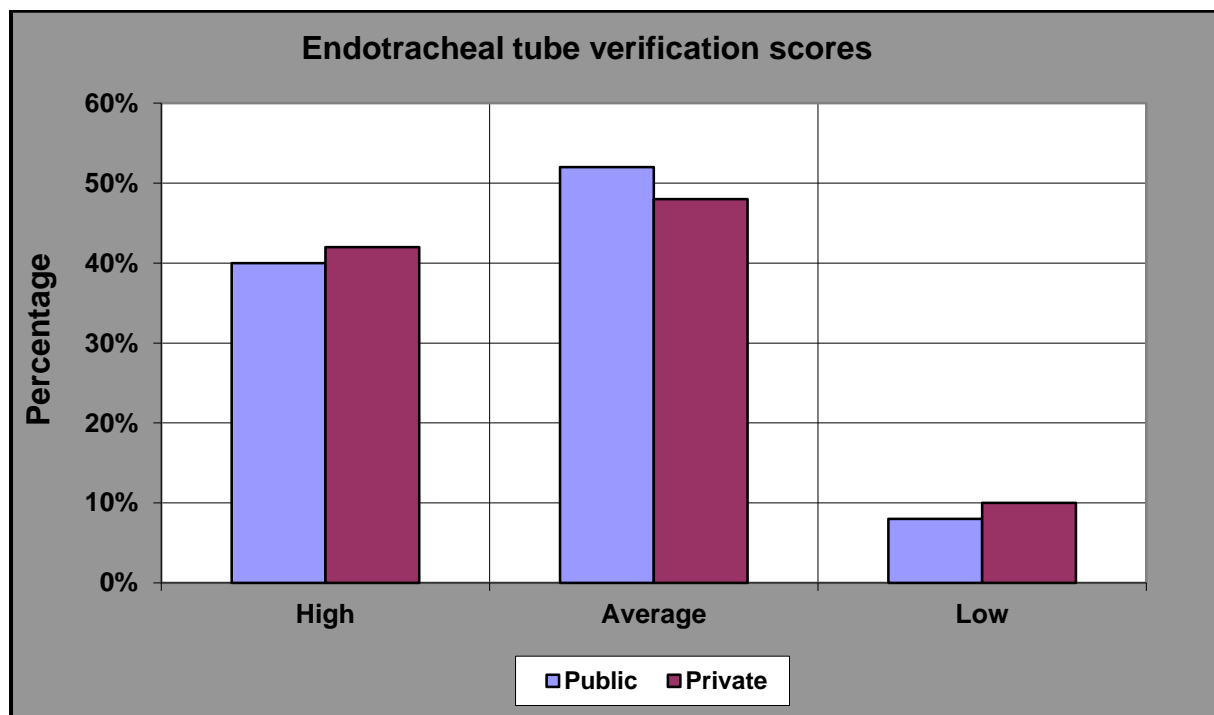


Figure 4.61 Endotracheal tube verification scores

4.9.2 Endotracheal tube cuff pressure monitoring

Of the 100 participants, only 27% [$n_1=7$ (18%), $n_2=20$ (33%)] obtained a rating in the high-score category indicating the best practice. Furthermore, the results showed that 60% [$n_1=24$ (60%), $n_2=36$ (60%)] of participants obtained a rating in the average-score category, indicating that they practiced according to suitable but not best recommended practices. The remaining of the participants [13%; [$n_1=9$ (23%), $n_2=4$ (7%)] obtained a low-score rating. The difference between the performance with regard to endotracheal tube cuff pressure monitoring of professional nurses in the critical care units in the public and private sectors was statistically significant ($\text{Chi}^2(\text{d.f.}=2) = 6.86, p = .032, V = 0.26$).

From the results depicted in Figure 4.62, it is clear that professional nurses in the critical care units of both health groups practice according to suitable, but not best, recommended practices. Professional nurses in the critical care units in the private sector obtained a higher rating in the high-score category, implying that they are more inclined to practice endotracheal tube verification according to best recommended practices than public sector nurses, who obtained a higher rating in the low-score category.

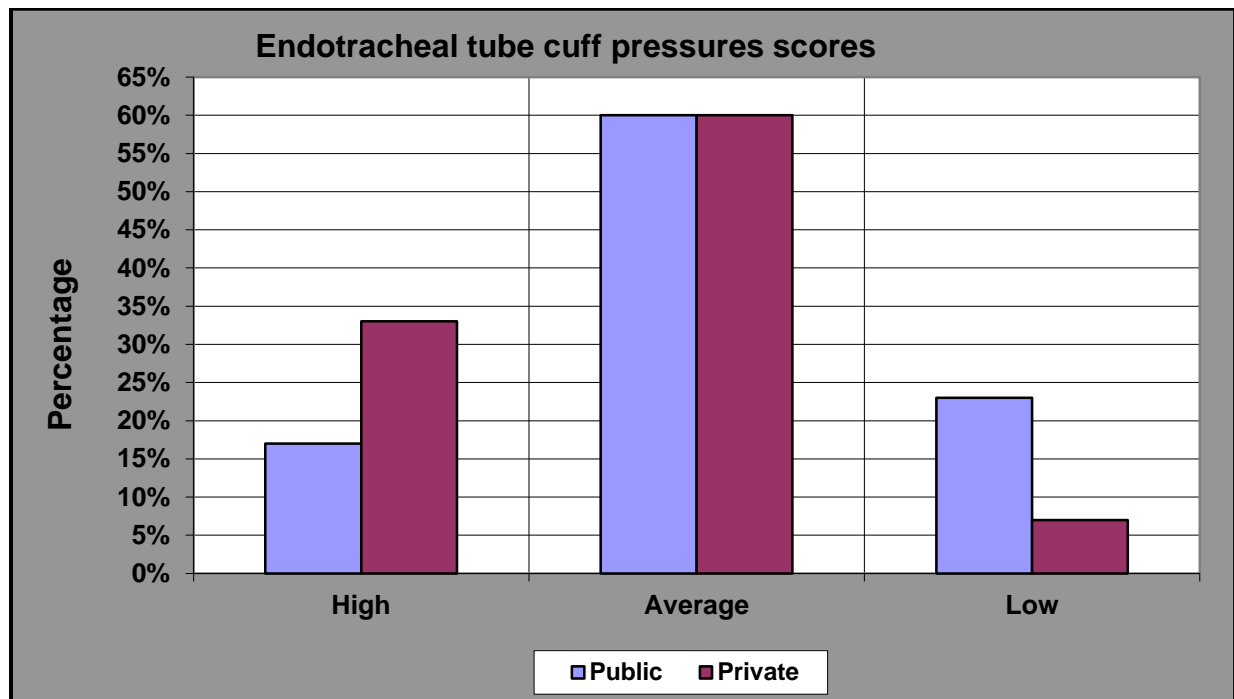


Figure 4.62 Endotracheal tube cuff pressure monitoring scores

4.9.3 Endotracheal tube suctioning

The results for this section showed that 23% [$n_1=9$ (23%), $n_2=14$ (23%)] of participants obtained a rating in the high-score category indicating that they practiced according to the best recommended practice, while 64% [$n_1=23$ (58%), $n_2=41$ (68%)] obtained a rating in the average-score category indicating suitable, but not recommend, best practice. The remaining 13% [$n_1=8$ (20%), $n_2=5$ (8%)] obtained a rating in the low-score category. The difference in responses from professional nurses in the critical care units in the public and private sectors with regard to endotracheal tube suctioning was not statistically significant ($\text{Chi}^2(\text{d.f.}=2) = 2.96, p = .228$). The results are displayed in Figure 4.63.

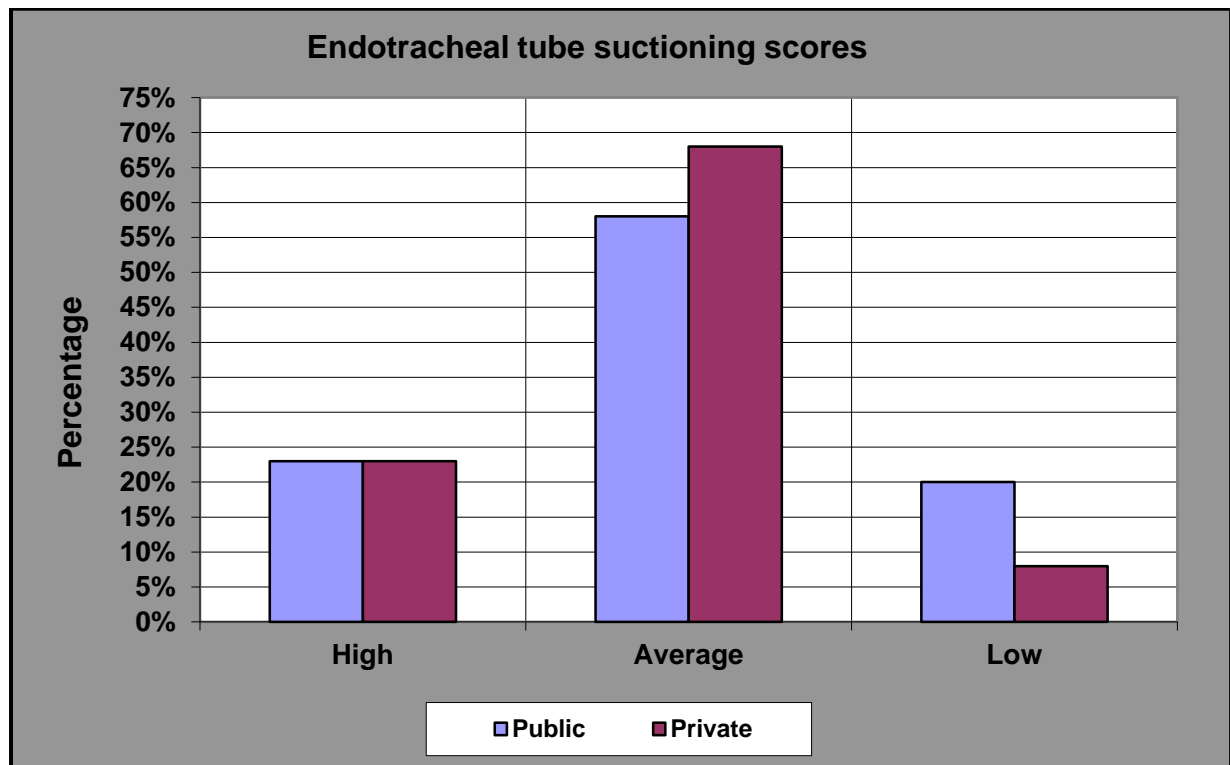


Figure 4.63 Endotracheal tube suctioning scores

4.9.4 Mechanical ventilator settings

Of the 100 participants in the study, 32% [$n_1=15$ (37%), $n_2=17$ (28%)] obtained a rating in the high-score category indicating that they practiced according to the best practices' recommendations. Furthermore, 50% [$n_1=17$ (43%), $n_2=33$ (55%)] of participants obtained a rating in the average-score. The remaining 18% [$n_1=8$ (20%), $n_2=10$ (17%)] obtained a rating in the low-score category. The difference between the responses from professional nurses in the critical care units in the public and private sectors was not statistically significant ($\chi^2(d.f.=2) = 1.53$, $p = .466$). The results are displayed in Figure 4.64.

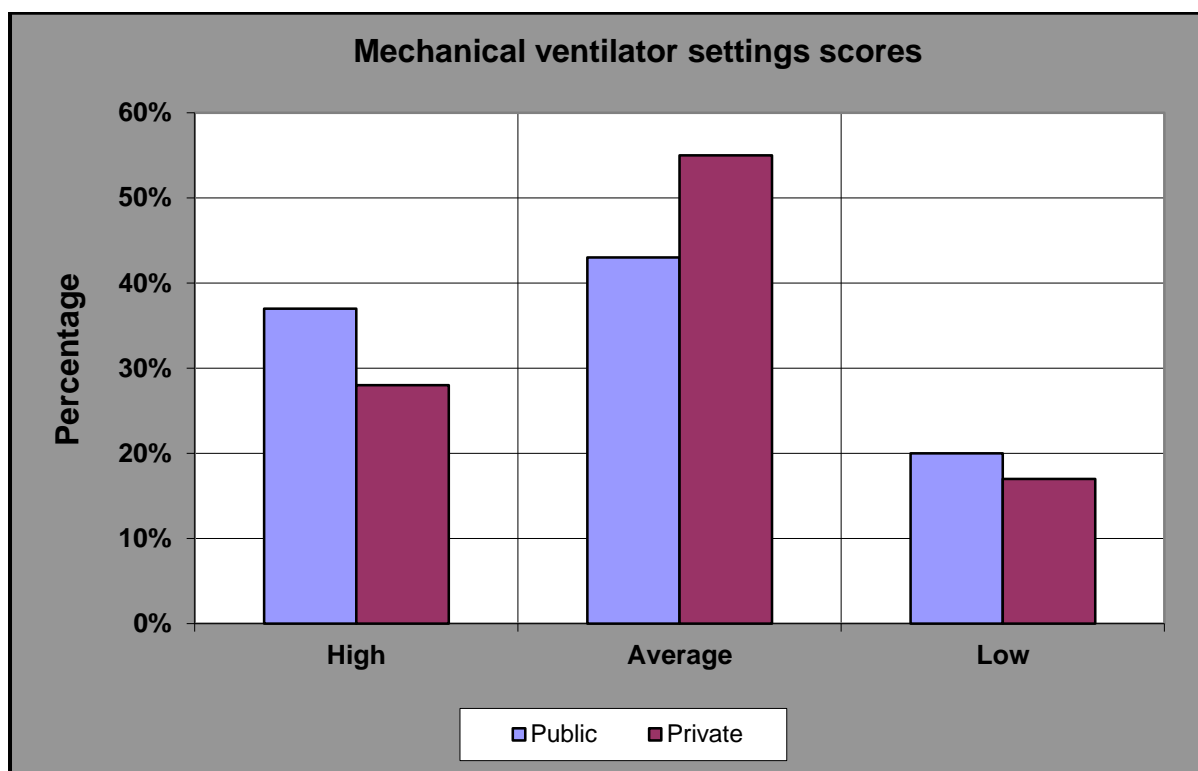


Figure 4.64 Mechanical ventilator settings scores

4.10 THE COMBINED RESULTS OF ALL FOUR NURSING CARE PRACTICES

In combining the results of all four identified nursing care practices, the following was revealed: only 27% [$n_1=13$ (32%), $n_2=14$ (23%)] of participants obtained a rating in the high-score category, which indicated that of the 100 participants, only 27 professional nurses in the critical care units in the Nelson Mandela Metropole performed nursing care according to the best recommended practices, while 62% [$n_1=19$ (48%), $n_2=43$ (72%)] participants obtained a rating in the average-score category, indicating that they performed the nursing care practices suitably, but not according to best recommended practices. The remaining 11% [$n_1=8$ (20%), $n_2=3$ (5%)] obtained a rating in the low-score category, indicating that they did not perform nursing care according to best recommended practice. The differences in the overall performance with regard to the identified nursing care practices between the professional nurses in the critical care units of the public and private sectors were statistically significant ($\text{Chi}^2(\text{d.f.}=2) = 7.92, p = .019, V = 0.20$). The differences in responses were noted in all three scoring categories, indicating that professional nurses in the critical care units in the public sector are more inclined to practice according to best recommendations, while the professional nurses in the critical care

units in the private sector are more inclined to practice according to suitable, but not best, recommended practice. The results are displayed in Figure 4.65.

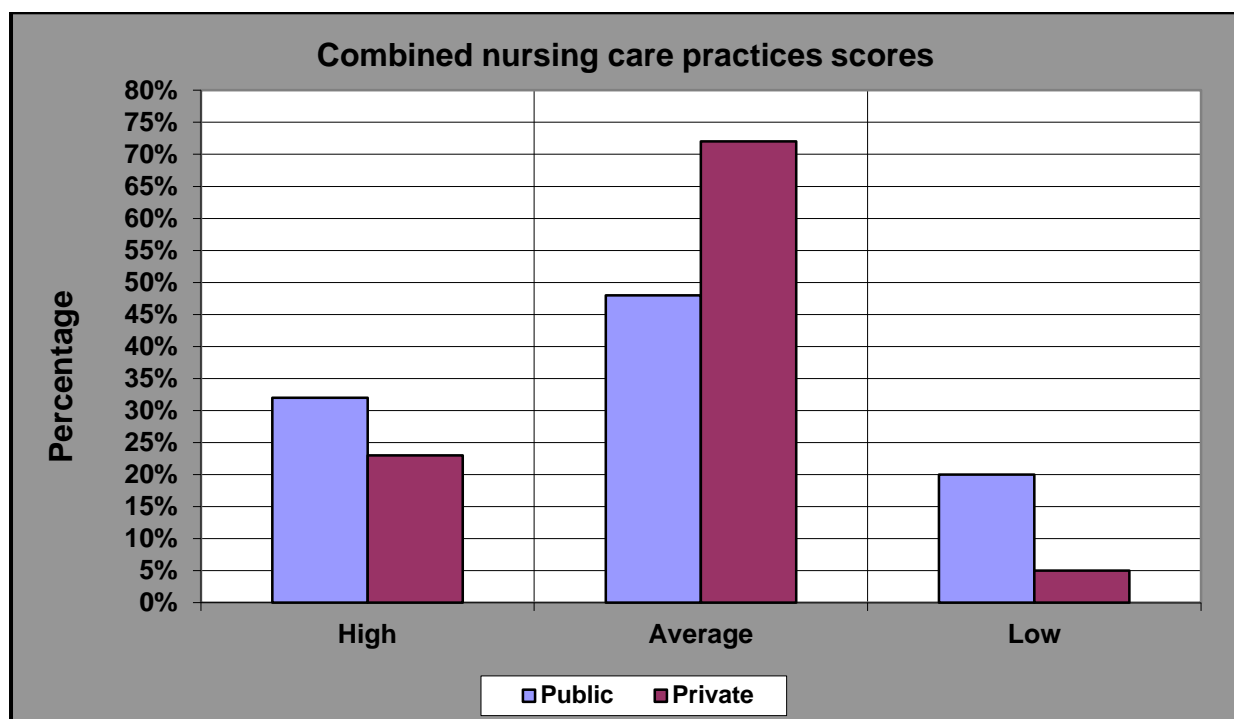


Figure 4.65 Combined results of the four identified nursing care practices

4.11 SUMMARY OF THE RESULTS OF ALL FOUR NURSING CARE PRACTICES

The summary results for the section of the study are depicted in Table 4.19.

Nursing care practice	Scores (%)		
	Low	Average	High
Endotracheal tube verification	9%	50%	41%
Mechanical ventilator settings	18%	50%	32%
Endotracheal tube cuff pressures	13%	60%	27%
Endotracheal tube suctioning	13%	64%	23%

From the summary, it can be concluded that professional nurses in the critical care units (included in the study) in the public and private sectors of the Nelson Mandela Metropole obtained the lowest rating in the high-score category for:

- Endotracheal tube suctioning (23%); and
- Endotracheal tube cuff pressure monitoring (27%).

This implies that these two nursing care practices were least to be done according to the best practice recommendations. These two practices obtained the highest percentage in the average-scoring category, indicating that the participants are performing nursing care which is suitable, but not based on the best practice recommendations. With the exception of the nursing care on mechanical ventilator settings, these two nursing care practices also obtained the highest percentage in the low-scoring category, thus indicating that the majority of professional nurses in the selected critical care units in the public and private sectors in the Nelson Mandela Metropole do not practice endotracheal tube pressure monitoring and endotracheal tube suctioning according to best practice recommendations.

Obtaining the lowest rating in the high-scoring category would imply that professional nurses are least inclined to perform these nursing care practice(s) according to best practice recommendations. Data as analysed, therefore, revealed that the nursing care practices, namely endotracheal tube cuff pressure monitoring and endotracheal tube suctioning, were the least likely to adhere to best practice recommendations. Due to scope of the study and the extent of a systematic review, it was decided to include the nursing care practices which were least likely to be done according to best practice recommendations. Therefore, systematic reviews were conducted on endotracheal tube suctioning and endotracheal tube cuff pressure monitoring.

4.12 SUMMARY OF CHAPTER

This chapter presented the data as derived and analysed from the structured questionnaires. Not only were the different variables analysed, but comparisons were made between the public and private sectors, indicating practice variances between the critical care units of the two health care institutions. The study findings illustrated that professional nurses in the critical care units in the Nelson Mandela

Metropole only partially adhere to best recommended practise. Under the code of professional practice, nurse are obliged to ensure patient safety and are expected by the public and their employers to provide high-quality, efficient, well-executed and appropriate care of individuals, which should be based on the latest available evidence.

Nurses need to assess and improve their current practices continually to guarantee that evidence-informed practices recommendations are being adhered to and patient safety is being assured. This can only be achieved when nurses become more aware of their professional responsibilities, receive adequate support in practice and have the necessary clinical guidelines to aid their decision-making in caring for the patients who are connected to mechanical ventilators. Therefore, based on the study findings, it was decided to develop evidence-informed clinical guidelines on endotracheal tube cuff pressures and endotracheal tube suctioning. A systematic review is core to evidence-based care and the development of clinical guidelines. The next chapter will focus on the systematic reviews done on these two identified nursing care practices.

SYSTEMATIC REVIEW REPORTS

5

“Nothing in this world can take the place of persistence...persistence and determination alone is omnipotent.” Calvin Coolidge

“The hundreds of hours spent conducting a scientific study ultimately contributes only a piece of an enormous puzzle. The value of any single study is derived from how it fits with and expands previous work, as well as from the study’s intrinsic properties. Through systematic review the puzzle’s intricacies may be disentangled.”

- C.D Mulrow

IN THIS CHAPTER

Chapter 1 introduced the reader to an overview of the study. In Chapter 2, the core concepts of the study were described by means of the narrative literature review. Chapter 3 described the research design and method used in this study. Data derived from the structured questionnaires exploring the current nursing care practices as performed by professional nurses in the critical care units in the Nelson Mandela Metropole were graphically presented and discussed in Chapter 4.

This chapter discusses:

The systematic review reports of the two identified nursing care practices namely:

- Endotracheal tube suctioning;
- Endotracheal tube cuff pressure monitoring.

5.1 INTRODUCTION

As already discussed in Chapter 1, four nursing care practices were identified to be included in this research study: endotracheal tube verification, endotracheal tube cuff pressure monitoring, endotracheal tube suctioning and mechanical ventilator settings. A narrative literature review was done on the four identified nursing care practices in Chapter 2. Data derived and analysed from the structured questionnaires revealed that nursing care related to the safety of the mechanically ventilated patient was not consistently done according to best practice

recommendations. Two of the four nursing care practices that obtained the lowest score are described in Chapter 4, thus indicating that they were done least according to best practice recommendations. Due to the scope of the study, it was decided to perform a systematic review of these two practices (see Table 4.19).

The two identified nursing care practices include:

- Endotracheal tube suctioning; and
- Endotracheal tube cuff pressure monitoring.

As described in Chapter 3 of this study, systematic reviews are the core of evidence-based practice. On completion of a systematic review, it is important to disseminate the information in the form of a systematic review report. Systematic review reports can provide a sound basis for clinical guideline formulation and give a comprehensive background justifying the reasons for conducting the review, a description of the questions for the review, an account of the criteria that were used to consider inclusion and exclusion of studies for the review, the search strategy used, methods utilised for critical appraisal, extraction and synthesis of data. Furthermore, the systematic review report includes a description of studies, including the type and number of papers identified and a summary of the overall quality of the papers identified. The discussion should include an overview of the results and aims to address issues arising from the conduct of the systematic review, including limitations. The final systematic review report should include appendices of critical appraisal tools, data extraction forms and tables of included and excluded studies (Pearson *et al*, 2007:102).

In this chapter, the systematic review reports will be discussed for each of the two identified nursing care practices related to the safety of the mechanically ventilated patient in a critical care unit. Copies of the critical appraisal forms, data extraction forms and tables of excluded studies with the justification for exclusion are attached in the list of Annexures K-S.

5.2 ENDOTRACHEAL TUBE SUCTIONING

The respiratory mechanics in a healthy patient allow for clearing debris from the lungs by means of the cough reflex and action of the ciliated cells of the respiratory

system. The presence of an artificial airway bypass the normal physiological processes and inhibits the cough reflex, which might prevent glottis closure, increase the production of mucus and increase the patient's susceptibility to infection. Endotracheal suctioning is necessary to facilitate the removal of airway secretions and is an essential part of care for patients receiving mechanical ventilation in a critical care unit (Morton and Fontaine, 2009:578).

Endotracheal tube suctioning is often performed on the basis of the assumption that it maintains airway patency and prevents pulmonary infection. However, this procedure is associated with complications and risks including bleeding, infection, atelectasis, hypoxemia, cardiovascular instability, elevated intracranial pressure, tissue trauma to the trachea or bronchial mucosa and broncho-constriction (Adam and Osborne, 2005:103). Endotracheal tube suctioning is experienced differently by patients. According to a study done by Jordan, van Rooyen and Strumpher (2002:31), some patients reported that the procedure was helpful and provided relief as breathing was made easier after the secretions have been removed, while others said that the procedure produced pain and discomfort and that they would rather not have it. Considering the patient discomfort and potential risks and associated complications linked to endotracheal suctioning, it is thus important that the procedure be performed according to the latest and best available evidence to guide practice.

Three clinical practice guidelines related to suctioning have been published thus far. The American Association of Respiratory Care provides guidelines for suctioning mechanically ventilated adults and children with artificial airways (Branson *et al*, 1993:500-534). A clinical practice guideline, based on a systematic review, for suctioning the airway of the intubated and non-intubated adult and child was published in 2001 (Brooks *et al*, 2001:163-182). A national best practice guideline on endotracheal suctioning of adults was published in 2007 (Perrie and Scribante, 2007:1-10). Furthermore, The Joanna Briggs Institute for Evidence Based Nursing and Midwifery (Thompson, 2000:1-6) published a best practice information sheet based on a systematic review of tracheal suctioning for adults with an artificial airway. The best practice guideline that is available at national level does not appear

to follow a consistent, structured, rigorous critical appraisal, data extraction and synthesis approach and should thus be used with caution. Furthermore, the previous reviews and clinical practice guidelines included adults, children and non-intubated patients, with no specific contextualisation to critical care units.

Given the concerns about the previous reviews, the numerous gaps in evidence on endotracheal tube suctioning, as well as the lack of practice according to the latest available evidence as illustrated in Chapter 4 of the study, the need arose to perform a systematic review on the most recent literature on the methods and techniques related to endotracheal tube suctioning in adult mechanically ventilated patients.

The purpose for performing a systematic review in this study was to:

- Perform an updated systematic review on endotracheal tube suctioning in the adult, intubated mechanically ventilated patient, as the previous reviews were out-dated and included adults, children and non-intubated patients;
- Search for literature that addresses the specific nursing care interventions in relation to endotracheal tube suctioning methods, as identified from the analysed data in the structured questionnaires completed by the professional nurses in the critical care units in the Nelson Mandela Metropole. Normal saline instillation, hyperinflation, suction pressures and the frequency of the suctioning procedure were some of the interventions that obtained the lowest scores (see Table 4.12);
- To use the information obtained from the systematic review to develop an evidence-informed clinical guideline in the critical care unit for adult mechanically ventilated patients, especially since it appears that no evidence-informed clinical guidelines are currently available in the Nelson Mandela Metropole.

Based on the literature found, evidence-informed clinical guidelines are provided to ensure that nursing care practices related to endotracheal tube suctioning is done safely and according to the best evidence available.

The items for discussion in this section of the research study are reflected in Table 5.1.

Table 5.1 Items for discussion on the systematic review report on endotracheal tube suctioning	
5.2.1	METHODS
5.2.1.1	The review question
5.2.1.2	Searching for evidence
5.2.1.3	Selection of evidence
5.2.1.4	Critical appraisal
5.2.1.5	Data extraction
5.2.1.6	Data analysis and synthesis
5.2.2	DISCUSSION AND RESULTS OF THE SYSTEMATIC REVIEW
5.2.2.1	Description of evidence
5.2.2.2	Results
5.2.3	SUMMARY FOR THE SYSTEMATIC REVIEW ON ENDOTRACHEAL TUBE SUCTIONING

5.2.1 METHODS

This section of the research study aim to describe the methods as applied in conducting the systematic review on endotracheal tube suctioning in the adult mechanically ventilated patient.

5.2.1.1 The review question

The PPC format, as described in Chapter 3, was used in the structuring of the question where the population (P) refers to the adult intubated patient, the phenomenon (P) of interest is the endotracheal tube suctioning and the context (C) refers to the critical care unit. Based on the above premise, the following review question was thus posed:

- How should endotracheal tube suctioning in the adult mechanically ventilated patient in a critical care unit be done in order to minimise and/or prevent the complications associated with the procedure?

The formulated review question was supported by the data analysed in Chapter 4, which was related to the nursing care practices on endotracheal tube suctioning in the mechanically ventilated patient in the critical care unit. Data analysis revealed that nursing care practices with regard to the methods and/or techniques and solutions used for endotracheal tube suctioning was least done according to best practice recommendations. Practice variances amongst professional nurses existed in the critical care units in both the private and public sectors.

5.2.1.2 Searching for evidence

An initial search strategy was devised prior to undertaking the literature searching process. The three-step approach, as set out in the search strategy, described in Chapter 3 of the study, was used to search for literature. CINAHL, MEDLINE (via PubMed), EBSCO HOST, the JBI systematic review library, the Cochrane Library, clinical evidence from the British Medical Journal (BMJ), the National Guidelines Clearinghouse and Google Scholar were initially searched using broad terms, for instance, “endotracheal tube suctioning”.

Step two involved searching all the above data bases using the identified search terms and the inclusion and exclusion criteria to determine which papers had to be retrieved. Search terms used for identifying literature pertaining to endotracheal tube suctioning were for instance “endotracheal suctioning AND Adult NOT neonate”; “tracheal* AND suctioning”; “ventilation AND suctioning”; “mechanical ventilation AND suctioning OR suction*”; “endotracheal tube suctioning”. The search terms pertaining to the various databases are reflected in Annexure I. The inclusion and exclusion criteria used in identifying the appropriate literature are described later in this chapter.

Step three comprised of searching the reference lists and bibliographies of all papers for identification of additional studies. Other databases that were found during this searching process included Highwire, Ingenta, the online Worldviews on Evidence-Based Nursing. Pearl-growing within these databases allowed access to other pieces of literature that probably would have been missed. Furthermore, hand searching for articles in critical care, respiratory, emergency care and anaesthetic

journals was done to ensure that all possible evidence was included. The local university and health care institution libraries were used to access these journals. Abstracts on the topic were also identified. Librarians aided in obtaining the full articles if the abstracts proved to be relevant to the topic. Abstracts with sufficient information to allow methodological assessment were included in the review. The librarians and the interlibrary loan facility assisted in obtaining articles that could not be accessed via the local university. A search for conference papers, unpublished dissertations and thesis was done. Two dissertations related to the knowledge of professional nurses regarding mechanical ventilation were found. One thesis relating to clinical guidelines for the neonatal critical care unit was found. However, these studies could not be included in the review as they did not address the focus of the research. The Critical Care Society of Southern Africa was contacted to find out if any literature was available at national level. One best practice guideline on endotracheal tube suctioning of adults was found and included for critical appraisal in the review.

5.2.1.3 Selection of evidence

The inclusion and exclusion criteria, as stated in the systematic review protocol, were used to guide the selection of studies to be included in this review. The inclusion criteria considered the types of evidence, types of participants, types of interventions, types of outcomes measures, language of publications, and the time period the studies were conducted and published. The inclusion and exclusion criteria are discussed below.

5.2.1.3.1 Inclusion criteria

The papers selected for inclusion in the review had to adhere to the criteria as set out below.

Types of evidence

In order to draw on all types of evidence, all papers that described endotracheal tube suctioning were included in the systematic review. Therefore, best practice information sheets, clinical practice guidelines, randomised and non-randomised control trials, cohort studies, observational and descriptive studies, systematic

reviews based on randomised control trials and meta-analysis, expert opinion and literature review papers were envisaged to be included in the systematic review.

Papers were assessed against the evidence hierarchy for rating levels of evidence, as stated in LoBiondo-Wood and Haber (2010:16). The number of studies (according to the hierarchy of evidence) initially located is shown in Table 5.2. The papers included were based on relevance to the review question, prior to the critical appraisal process. A description of the total amount of papers found is reflected in Figure 5.1.

Table 5.2 Papers included for the critical appraisal on endotracheal tube suctioning (adapted from LoBiondo-Wood and Haber, 2010:6)		
Level	Types of evidence	No of papers allocated
I	Systematic review or meta-analysis of randomised control trials	0
	Clinical practice guidelines based on systematic reviews	0 (+2)
II	A well-designed randomised controlled trail	7
	Randomised cross-over studies	5
III	Controlled trial without randomization (quasi-experimental study)	5
IV	Single non-experimental study:	
	• Observational	3(+1)
	• Case reports	0
V	Systematic reviews of descriptive and qualitative studies	0
VI	Single descriptive or qualitative study	0
VII	Opinion of experts and/or reports or expert committees	
	Conference papers	
	Literature review papers (added by the researcher)	15(+2)
	Best practice information sheets/guidelines	1 (+1)
Total number of papers		36 (+6)=42

Note the papers indicated in brackets () were excluded after the critical appraisal

Types of participants

All studies that comprised human, adult patients aged 18 years and above were included in the systematic review. In addition, the participants in the included studies had to have been intubated with an artificial airway, namely an endotracheal tube or tracheostomy. Being connected to a mechanical ventilator in a critical care unit was not considered to be compulsory for inclusion in the systematic review. The rationale for this was that endotracheal tube suctioning can be performed in an emergency room, operating theatre, recovery room and high care units. Despite the context or clinical area, the techniques and solutions used prior to and during endotracheal tube suctioning remain the same as those implemented in a critical care unit.

Types of interventions or activities

Interventions of interest include those related to endotracheal tube suctioning, irrespective of whether it is closed or open suctioning. Specific interventions included suctioning techniques and instillation of normal saline prior to and during endotracheal tube suctioning.

Types of outcome measures

The primary outcome is reduced suctioning-related complications. Secondary outcomes include reduced duration of mechanical ventilation, duration of stay in the critical care unit, increased patient safety and a decrease risk for adverse effects related to the complications of suctioning.

Language of publications

No language restrictions were applied to the initial search. However, after exploring the translation cost per article, it was decided to exclude all studies that were not published in English. Three articles that were not published in English were found and were thus excluded from inclusion in the review (see Annexure K).

Time period

Studies dated back to the year 1990 were included in the systematic review.

5.2.1.3.2 Exclusion criteria

Due to the differences between the human and animal normal anatomical and physiological responses, it was decided to exclude all animal studies from the systematic review. For the same reason, all studies conducted in the neonatal or paediatric settings were also excluded. See Annexure K for the characteristics of the studies excluded from the systematic review.

5.2.1.4 Critical appraisal

The methodological quality of studies was assessed using the critical appraisal tools within the JBI NOTARI and MASTARI modules accessed via the SUMARI software packages, Version 4.0. The JBI NOTARI module accessed via the CReMS in the SUMARI software package was used to critically appraise the opinion, conference and literature review papers found. See Annexure Q for a copy of the critical appraisal tool used.

The MASTARI module accessed via the CReMS in the SUMARI software package was used to appraise Levels II, III and IV evidence found. Different critical appraisal tools were available for different types of evidence used. Once the study design was entered, the critical appraisal tool for the specific design was made available. See Annexures N, O and P for copies of the critical appraisal tools used. The AGREE appraisal tool was used to assess the quality of the clinical practice guidelines or best practice guidelines available on endotracheal tube suctioning. The AGREE instrument was discussed in Chapter 3 of this study.

Two reviewers independently appraised the papers found. The primary reviewer (the researcher) collated the results in order to make the final appraisal. When discrepancies were detected between the appraisal results of the two reviewers, consensus discussions were held to establish the reasons for the indiscrepancies. After consensus was reached by the two reviewers, the final selection of papers was done for inclusion in the systematic review.

5.2.1.5 Data extraction

Data from each study was extracted using the data extraction tools in the JBI SUMARI software packages. Following the critical appraisal process, the details of each study and paper were entered into the respective data extraction tools available within the NOTARI and MASTARI modules.

NOTARI was used to capture each of the papers that were appraised in Level VII. Each paper was carefully read and re-read in order to capture all the details needed for extraction. Special attention was given to the conclusions and recommendations made in the papers in order to understand the core concepts and ideas. Extraction details for Level VII opinion, conference and literature review papers included the following:

- Type of text, for example, an expert opinion, a best practice information sheet or a literature review paper;
- Those who are represented in the paper, referring to whom the study refers or relates to;
- The setting where the research was conducted, for example, a critical care unit;
- The geographical context refers to the location of the research,
- The cultural context refers to features of the study such as age, gender, ethnicity of the study population;
- The clarity and logic of each paper's presentation and argument. The reviewer had to assess whether there were enough evidence provided to support the assumptions or conclusion made in the study;
- The author's conclusions, stating the main findings of the publication (www.joannabriggs.edu.au).

The data extraction tools in MASTARI module accessed via the SUMARI software package were used to extract data for Level II, III and IV evidence. The extraction-details' page lists a range of fields which describe the study: method, setting, participants, number of participants, interventions, author's conclusions and reviewer conclusions. These fields are present in each of the different study design types that can be included in a systematic review using JBI-MAStARI; however, the exact

details differ slightly for different study designs. It was particularly important that the number of participants' field was completed, as this data was used in later calculations. Also, in the interventions field, where a new or modified intervention (the 'treatment') was being compared to a traditional or existing procedure (the 'control'), the treatment(s) as intervention A (whose participants are in group A) and the control as intervention B (whose participants are in group B) were recorded.

No data extraction tool was available for the AGREE tool, therefore, data was summarized using the different headings as stated in the AGREE appraisal tool.

5.2.1.6 Data analysis and synthesis

Following the data extraction process, data analysis and synthesis were done using the SUMARI software packages. The JBI NOTARI software package allowed for conclusions and categories to be formulated and captured. Conclusions are principal findings reached by a reviewer after examining the results of data analysis (e.g., themes, metaphors) consisting of a statement that relates to two or more phenomena, variables or circumstances that may inform practice. Categories are groups of conclusions that reflect similar relationships (www.joannabriggs.edu.au).

The content of each Level VII paper included, after being critically appraised, was summarized in order to provide a description of it. The main findings of each paper were summarized in a table format, stating the author and publication details, the aim of the paper, the type of study or paper, the main findings and its strengths and limitations. A code(s) was then assigned to the main finding(s) of the paper, for instance, if it focussed on the effects of normal saline instillation, the code assigned was normal saline instillation. Once each paper was coded, the codes were grouped to formulate a conclusion on the paper. The conclusions were used to formulate categories. The synthesized data are illustrated in Table 5.3.

Table 5.3 Synthesized data from evidence found on endotracheal tube suctioning	
Category	Conclusions (on the nursing interventions related to endotracheal tube suctioning)
Assessment prior to endotracheal tube suctioning	Patient assessment
	Frequency of endotracheal tube suctioning
	Hyperinflation and hyperoxygenation
	Normal saline instillation
Implementation of endotracheal tube suctioning	Suction catheter size selection
	Depth of suction catheter insertion
	Duration of the suctioning procedure
	Suction pressure
Evaluation following endotracheal tube suctioning	Patient assessment

The MASTARI module in the SUMARI was used for synthesis of data appraised. Once data is captured on MASTARI, it automatically becomes available on CREMS for synthesis. However, in assessing the various studies, it was noted that the outcomes were not similar. Furthermore, not all the studies gave an account of their statistical analysis used, for instance, reports on the standard deviations and other inferential statistics. Due to the heterogeneity of the studies, it was thus not possible to perform a meta-analysis and to present the data in the form of a forest plot.

Summaries were made for each paper once critically appraised. The main findings were coded, and where possible, they were linked to the categories formulated from the Level VII evidence as discussed.

The same process of identifying main findings, coding and categorizing literature was applied to the clinical guidelines once critical appraisal by means of the AGREE tool was done.

5.2.2 DISCUSSION AND RESULTS OF THE SYSTEMATIC REVIEW

The results of the systematic review will be discussed in this section of the study. The section is organized according to categories and conclusions as set out in Table 5.3. A description of the studies found and critically appraised as per the systematic review is also discussed in this section.

5.2.2.1 Description of evidence

The initial search of literature identified 100 possible papers for inclusion in the systematic review after eliminating duplications (n=15), abstracts (n=10) that were insufficient to provide adequate data (full text articles could not be obtained via the interlibrary loan facility), and studies (33) that did not appear to answer the systematic review question and did not adhere to the inclusion criteria (see characteristics for excluded studies: Annexure K). Papers were excluded for the following reasons:

- Animal studies (two);
- Languages other than English (three);
- The incidence of VAP related to suctioning (eight);
- Paediatrics (ten)
- Not relevant and related to the review question (ten).

A total of 42 papers were included for critical appraisal (see Table 5.2).

Following the critical appraisal process, six papers were excluded for inclusion in the systematic review. Three were literature review papers (Level VII), and were excluded as they had out-dated references ranging back to the early 1980s. Two papers addressed the effects of hyperinflation, but were not directly related to the endotracheal suctioning procedure. The AARC (Branson *et al*, 1993:500-534) respiratory clinical guideline, which was out-dated and contained data that conflicted with newer data was excluded, as well as the second clinical guideline (Brooks *et al*, 2001:163-183) found as it mainly focussed on non-intubated, adult and children recommendations. The national best practice guideline (Perrie and Scribante, 2001:1-10) was excluded from the review as it appeared that a rigorous process was not followed in the development of the guideline. A total of 36 papers were thus

included in the systematic review for endotracheal tube suctioning. Figure 5.1 reflects the search results.

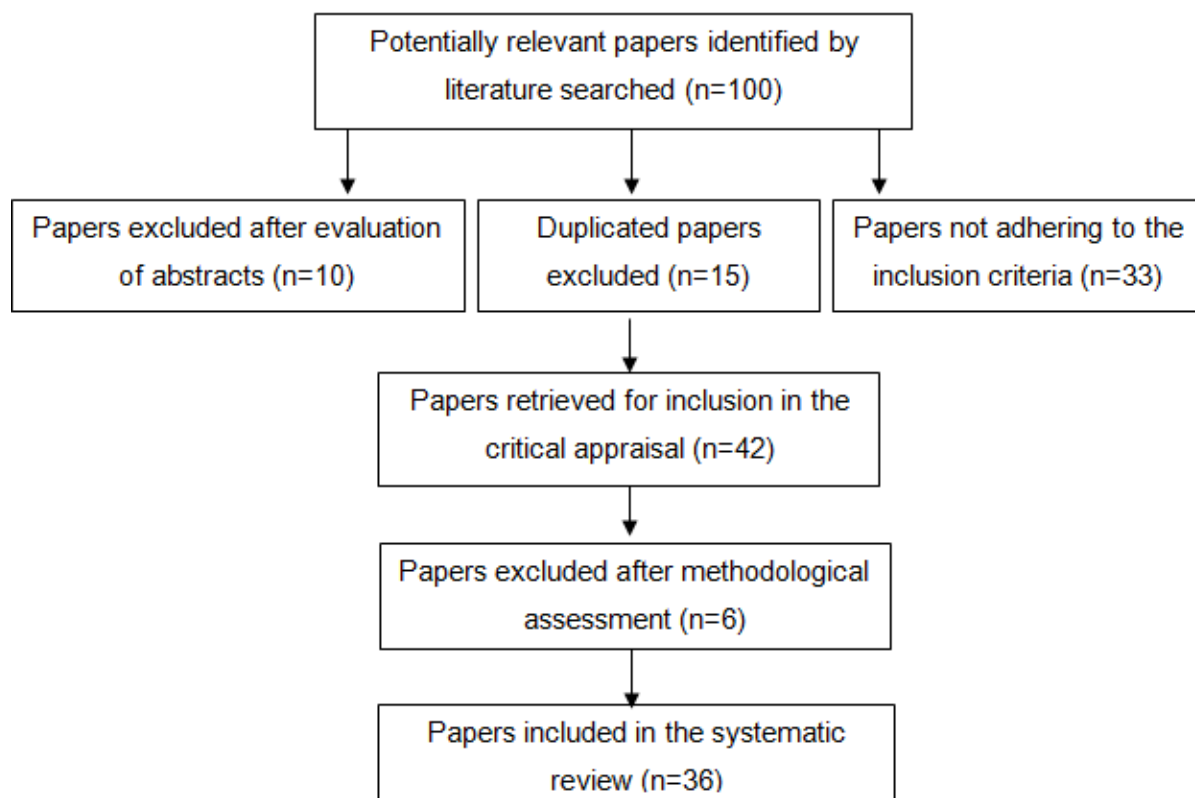


Figure 5.1 Results of the papers found and included in the systematic review: endotracheal tube suctioning

5.2.2.2 Results

The results of the systematic review on endotracheal tube suctioning will be discussed under the headings as set out in Table 5.3.

5.2.2.2.1 Assessment prior to endotracheal tube suctioning

The purpose of assessing a patient is to recognize changes in the patient's health status that would necessitate nursing or medical intervention. In this section of the research, assessment refers to the assessment of patient to establish the need for endotracheal tube suctioning, how often it should be done, and what solutions and methods should be used in preparation for the procedure.

5.2.2.2.1.1 Patient assessment

Patient assessment in the mechanically ventilated patient who requires endotracheal tube suctioning includes history taking, and performing a physical examination. In reviewing this section of the research, data pertaining to the patient assessment prior to endotracheal tube suctioning was extracted from four literature review papers, one best practice sheet (Level VII evidence), and one observational study (Level IV).

Glass and Grap (1995:51) report in a literature review paper on tips for safer suctioning that the procedure should only be done when the patient is coughing or experiencing respiratory distress. A physical assessment should be done prior to performing endotracheal tube suctioning as the auscultation findings revealing rhonchi indicate the need for endotracheal tube suctioning. The authors of this paper also indicated that other parameters, for instance, pressure rises on the ventilator and a decrease in PaO₂ or SaO₂ might indicate the need for endotracheal tube suctioning in the critically ill intubated patient.

According to the best practice information sheet authored by Thompson (2000:2), clinical respiratory assessment indicators for endotracheal tube suctioning include coarse breath sounds, noisy breathing, and prolonged expiratory breath sounds on auscultation. The best practice information sheet was based on a systematic review published on the JBI systematic review database and indicated a rigorous process for literature searching. Therefore, even if it is a Level VII type of evidence, the information can be used for the recommendations in the development of the clinical guideline.

Day, Farnell and Wilson-Barnett, (2002:86) performed a literature review on 59 papers in which they explicitly explained the searching process. For the purpose of the literature review performed by these authors, CINAHL and MEDLINE data bases were searched from 1990 to 2001. In their report, they state that endotracheal tube suctioning should be performed following a comprehensive assessment of the patient's respiratory status, which should include a chest auscultation.

Branson (2007:1334) conducted a literature review to explore the secretion management in the mechanically ventilated patient. According to the recommendation in this paper, patient assessment including a lung auscultation and visual inspection of the chest should be done prior to performing endotracheal tube suctioning to determine the need for it.

Pedersen, Rosendahl-Nielsen, Hjerminde and Egerod (2009:23) illustrate the importance of assessing the patient prior to performing endotracheal tube suctioning in a literature review paper comprising of 77 papers (four qualitative, 19 literature reviews, two meta-analysis and 52 clinical trials). The methods in searching for literature and critically appraising data and analysis of the evidence obtained is clearly explained in the literature review paper, thus making the article credible and trustworthy for incorporating extracted data into the final review and recommendations. According to the findings in this literature review paper, endotracheal tube suctioning should only be performed once the patient assessment has been done. Indications for suctioning are cough, rhonchi or audible secretions on auscultation, increased airway pressure, desaturation or increased work of breathing. The authors recommend auscultation as part of clinical assessment prior to implementation of endotracheal tube suctioning.

In an observational study done by Guglielminotti, Alzieu, Maury, Guidet and Offenstadt (2000:1095) on 66 patients requiring mechanical ventilation, predictors of retained secretions were assessed. This study signified the importance of performing a patient assessment. They found that if respiratory breath sounds were present over the trachea area on auscultation, the presence of secretions to be greater than 0.5 ml was more likely. The study also reveals the need to use the mechanical ventilator pressure and flow curves that might suggest the need for suctioning. The most common finding in their study was a saw tooth pattern in the expiratory flow signal on the mechanical ventilator graphs that suggest secretions in the large airways.

Based on the findings of the evidence found, it can be concluded that patient assessment prior to endotracheal tube suctioning should be part of the nursing care

rendered to a patient who is intubated and requiring mechanical ventilation. The patient assessment should include a lung auscultation. Clinical indicators for suctioning should be used when determining the need for endotracheal suctioning in the intubated patient. However, apart from the clinical data obtained from the lung auscultation, it is important that the nurse practitioner use other parameters, for instance, the ventilator graphics, where a saw-tooth appearance is visible to assess the need for suctioning.

5.2.2.2.1.2 Frequency of the suctioning procedure

Traditionally, nurses were taught to perform endotracheal tube suctioning on patients routinely, perhaps every two hours. However, it has been documented in several of the literature and opinion papers found that routine endotracheal tube suctioning might increase the risk for complications and adverse effects, for instance, increasing the production of airway secretions, possible trauma to the airway, infection, hypertension and cardiac arrhythmias. Therefore, it is recommended that endotracheal tube suctioning should not be done routinely but rather by individualized patient assessment (Glass and Grap, 1995:51; Thompson, 2000:2; Day *et al*, 2002: 87; Branson, 2007:1334).

Jelic, Cunningham and Factor (2008:210) support the recommendation in their literature review paper stating that suctioning has been associated with deleterious adverse effects such as decreased arterial oxygen tension, mucosal injury and risk for airway infections. In order to minimize the adverse effects, endotracheal tube suctioning in the intubated patient should be performed on an as-needed basis that is defined by the quantity of secretions obtained and not at prescribed set intervals. Pedersen *et al* (2009:23) agree that due to these possible suctioning-related complications, it is recommended that suctioning be done only when necessary, and not routinely.

A quasi-experimental study was done to compare if there were any differences in endotracheal tube suctioning outcomes between patients receiving routine 2-hourly suctioning and endotracheal tube suctioning performed on the basis of the nurse's clinical judgement following training in clinical assessment. The patient sample

comprised nine patients assessed before endotracheal tube suctioning and five patients of varying age, sex and diagnosis having routine endotracheal tube suctioning. The mean age for the assessed group was 56 and 55 for the control group. There were 87 suction episodes recorded in the assessed group and 92 in the 2-hourly routine groups. Data was collected by means of questionnaires for nurses, which were then used to assess the nurses' levels of knowledge related to endotracheal tube suctioning. A patient assessment form was designed to record the physiological variables and criteria the nurses used as indicators for endotracheal tube suctioning. The study results show that if endotracheal tube suctioning was performed when needed and only after doing a physical assessment, accumulated secretions were successfully cleared. Furthermore, it was proven that if a minimum frequency is deemed necessary to maintain a clear airway then, unless indicated, every two hours is too frequent as no secretions were cleared for 46% of the time the procedure was performed. The study also proves that endotracheal tube suctioning performed only when necessary appears to be less distressing to the patients. However, the study shows no statistically significant difference in complications related to the frequency of suctioning, namely decreased saturation, peak airway pressure, heart rate, rhythm and means arterial pressure (Wood, 1998:176). The clinical implication of this study, however, was limited due to the small sample size and was applicable to short-term ventilated patients only.

A randomised control clinical trial done by Van de Leur, Zwaveling, Loef and van der Schans (2003:426-432) assessed the effects of routine versus minimally invasive suctioning. The study included 380 patients requiring endotracheal intubation for more than 24 hours. Of these patients, (n=197) received routine suctioning while the control group (n=186) received minimally invasive suctioning only when needed. It was found that suction-related complications occurred more frequently with routine suctioning. These events included decreased saturation ($p=0.010$), increased systolic blood pressure ($p<0.001$), increased pulse rate ($p=0.007$) and blood in mucus ($p<0.001$). The study thus conclusively supports the fact that endotracheal tube suctioning should only be done when needed as per assessment findings and clinical indicators and should not be performed routinely.

Thompson (2000:2) states in the best practice information sheet that suctioning should only be done when clinically necessary. Practitioners should use the clinical assessment indicators as a guide for performing endotracheal tube suctioning. These clinical indicators includes coarse breath sounds, noisy breathing, crackles, wheezes and prolonged expiratory breath sounds, which can be heard when doing a chest auscultation.

In a literature review paper by St John (2004:93), it is stated that suctioning frequency should be based on the clinical need of the patient and not on a fixed schedule. The clinical indications include secretions in the endotracheal tube, frequent or sustained coughing, adventitious breath sounds on auscultation, e.g., rhonchi, desaturation related to airway secretions, increased peak airway pressures and sudden onset of respiratory distress. A physical assessment is thus necessary prior to performing endotracheal tube suctioning as it can aid in determining the need for suctioning rather than doing it routinely.

Limiting the frequency of suctioning may prevent adverse effects and suctioning-induced complications as stated by Jelic *et al* (2008:209). However, apart from the adverse events associated with more frequent suctioning, Wood (1998:177) states that it is expensive, inefficient and a wasteful use of valuable resources when endotracheal tube suctioning is applied routinely and without clear indications. Therefore, it is recommended that health care practitioners use their physical assessment skills to determine if a patient requires endotracheal tube suctioning, rather than performing the procedure on a routine basis.

In reviewing the literature found, no definite recommendation was made for the intervals when endotracheal tube suctioning should be done. However, it is recommended that the frequency of performing endotracheal tube suctioning be guided by the clinical indicators and the physical assessment data as done by a health care practitioner. Routine endotracheal tube suctioning is not recommended.

5.2.2.2.1.3 *Hyperinflation and hyperoxygenation*

Hyperinflation is the practice of inflating the patient's lungs with extra volumes of air, which can either be done by means of using a manual ventilation bag or via a mechanical ventilator before suctioning. The aim of hyperinflation is to improve the patient's oxygenation capacity by recruiting pulmonary volume and loosening secretions. It has also been demonstrated that hyperinflation improves total lung compliance, aids in resolving atelectasis and improves gas exchange in mechanically ventilated patients. Hyperinflation further aims to assist mobilisation of pulmonary secretions in addition to endotracheal tube suctioning in the intubated patient (Jones, 2002:321).

Two studies were found that assess the effects of using hyperinflation prior to endotracheal tube suctioning in the mechanically ventilated patient. In a RCT done by Barker and Adams (2002:157-169) using 17 patients with acute lung injury requiring mechanical ventilation, the use of hyperinflation had no effect on oxygenation, heart rate, blood pressure and dynamic lung compliance. Three groups of patients were used in the study where the control group (n=7) received hyperinflation prior to endotracheal tube suctioning. The other two groups did not receive hyperinflation. Study results show that the use of hyperinflation did not have any effect on the outcomes measured in comparison with the patients that did not receive hyperinflation.

The above study results are supported by a RCT done by Stone (1990:289-299). The author of the study used 26 post-cardiac surgery intubated and mechanically ventilated patients. Hyperinflation was done using five different inspiratory volumes by means of the mechanical ventilator. The heart rate and the oxygenation levels were assessed during the use of hyperinflation. The study results show no clinical significant difference in the oxygenation and heart-rate parameters. In reviewing the above two studies, it appears that the use of hyperinflation with a reservoir ventilation bag or even when using different volumes by means of a mechanical ventilator does not have any effect on the oxygenation, hemodynamic parameters or lung compliance when used prior to endotracheal tube suctioning. See Table 5.4 for a summary of the study results.

Table 5.4 Summary of studies on hyperinflation				
Author reference, study design	n	Patient type	Outcomes measured	Summary of main results
Barker and Adams, 2001, RCT	17	Patients in the critical care unit with acute lung injury (ALI) <u>Group 1</u> (n=5) suctioned in supine position <u>Group 2</u> (n=5) suctioned in alternative side <u>Group 3</u> (n=7) suctioned with hyperinflation used	PaO ₂ Heart rate Blood pressure Dynamic lung compliance	No significant difference noted between the groups for any of the outcomes measured when using hyperinflation
Stone, 1990, RCT	26	Post-cardiac surgery intubated and mechanically ventilated. Patients hyperinflated at 5 different inspiratory volumes (TV 12, 14, 16, 18 ml/kg)	PaO ₂ Heart rate	No clinically significant difference in PaO ₂ and heart rate noted using hyperinflation with different volumes by means of a ventilator

In fact, evidence found indicates that the use of hyperinflation can have negative effects for the intubated patient. Hyperinflation is associated with the risk of barotrauma, cardiovascular instability and increased intracranial pressure. Therefore, it should be used with caution in patients who have raised intracranial pressure,

those patients who are in the post-operative period following vascular or cardiac surgery and those who are hemodynamically unstable (Thompson, 2000:3; Day *et al*, 2002:80). Large variations in peak inspiratory pressure, tidal volume, respiratory rate and I:E (inspiratory:expiratory) ratio have been shown during hyperinflation. These can have detrimental effects on cardiac output and oxygen delivery (Singer, Vermaat and Hall, 1994:1182-1187; Clark, Kelly, Convery and Free, 1999:936-940).

From the evidence as stated above, it can be concluded that hyperinflation alone can have negative effects and it is not beneficial for the intubated patient. However, studies were found that investigated the combined effect of hyperinflation with suctioning, positioning change and hyperoxygenation.

In a randomised control trial conducted to demonstrate an additional mechanical benefit to the respiratory system, hyperinflation and suction techniques were combined. The application of hyperinflation and suction with suction alone on static lung compliance (C(L)) and inspiratory resistance (R(AW)) in mechanically ventilated patients with ventilator-associated pneumonia were compared. Fifteen adult patients with ventilator-associated pneumonia were recruited and acted as their own controls. Hyperinflation followed by suction (hyperinflation plus suction) and suction alone were applied consecutively, in random order, on two occasions, four hours apart. Respiratory variables, C(L) and R(AW), were measured five times and the averaged value documented. Data were recorded before, immediately after and 30 minutes after each intervention protocol. C(L) increased by 22% and R(AW) decreased by 21%, up to 30 minutes after hyperinflation plus suction, but not after suction alone. This study suggests that hyperinflation, in conjunction with suction, induces beneficial changes in respiratory mechanics in mechanically ventilated patients with ventilator-associated pneumonia (Choi and Jones, 2005:25-30).

Another quasi-experimental study was designed to assess the safety and short-term effectiveness of lung hyperinflation in mechanically ventilated patients. Eighteen patients from the intensive care units of two tertiary institutions were included and acted as their own control. Hyperinflation treatment involved patient positioning (side-lying), suctioning and hyperinflation. Side-lying treatment involved patient

positioning and suctioning alone. Patients received both treatments on the day of data collection. Results demonstrate significant improvement for static respiratory system compliance ($p=0.001$) with hyperinflation treatment compared to side-lying treatment. Hyperinflation treatment also cleared a significantly greater wet weight of sputum ($p=0.039$). There were no differences between hyperinflation and side-lying treatment for gas exchange (PaO_2/FIO_2 and $PaCO_2$), mean arterial pressure or heart rate. In conclusion, total static respiratory system compliance and sputum clearance were improved by the addition of hyperinflation to a physiotherapy treatment of positioning and suctioning in mechanically ventilated patients without compromise to cardiovascular stability or gas exchange (Hodgson, Denehy, Ntoumenopoulos, Santamaria and Carroll, 2000:255-61).

Two studies were found that investigated the effects of using hyperinflation combined with hyperoxygenation prior to endotracheal tube suctioning. These study results are reflected in Table 5.5. A quasi-experimental study, done by Paratz, Lipman and McAuliffe (2002:317-324), investigates the effects of hyperinflation on hemodynamics and gas exchange in patients on mechanical ventilation. Sixteen critically ill patients with septic shock and acute lung injury were studied. Hyperinflation using a 2L reservoir ventilation bag connected to 100% wall oxygen at 15L per minute was performed for 3 minutes using a manual reservoir ventilation bag. The heart rate, arterial blood pressure, mean pulmonary artery pressure, PaO_2 and $PaCO_2$ were recorded one minute prior to disconnection from the mechanical ventilator, at one, two and three minutes during hyperinflation and one and five minutes after hyperinflation. The study results reveal that there was an improvement in gas exchange evident by the increase in the PaO_2 , which was sustained 20 minutes after using hyperinflation. There was no significant change in the $PaCO_2$. The diastolic arterial blood pressure increased significantly when using hyperinflation ($p<0.001$). However, all the other hemodynamic parameters, including heart rate and pulmonary artery pressure, did not alter during or after hyperinflation. The results in this study thus highlight the fact that hyperinflation improves oxygenation. However, in this study, hyperinflation was used in combination with hyperoxygenation, thus explaining the improvement in the oxygenation status.

Table 5.5 Summary of studies assessing the effects of hyperinflation combined with hyperoxygenation

Author reference, study design	n	Patient type	Outcomes measured	Summary of main results
Paratz, Lipman and McAuliffe, 2002, Quasi-experimental	16	Critically ill patients with septic shock and acute lung injury	Heart rate Arterial pressure Mean pulmonary artery pressure, PaO ₂ and PCO ₂	The use of hyperinflation and hyperoxygenation had no effect on the heart rate or mean pulmonary artery pressure. The diastolic arterial pressure and PaO ₂ increased when using hyperinflation and hyperoxygenation No effect on the PaCO ₂
Lookinland and Appel, 1991, RCT	24	Non-head injured trauma patients <u>Group 1:</u> No hyperinflation or hyperoxygenation used <u>Group 2:</u> Only hyperoxygenation used <u>Group 3:</u> Only hyperinflation used <u>Group 4:</u> Hyperoxygenation and hyperinflation used prior to suctioning	Mean arterial pressure Cardiac output PaO ₂	No difference noted in the mean arterial pressure and cardiac output amongst the four groups Increase in the PaO ₂ in groups 2 and 4 (use of hyperoxygenation and hyperinflation with hyperoxygenation).

Lookinland and Appel (1991:133-139) did a RCT on 24 non-head injured trauma intubated patients, who were divided into four groups. In the first group of patients, no hyperinflation or hyperoxygenation was used, whereas in group 2, only hyperoxygenation was used. In group 3, only hyperinflation was used, while hyperoxygenation and hyperinflation was used in group 4 prior to endotracheal tube suctioning. The study results show no difference noted in the mean arterial pressures and cardiac outputs in the four groups. An increase in the PaO₂ in groups 2 and 4 was noted, implying that the use of hyperinflation with hyperoxygenation is more beneficial when used prior to endotracheal tube suctioning.

According to one literature review paper (Glass and Grap, 1995:52), hyperinflation and hyperoxygenation should be combined, but if, after the use of hyperoxygenation, the patient's oxygen tension saturation remains stable during suctioning, hyperinflation is deemed unnecessary.

As stated before, hyperinflation can be done by means of using a manual ventilation bag or it can be delivered via a mechanical ventilator. Two literature review papers support the use of hyperinflation by means of a mechanical ventilator and recommend it as a superior method in delivering hyperinflation. Pedersen *et al* (2009:25) state that using a hyperinflation volume of 1.5 x the baseline tidal volume on the mechanical ventilator is the most common for hyperinflation prior to endotracheal tube suctioning. Thompson (2000:4) states that using a ventilator for hyperinflation results in less hemodynamic alterations than when using a manual resuscitation bag.

Based on the evidence found, it can be concluded that hyperinflation should be used with caution in patient populations who presents with increased intracranial pressure, vascular and cardiac surgery and those who are hemodynamically unstable. If hyperinflation is used prior to suctioning, it is recommended that it must be done by means of a ventilator rather than using a resuscitation bag. The use of hyperinflation combined with hyperoxygenation appears to be beneficial in improving the oxygenation level of intubated adult patients.

5.2.2.2.1.4 Normal saline instillation

Traditionally, it is believed that normal saline instillation prior to endotracheal tube suctioning induces coughing, facilitates in secretion removal and ultimately improves the oxygenation levels. The procedure is conducted by instilling 2-5ml of sterile normal saline into the endotracheal tube prior to suctioning (Wood 1998:177, Celik and Kanan, 2006: 11-14; Pedersen *et al*, 2009:25).

Eight studies (two RCTs: Ackerman and Mick (1998:261-266); Caruso, Denari, Ruiz, Demarzo and Deheinzelin (2009:32-38) and five randomised cross-over studies: Ackerman, 1993:326; Ackerman and Gugerty, 1990:14-17; Akgül and Akyolcu, 2002:826-830; Gray, MacIntyre and Kronenberger, 1990:785-790; Ji, Kim and Park, 2002:607-612) assess the effectiveness of normal saline instillation prior and during endotracheal tube suctioning on the recovery of secretions, oxygenation and the hemodynamic status of the patient.

The studies mainly compare the effects of the instillation of normal saline with no saline prior to endotracheal tube suctioning. The effects of normal saline use on hemodynamic variables, for instance, heart rate and blood pressure were assessed in the majority of these studies. The level of dyspnea experienced by patients, oxygenation levels, sputum recovery and risk for infection were also investigated. See Table 5.6 for a summary for the study results.

Table 5.6 Summary of studies on normal saline instillation				
Author reference, study design	N	Patient type	Outcomes measured	Summary of main results
Ackerman and Mick, 1998, RCT	n=29	Patients in the critical care unit with pulmonary infections requiring mechanical ventilation Group 1:(n=15) no saline instilled	-Oxygen saturation (SaO ₂) -Heart rate -Blood pressure	-Decrease in oxygenation for group 2 who had normal saline instillation -No significant differences noted in heart rates and

Table 5.6 Summary of studies on normal saline instillation

		Group 2 (n=14) 5ml bolus saline instilled prior to suctioning		blood pressure in the two groups
Ackerman, 1993, RCO	n=40	Surgical and Medical patients Intervention 1: no saline instilled prior to suctioning Intervention 2: 5ml saline instillation done prior to suctioning	SaO2	Lower oxygenation levels noted in patient where normal saline was used than in patients where normal saline was not used.
Ackerman and Gugerty, 1990, RCO	n=26	Critically ill patient in the medical CCU requiring mechanical ventilation Intervention 1: no saline Intervention 2: 5ml saline instilled prior to endotracheal tube suctioning	SaO2	Lower oxygenation levels with normal saline instillation noted
Ji <i>et al</i> , 2002, RCO	n=21, 16 completed study	Neurosurgical patients with pneumonia requiring mechanical ventilation Intervention 1: no saline Intervention 2: 2ml saline instilled	SaO2	SaO2 returned to baseline immediately for intervention 1, at 45s for intervention 2 and did not return to baseline by 5 minutes post saline instillation for intervention 3

Table 5.6 Summary of studies on normal saline instillation

		Intervention 3: 5ml saline instilled		(p=0.003), thus indicating the more normal saline instilled the more significant the adverse effects on the SaO ₂
Akgül and Akyolcu, 2002, RCO	n=20	Patients in the CCU requiring mechanical ventilation Intervention 1: no saline Intervention 2: 5 ml saline used	Heart rate SaO ₂	Increase in heart rates when using normal saline Decrease in SaO ₂ levels when using normal saline
Gray <i>et al</i> , 1990, RCO	n=15	Medical patients with pulmonary disease requiring mechanical ventilation Intervention 1: no saline Intervention 2: 5ml saline instillation	Heart rate Blood pressure SaO ₂ Volume of material suctioned	No statistically significant difference in heart rate, blood pressure or oxygenation levels noted in using the two methods Clinical significance of sputum recovery of 1.3 g, thus indicating that more sputum is suctioned following normal saline instillation
O Neal <i>et al</i> , 2001, RCO	n=20, 17 completed the study	Patients in CCU requiring mechanical ventilation	Visual Analogue Scale for dyspnea	Normal saline instillation precipitate a significantly

Table 5.6 Summary of studies on normal saline instillation

		Intervention 1: no saline Intervention 2: 5ml saline used		increased level of dyspnea in patient older than 60 years of age
Caruso <i>et al</i> , 2009, RCT	n=262	Patients in the CCU requiring mechanical ventilation Group 1: no saline Group 2: 8 ml normal saline instilled	Incidence of VAP	Saline instillation prior suctioning reduces the incidence of VAP

Ackerman and Mick (1998:261-266) performed a randomised control trial to determine the effect of normal saline instillation before endotracheal tube suctioning on oxygen saturation, heart rate and blood pressure in patients with pulmonary infections. The study was conducted in the surgical, medical, burn and trauma critical care units of an academic medical centre. Eighteen men and 11 women (mean age=60) receiving mechanical ventilation, who met the criteria for pulmonary infection, were randomly assigned to two groups. One group had instillation of 5ml bolus of normal saline before endotracheal tube suctioning, while the other group did not. Endotracheal tube suctioning was done as required during an eight to 12-hour period. Oxygen saturation, heart rate and blood pressure were measured non-invasively immediately before and after endotracheal tube suctioning at one-minute intervals for five minutes after performing endotracheal tube suctioning and at ten-minute intervals after suctioning. The study results show that immediately after performing endotracheal tube suctioning, oxygen saturation decreased for both groups of patients. However, oxygen saturation for the group who had instillation of normal saline decreased remarkably four minutes after suctioning, whereas the levels for the control group increased greater than the baseline values and continued to increase until the ten-minute measurement period. In the group who had instillation of normal saline, oxygen saturation began to increase at four minutes after

endotracheal tube suctioning was performed and did not returned to baseline until ten minutes after suctioning. The differences in oxygen saturation between the control and experimental groups were significant ($p < .05$). Heart rates increased for both groups, but the increases were small and were not clinically important. Blood pressure increased in both groups, but the differences between the two groups were not significant. The study results thus reveal that instillation of normal saline prior to endotracheal tube suctioning had a detrimental effect on oxygen saturation. The findings confirm that the practice of instilling normal saline prior to endotracheal tube suctioning compromises oxygenation and should thus be not be implemented as a routine intervention.

In another study done by Ackerman (1993:326-330), the effect of normal saline instillation on the oxygen level in 40 critically ill patients requiring mechanical ventilation in a medical critical care unit was studied. Patients served as their own control. Endotracheal tube suctioning was performed as needed for a period of 24 hours. Oxygenation levels were measured by means of SaO₂ measurements immediately before and after suctioning at one-minute intervals for five minutes after suctioning. The study results indicate that the SaO₂ levels were lower in patients where normal saline instillation was used prior to endotracheal tube suctioning than in patients where it was not used, thus further strengthening the argument that normal saline instillation has a detrimental effect on oxygenation.

Ackerman and Gugerty (1990:14-17) studied the effects of normal saline instillation on the oxygenation levels of 26 critically ill patient requiring mechanical ventilation in a medical critical care unit. Patients served as their own control. The oxygen saturation decreased significantly in patients receiving normal saline instillation prior to endotracheal tube suctioning than those patients who did not receive normal saline instillation. The results in this study add to the evidence that normal saline instillation prior to endotracheal tube suctioning has a detrimental effect on the oxygenation levels of patients in a critical care unit.

Ji *et al* (2002:607-612) conducted a study to investigate the effects of 2 ml, 5 ml and no normal saline instillation prior to endotracheal tube suctioning on oxygen

saturation in patients with pneumonia. The patients in this study were 16 intubated patients who had been admitted to the neuro-surgical critical care unit at a university hospital in Seoul, Korea. Patients served as their own control and all three (0, 2 ml and 5 ml) saline instillation methods were applied to the 16 patients. The methods were randomly assigned to each patient. Each of the normal saline instillation methods was applied in a four-step sequence: recording the level of oxygen saturation (baseline levels), instilling normal saline, supplying oxygen and endotracheal tube suctioning and recording the level of oxygen saturation using pulse oximetry. The study results show that there was a significant difference decrease in the oxygenation levels of patients who received normal saline instillation prior to endotracheal tube suctioning than those patients who did not. The more normal instilled prior to endotracheal tube suctioning, the more profound the effects were on the oxygenation levels. The study results thus strengthen the evidence that normal saline instillation prior to endotracheal tube suctioning has adverse effects on oxygen saturation and should thus not be used as a routine intervention in the critically ill intubated patient.

A more recent study done by Akgül and Akyolcu (2002:826-830) determined the effect of normal saline instillation prior to endotracheal tube suctioning on oxygenation and heart rates. The study was conducted on 20 patients, who were mechanically ventilated due to pulmonary, cardiovascular or trauma alterations in the critical care unit of a university hospital in Turkey. Endotracheal tube suctioning was performed on the same patient at two-hour intervals, both with and without the use of normal saline instillation. The study results show a statistically significant difference ($p < 0.05$) in the oxygenation levels, which was decreased in patients who received normal saline instillation prior to endotracheal tube suctioning compared to patients who did not receive it. There was a statistically significant increase ($p < 0.05$) in the heart rate of patients when using normal saline compared to when it was not used. The study findings support the evidence stating that normal saline instillation decrease oxygenation levels in the critically ill intubated patient. The findings further found that the heart rate of patients increased when normal saline instillation is used, which was not evident in a previous study done by Ackerman and Mick (1998:261-266).

An observational study done by Kinloch (1999:231-242) aimed to investigate the effects of 5ml of normal saline instillation during endotracheal suctioning on mixed venous saturation. The participants were 35 cardiothoracic surgical patients, where one group had 5 ml of normal saline instilled at the beginning of the endotracheal suctioning procedure, while the other group had the same endotracheal suctioning procedure without the normal saline instillation. The findings of the study revealed that normal saline instillation at the beginning of endotracheal suctioning had significantly lowered the mixed venous saturation values.

In a study done by Gray *et al* (1990:785-790), 15 critically ill patients with pulmonary disease were studied to determine oxygenation levels, heart rate, blood pressure and the amount of secretions suctioned with a 5ml normal saline instillation compare to no normal saline instillation. The two methods of suctioning (with 5ml normal saline and without normal saline) were done in each patient with a randomised method order. The study results show no statistically significant difference between the two methods of endotracheal tube suctioning with reference to the normal saline instillation in the oxygenation levels, heart rate, blood pressure and other respiratory mechanics. However, it revealed that all patients receiving normal saline instillation coughed immediately after the instillation of normal saline as well as during stimulation by the suction catheter. The cough was elicited more frequently during endotracheal tube suctioning with normal saline instillation than during suctioning without it. A significant difference was found between the two methods in the weight of the material suctioned. Material suctioned following instillation of normal saline weighted more than when suctioned without it. The conclusive findings for this study indicate that although normal saline instillation does not have a statistically significant effect on the heart rate, blood pressure and oxygenation level of the patient, it may enhance secretions clearance through cough stimulation.

A literature review paper by Branson (2007:1328-1347) states that normal saline instillation does cause the patient to cough, which may aid in the secretion removal process. However, the properties of mucus are unlikely to change with the addition of water unless some physical means of mixing the two is accomplished. Based on the premise, saline instillation to thin secretions is unsupported and can be

dangerous, thus jeopardising the safety of the intubated patient. Blackwood (1999:928-934) concurs in highlighting in the literature review paper that normal saline instillation produces no physiological benefits for the patient.

A study done by O'Neal, Grap, Thompson and Dudley (2001:356-363) compares the level of dyspnea experienced in mechanically ventilated patients with and without normal saline instillation prior to endotracheal tube suctioning. A quasi-experimental study design was used. Seventeen, alert mechanically ventilated patients were asked to rank their level of dyspnea using the vertical visual analogue scale at ten, 20 and 30-minute time intervals with saline and without saline instillation. The study results reveal that the level of dyspnea based on the treatment type (with or without normal saline instillation) was non-significant. However, treatment type by age of the group was significant. Older patients (<60 years of age) experienced less dyspnea without saline prior to endotracheal tube suctioning and greater dyspnea with saline instillation as compared to younger patients. This study documents no beneficial effects of normal saline. But it does demonstrate that normal saline might precipitate a significantly increased level of dyspnea for up to ten minutes after suctioning in patients older than 60 years of age. Recommendations based on the results of this study are to avoid the use of normal saline instillation prior to endotracheal tube suctioning.

Other detrimental effects of normal saline instillation include infection control issues and bacterial contamination. A quasi-experimental study done by Hagler and Traver (1994:444-447) examined endotracheal tubes that had been removed from ten critical care patients after a minimum of 48 hours of intubation. They evaluated dislodgement of bacteria caused by insertion of a suction catheter with or without normal saline instillation before insertion of the catheter. They found that a 5ml normal saline instillation dislodged up to 310,000 viable bacterial colonies, supporting the fact that normal saline instillation has the potential for producing airway infection by dislodging bacteria into the lower airway. Another observational study done by Freytag, Thies, Konig and Welte (2003:31-37) found that normal saline instillation with endotracheal tube suctioning may lead to a dispersion of micro-organisms into the lower respiratory tract. Several literature review papers

support the fact that normal saline increases the release of viable bacteria into the lower airway (Glass and Grap, 1995:53; Blackwood, 1999:930 Thompson, 2000:3; Branson, 2007:1334; Halm and Kristo-Hagel, 2008:470, Jelic *et al*, 2008:300; Rauene*et al*, 2008:101).

However, only one large-scale study done by Caruso*et al* (2009:32-38) indicates controversial findings. They conducted a randomised control trial using 262 critically ill patients in a medical-surgical critical care unit in Brazil. The primary outcome measured in this study was the incidence of ventilator-associated pneumonia with or without normal saline instillation. The study results found that significantly fewer participants (14/130 patients) in the normal saline group developed ventilator-associated pneumonia than in the control group (31/132 patients). The study concludes by stating that instillation of normal saline prior to endotracheal tube suctioning decreases the incidence of ventilator-associated pneumonia in mechanically ventilated adults in critical care units. Although this was a large-scale study and Level II evidence, one should take cognisance of the fact that outcome measures, in comparison to the previous evidence mentioned, are different for this study.

Collectively, the studies demonstrate that normal saline instillation has adverse effects. They illustrated that normal saline instillation adversely affects arterial and global tissue oxygenation, increases the heart rate and stimulates the cough reflex. Furthermore, it dislodges bacterial colonies, thus contributing to lower airway contamination and infections. Based on the findings of studies, it can be recommended that normal saline instillation should not be used prior to endotracheal tube suctioning.

5.2.2.2.2 Implementation of the endotracheal tube suctioning procedure

During the implementation phase of endotracheal tube suctioning, it is important to consider factors such as the suction catheter size, duration of the suctioning procedure, depth of suction catheter insertion and the suction pressures to use.

5.2.2.2.1 Suction catheter size

When performing endotracheal tube suctioning, it is of the utmost importance to use the correct catheter size. In reviewing this section, only four literature papers (Level VII evidence) were found.

Glass and Grap (1995:53) state that using a suction catheter with an external diameter less than half the internal diameter of the endotracheal tube will allow air to enter the lungs while oxygen is being removed by suctioning. This will help to prevent excessive negative pressure and atelectasis. Thompson (2000:3) supports this by stating that the internal diameter of the endotracheal tube may be directly related to the negative pressure within the lungs. The size of the suction catheter should be less than half of the internal diameter of the artificial airway to avoid greater negative pressures in the airway and to potentially minimize a decrease in the arterial oxygenation. According to a literature paper authored by St John (2004:94), the selection of an appropriately sized suction catheter for a given tube inner lumen diameter should be done correctly in order to avoid complications during the suctioning.

The widely accepted formula for calculating catheter size is: suction catheter size [Fr] = (ET tube size [mm] -2) x 2. When a suction catheter occludes less than half the lumen of the endotracheal tube, the negative pressure in the lungs is minimized because the space in the tube that allows air to pass to the lungs during suctioning correlates with the tube lumen (Pedersen *et al*, 2009:23).

There is consensus in the four literature papers found that suction catheters should be as small as possible, yet large enough to facilitate secretion removal. It is recommended that the external diameter of the suction catheter size should be less than half of the internal diameter of the endotracheal tube. No clinical trials were found to support this recommendation.

5.2.2.2.2 Duration of the suctioning procedure

The duration of the suctioning procedure affects the severity of adverse effects related to endotracheal tube suctioning. The three literature review papers found

suggest that a maximum of ten seconds be recommended for performing the procedure. Performing endotracheal tube suctioning for durations longer than ten seconds is associated with an increased risk of mucosal damage and hypoxia thus compromising the safety of the intubated mechanically ventilated patient (Wood, 1998:172; Thompson, 2000:3; Pedersen *et al*, 2009:24).

Based on the literature review papers, it is recommended that suctioning procedure should not last longer than 10 seconds. No clinical trials or other pieces of evidence were found to support this recommendation.

5.2.2.2.3 Depth of catheter insertion

The effect of deep suctioning is tracheal mucosal damage, including epithelial denudement, hyperemia, loss of cilia, edema, fibrosis and granuloma formation. This damage occurs when the tissue is pulled into the catheter tip holes and increases the risk of infection and bleeding for the patient. The purpose of suctioning is to remove secretions that are not accessible by bypassed cilia. Therefore, insertion of suction catheters only as far as the end of the placed endotracheal tube has been recommended. Passing suction catheters no further than 1cm past the length of the endotracheal tube can avoid contact with the trachea and carina. Resistance should not be met. If resistance is met, the suction catheter should be withdrawn at least 0.5 cm-1cm before applying suction (Pate and St John, 2004:13). Four additional literature papers support this in stating that the suction catheter should be inserted to the level of the carina and retracted 1-2 cm before applying suctioning (Wood, 1998:80 Celik and Elbas, 2000:192, Day *et al*, 2002:80; Pedersen *et al*, 2009:25).

Van der Leur *et al* (2003:426-432) studied 383 adult patients requiring endotracheal tube intubation. The patients were randomised to either minimally invasive or routine catheter suctioning. The effect of deep suctioning, where the suction catheter is inserted pass the length of the endotracheal tube was compared to shallow suctioning which was to the level of the carina only. They found no difference in the suction methods relative to duration of intubation, intensive care stay and incidence of pulmonary infections. However, suction-related adverse events occurred more

frequently with deep suctioning versus shallow suctioning where the suction catheter was inserted to the length of the endotracheal tube only.

Based on the literature papers found, as well as a single, randomised control trial, it is recommended that the suction catheter be inserted to the length of the endotracheal tube only. The suction catheter should be inserted to the carina. The suction catheter should be inserted until resistance is felt and then retracted 1-2 cm before endotracheal tube suctioning is performed.

5.2.2.2.4 Suction pressure

Application of excessive negative pressure during endotracheal tube suctioning may cause trauma to the mucosa. The use of the lowest possible suction pressure, namely 80-120mmHg, is recommended in order to reduce the risk of atelectasis, hypoxia and damage to the tracheal mucosa (Glass and Grap, 1995:52; Day *et al*, 2002:85). According to St John (2004:94), the amount or level of suction pressure should be limited to effectively remove secretions and for as short a time as possible to minimize the potential for adverse effects in performing endotracheal tube suctioning. Using high negative pressures does not mean that more secretions will be aspirated. To prevent the suction catheter from adhering to the tracheal mucosa, negative pressure should only be applied during catheter withdrawal. Pedersen *et al* (2009:24) recommend use of the lowest possible suction pressure of 80-120 mmHg during endotracheal tube suctioning.

Based on the literature papers found, it is recommended that in order to ensure safety in the intubated mechanically ventilated patient, the suction pressure should be maintained at 80-120 mmHg during endotracheal tube suctioning. This recommendation is exclusively based on literature papers and expert opinion as no clinical studies were found to support an exact suction pressure limit.

5.2.2.2.3 Evaluation following endotracheal tube suctioning

On completion of the endotracheal tube suctioning, it is important to assess or evaluate if the procedure was done effectively, comprehensively and safely. The assessment of the patient post suctioning is thus important.

5.2.2.2.3.1 Patient assessment

There is a paucity of literature on the assessment data on completion of endotracheal tube-suctioning. Only Level VII evidence was found. It is recommended that a comprehensive respiratory assessment be undertaken following endotracheal tube suctioning, which should include chest auscultation to assess the air entry and breath sounds. Monitoring of the patient's heart rate, colour, perfusion and oxygenation levels should be done. Sputum should be observed for colour, consistency and the findings should be documented. Hand washing should be emphasized to avoid contamination and infection. In order to minimise stress and anxiety induced by the suctioning procedure, reassurance should be given to the patient after endotracheal tube suctioning (Day *et al*, 2002:87; St John, 2004:94).

5.2.3 SUMMARY FOR SYSTEMATIC REVIEW ON ENDOTRACHEAL TUBE SUCTIONING

The systematic review on endotracheal tube suctioning has incorporated various pieces of evidence. However, the paucity of clinical trials with regard to the implementation of endotracheal tube suctioning addressing suction catheter size, suction pressures to be used, depth of suction catheter insertion and duration of suctioning procedure still exists. Various clinical trials were found addressing normal saline instillation, but paucity on the latest available clinical trials still exists. In some of the studies found, the sample size was small and the methods were often not explicitly stated. More research is thus required with specific reference to the adult intubated mechanically ventilated patient in a critical care unit. However, despite the limitations, the findings in the review appeared to be consistent. Therefore, the information found can thus be used to formulate recommendations and develop clinical guidelines as the review illustrates the best recommended practices related to endotracheal tube suctioning.

Endotracheal tube suctioning is a procedure that has detrimental effects if it is not done according to the best recommended practice. The review has highlighted methods and techniques that are important to implement in order to minimize and/or prevent suctioning-related complications. Although the need for well-designed randomised trials with large sample sizes was identified in reviewing studies in this

review, definitive recommendations can be formulated based on the evidence found. The information collected in this review will be used to develop the clinical guideline for endotracheal tube suctioning, which is presented in Chapter 6 of this study.

5.3 ENDOTRACHEAL TUBE CUFF PRESSURE MONITORING

Patients are often admitted to critical care units with compromised airways, thus requiring mechanical ventilation as part of their treatment. These patients require the insertion of an artificial airway, which can either be an endotracheal tube or tracheostomy if the patient needs mechanical ventilation or protection of the airway from aspiration (Edwards and Sabato, 2009:237). The endotracheal tube is usually inserted through the mouth and its distal tip rests above the carina. The tube has a high-volume, low-pressure cuff at the distal end that is inflated. The pressure in this cuff must be maintained within a therapeutic range (25 to 30 cmH₂O or 18 to 22 mmHg) that is high enough to ensure delivery of mechanical ventilation and prevent marked aspiration, and low enough to ensure perfusion to the tracheal capillaries (Sole, Penoyer, Su, Jimenez, Kalita, Poalillo, Byers, Bennet and Ludy, 2009:134).

The endotracheal tube cuff has two main functions, namely to ensure airtightness and protect the lower airways from the aspiration of contaminated oropharyngeal secretions. Exposure of the tracheal mucosa to the pressure of the tracheal cuff has been implicated as one of the most important predisposing factors for mucosal injury. Over-inflation and under-inflation of the endotracheal cuff are associated with subsequent complications such as tracheal stenosis, tracheomalacia and ventilator-associated pneumonia. The measurement of cuff pressure is, therefore, one mechanism advocated to prevent complications related to excessive or inadequate cuff pressures in the intubated patient (Morton and Fontaine, 2009:603).

Based on the data analysis from the structured questionnaires exploring the nursing care practices related to endotracheal tube cuff pressure monitoring, it was found that this was one of the two practices that were done least according to best practice recommendations. Apart from one national best practice guideline and a best practice evidence information sheet on endotracheal tube cuff pressure monitoring, no clinical guideline, based on a systematic review, was found on this topic.

The purpose for performing a systematic review on endotracheal tube cuff pressure monitoring in this study was:

- To use the information obtained from the systematic review to develop an evidence-informed clinical guideline that is contextualized to the critical care unit for adult intubated mechanically ventilated patients, especially since it appears that no evidence-informed clinical guideline on the topic is currently available in the critical care units in the Nelson Mandela Metropole.

The items for discussion in this section of the study are reflected in Table 5.7.

Table 5.7 Items for discussion of the systematic review report on endotracheal tube cuff pressure monitoring	
5.3	ENDOTRACHEAL TUBE CUFF PRESSURE MONITORING
5.3.1	METHODS
5.3.1.1	The review question
5.3.1.2	Searching for evidence
5.3.1.3	Selection of evidence
5.3.1.4	Critical appraisal
5.3.1.5	Data extraction
5.3.1.6	Data analysis and synthesis
5.3.2	DISCUSSION AND RESULTS OF THE SYSTEMATIC REVIEW
5.3.2.1	Description of evidence
5.3.2.2	Results
5.3.3	SUMMARY FOR SYSTEMATIC REVIEW ON ENDOTRACHEAL TUBE CUFF PRESSURE MONITORING

5.3.1 METHODS

The methods undertaken to conduct the systematic review on endotracheal tube cuff pressure monitoring are discussed in this section of the study.

5.3.1.1 The review question

The review question was formulated based on the data analysis in Chapter 4 of the study, which revealed that endotracheal tube cuff pressure monitoring was least done according to best practice recommendations. The PPC format as described in Chapter 3 was used to guide the formulation of the review question. The population (P) refers to the adult intubated mechanically ventilated patient, the phenomenon (P) of interest is endotracheal tube cuff pressure monitoring and the context (C) refers to the critical care unit.

- What nursing care interventions are the most effective in monitoring endotracheal tube cuff pressure to minimize the complications of over-inflation or under-inflation in the adult intubated patient in a critical care unit?

5.3.1.2 Searching for evidence

The three-step approach, as set out in the search strategy, as described in Chapter 3 of the study, was used to search for literature. Initially CINAHL, MEDLINE (via PubMed), EBSCO HOST, the JBI systematic review library, the Cochrane Library, Clinical evidence from the British Medical Journal (BMJ), the National Guidelines Clearinghouse and Google Scholar was searched using broad terms for instance “endotracheal tube cuff pressure”.

Step two involved searching all the data bases (as stated above) using the identified search terms and the inclusion and exclusion criteria to determine which papers had to be retrieved. Search terms used for identifying literature pertaining to endotracheal tube cuff pressure were, for instance, “endotracheal tube AND cuff pressures AND monitoring”; “ventilation and cuff pressures”; “Cuff pressures and tracheal care”; “Cuff pressures and monitoring”; ventilation AND cuff pressures”; “endotracheal tube cuff pressures”; “aspiration AND cuff pressures”; “aspiration OR ventilator-associated pneumonia AND cuff pressures”. The search terms pertaining to the various databases are reflected in Annexure J. The inclusion and exclusion criteria used in identifying the appropriate literature are described later in this Chapter.

Step three comprised of searching the reference lists and bibliographies of all papers for identification of additional studies. Other databases that were found during this

searching process included Highwire, Ingenta, the online Worldviews on Evidence-based Nursing. Pearl growing on these databases allowed access to other pieces of literature that probably would have been missed. Furthermore, hand searching for articles in critical care, respiratory, emergency care and anaesthetic journals was done to ensure that all possible evidence was included. The local university and health care institution libraries were used to access these journals. Abstracts on the topic were also identified. The librarian aided in obtaining the full articles if the abstracts proved to be relevant to the topic. The librarian and interlibrary loan facility assisted in obtaining articles that could not be accessed via the local university. A search for unpublished dissertations and thesis was done but none was found. The Critical Care Society of Southern Africa was contacted to find out if any literature was available on national level. One best practice guideline on endotracheal tube cuff pressure monitoring was found.

5.3.1.3 Selection of evidence

The inclusion and exclusion criteria as stated in the systematic review protocol were used to guide the selection of evidence to be included in this review. The inclusion criteria considered the types of papers, types of participants, types of interventions, types of outcomes, language of publications, and the time period the studies were conducted and published. The inclusion and exclusion criteria are discussed below.

5.3.1.3.1 Inclusion criteria

In order to include different types of evidence in the systematic review, criteria were to be set. The studies selected for inclusion in the review had to adhere to the criteria as discussed.

Types of evidence

In order to draw on all types of evidence, all papers that described endotracheal tube cuff pressure monitoring were included in the systematic review. Therefore, it was decided to include best practice information sheets, clinical practice guidelines, randomised controlled trials, quasi-experimental, cohort studies, observational and descriptive studies, expert opinion and literature review papers, if found, in the systematic review.

Papers were assessed against the evidence hierarchy for rating levels of evidence as stated in LoBiondo-Wood and Haber (2010:16). Due to the paucity of randomised control trials, systematic reviews and meta-analysis on the topic and the amount of literature papers found, it was decided to add literature review papers as level VII evidence to the hierarchy of evidence. The number of papers (according to the hierarchy of evidence) initially located is displayed in Table 5.8. A description of the total amount of papers found is reflected in Figure 5. 2.

Level	Types of evidence	No of papers allocated
I	Systematic review or meta-analysis of randomised control trials	0
	Clinical practice guidelines based on systematic reviews	0
II	A well designed randomised controlled trail	0
III	Controlled trial without randomization (quasi-experimental study)	4
IV	Single non-experimental study:	
	• Correlation	1
	• Descriptive	1
	• Survey	6
	• Observational	10
	• Case reports	5
	• Retrospective	1
V	Systematic reviews of descriptive and qualitative studies	0
VI	Single descriptive or qualitative study	0
VII	Opinion of experts and/or reports or expert committees, conference papers	1
	Literature review papers	11
	Best practice information sheets or guidelines (added by the researcher)	(1)
Total number of papers		40 (+1) =41

Note the papers indicated in brackets () were excluded after the critical appraisal

Types of participants

All studies that comprised human, adult patients aged 18 years and above were included in the systematic review. Furthermore, the participants in the included studies had to be intubated with an artificial airway, namely an endotracheal tube or tracheostomy.

Types of interventions or activities

Interventions of interest included those related to endotracheal tube cuff pressure monitoring in the intubated adult patient.

Types of outcomes

The primary outcomes measured in the different types of evidence include the reduction of complications related to over- and under-inflation of the endotracheal tube cuff. Secondary outcomes include reduced risk for aspiration, reduced risk for ventilator-associated pneumonia and reduced stay on the mechanical ventilator, which are secondary complications of incorrect cuff pressure monitoring.

Language of publications

The initial search considered papers published in all languages. However, after exploring the translation cost per article, it was decided to exclude all papers that were not published in English. Eight non-English papers were found (see Annexure L).

Time period

To ensure a comprehensive search, all papers that were published up to the year 1990 were included in the systematic review. Literature prior to the year 1990 was out-dated and newer evidence was often available.

5.3.1.3.2 Exclusion criteria

Due to the anatomical and physiological differences noted between adults and neonates or paediatric patients, all studies that focussed on paediatrics were excluded. Animal studies were excluded for the same reasons.

5.3.1.4 Critical appraisal

The methodological quality of papers was assessed using the critical appraisal tools in the JBI SUMARI software packages, Version 4.0. The JBI NOTARI and the MASTARI modules accessed via the CReMS in the SUMARI software package (as described in Chapter 3) were used to critically appraise the evidence found. Two reviewers independently appraised the papers found. The primary reviewer (the researcher) collated the results in order to make the final appraisal. When discrepancies were detected between the appraisal results of the two reviewers, consensus discussions were held to establish the reasons for the discrepancies. After consensus was reached between the two reviewers, the final selection of papers was done for inclusion in the systematic review.

5.3.1.5 Data extraction

Data from each study were extracted using the data extraction tools in the JBI SUMARI software packages. Following the critical appraisal process, the details of each study and paper were entered into the respective data extraction tools available within NOTARI and MASTARI modules. The same process for data extraction described before was used (see 5.2.1.5).

5.3.1.6 Data analysis and synthesis

Following the data extraction process, data analysis and synthesis were done using the respective SUMARI software packages.

The main findings of each paper were summarized in a table format, stating the author and publication details, the aim of the paper, the type of study or paper, the main findings and the strengths and limitations of each paper. A code(s) was then assigned to the main finding(s) of the paper, for instance, if the paper focussed on the frequency or methods for measuring endotracheal tube cuff pressures. Once each paper was coded, the codes were grouped to form a theme related to the nursing interventions on endotracheal tube cuff pressure monitoring.

The MASTARI module in the SUMARI was used for the synthesis of appraised data. Once data are captured on the MASTARI, they were automatically available on the

CREMS for synthesis. Due to the paucity of randomised control trials, meta-analysis of data was not possible and only summaries of the evidence are provided.

5.3.2 DISCUSSION AND RESULTS OF THE SYSTEMATIC REVIEW

The results of the systematic review will be discussed in this section of the study. The section is organized according to the summaries made on the nursing interventions related to endotracheal tube cuff pressure monitoring. A description of the studies/evidence found, critically appraised and included in the systematic review is included in this section.

5.3.2.1 Description of evidence

The initial search of literature identified 87 possible papers for inclusion in the systematic review. After eliminating duplications (n=15), and studies (31) that did not appear to answer the systematic review question and did not adhere to the inclusion criteria of the review (see characteristics for excluded studies, Annexure L). The studies that were excluded were due to the following reasons:

- Animal studies (five);
- Languages, other than English (eight);
- Paediatrics (seven);
- Studies not relevant and related to the review question (11).

A total of 41 papers were included for critical appraisal. Figure 5.2 reflects the search results.

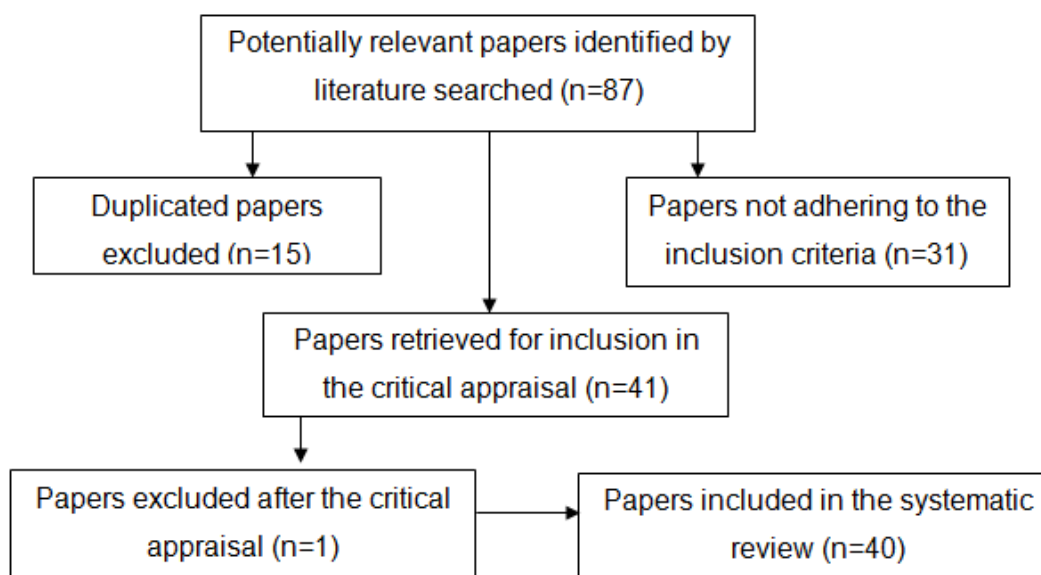


Figure 5.2 Results of the papers found and included in the systematic review: endotracheal tube cuff pressure monitoring

5.3.2.2 Results

The results of the systematic review on endotracheal tube suctioning will be discussed according to summaries made as derived from the evidence. Firstly, we need to understand the consequences related to over or under-inflation of the endotracheal tube cuff pressures if incorrectly maintained. Secondly, factors that contribute to inadequate or incorrect cuff pressure monitoring need to be understood. Thirdly, professional nurses need to know how often they should monitor endotracheal tube cuff pressures. Fourthly, professional nurses need to have insight about the best recommended methods to monitor endotracheal cuff pressures and the normal range for cuff pressures monitoring and maintenance. Lastly, management of trouble-shooting related to endotracheal tube cuffs should be highlighted in order to prevent complications secondary to incorrect cuff pressure management practices.

5.3.2.2.1 Consequences related to over and under-inflation of endotracheal tube cuffs

Cuff pressure management in the intubated mechanically ventilated patient is an important aspect of care. It is important that the pressure in the cuff be maintained within a therapeutic range (as discussed later) to prevent complications related to

over-inflation or under-inflation of the cuff. Complications of over-inflation of the cuff include nerve palsy, tracheosophageal fistula, tracheal wall damage or stenosis (Soleet *al*, 2009:134).

A descriptive study was conducted in a 20-bed medical critical care unit by Tadie, Behm, Lecuyer, Benhmamaed, Hans, Brasnu, Diehl, Fagon and Guerot (2010:991-998). The aim of the study was to describe the incidence of laryngeal and tracheal injuries in 136 patients who were extubated after more than 24 hours of mechanical ventilation in a critical care unit. The study results show a high incidence of laryngeal and tracheal injuries after extubation. One hundred of the patients (73%) had laryngeal abnormalities in terms of lesions, edema, ulceration or granulation. A literature paper confirms the consequences of over-inflation of endotracheal cuffs stating that ischemic airway injury can be related to high cuff pressures. With prolonged ischemia, mucosal ulceration can occur, leading to the formation of granulation tissue. Tracheal stenosis may present while the patient is still undergoing mechanical ventilation. Tracheal stenosis may produce no symptoms until the lumen has been reduced by 50 to 75% (Epstein, 2005:544).

Another case report refers to a 56-year old male who developed tracheal stenosis within 4 days of mechanical ventilation in a critical care unit. The patient presented one month later with increasing difficulty in breathing and an audible wheeze. On assessment it was found that the cuff pressures exceeded 30 cmH₂O (De, 2008, 195). Patients with tracheal stenosis remain asymptomatic for a variable period and then develop difficulty in breathing, which can progress to airway obstruction with the development of stridor. An observational study done on post-intubation tracheal stenosis reveals that this condition can be misdiagnosed at initial presentation in as many as 44% of patients. Patients usually remain asymptomatic until the tracheal has stenosed to 30% of its original diameter and may take as long as three months before diagnosis is confirmed (Spittle and McCluskey, 2000:1000).

A retrospective study of 756 patients at a long-term critical care unit, who had been ventilated for 3 weeks with an endotracheal tube, was conducted by Rumbak, Walsh, Anderson, Rolfe and Solomon (1999:1092-1095). In this study, it was found that 37

(5%) of the patients developed failure to wean secondary to tracheal stenosis or obstruction to granulation tissue, often manifested as higher peak airway pressure or difficulty in passing a suction catheter down the airway. High cuff pressures were reported. The study findings confirm that tracheal stenosis is a common complication related to over-inflation of endotracheal tube cuff pressures.

A case report presented by Robert, Mooty, Rath, Self, Dunn and Mangram (2007:237-240) illustrated that the incidence of trachea-esophageal fistula (TEF) increases if endotracheal tube cuff pressures are not correctly measured and maintained. In the case reported, a 53-year old man developed TEF, which was located approximately 2 cm inferior to the vocal cords and 2 cm superior to the tracheostomy site. Over the course of his hospital stay in the critical care unit, multiple occurrences of a cuff leak around the endotracheal tube were noted, subsequently remedied by increasing the endotracheal tube cuff volume. The patient presented with two episodes of aspiration and a worsening in his respiratory status. On examination, the endotracheal tube cuff pressure was measured at 48 cmH₂O and a CT scan of the chest found that the cuff was inflated to 44 mm in diameter. In this case, it was found that the patient presented with severe agitation, excessive head movement and was exposed to a prolonged duration of an over-dilated and over-inflated endotracheal tube cuff. The combination of these situations led to mucosal ischemia, necrosis and eventually erosion into the esophagus. Recognising that poorly managed endotracheal tube cuff pressure was likely the cause of TEF, the case report emphasises the importance of maintaining endotracheal tube cuff pressure at not greater than 22 mmHg. It suggests that endotracheal tube cuff pressures be monitored and documented at least every 8 hours.

Hameed, Mohamed and Al-Mansoori (2008:23) reported on another case report where a 35-year old male in a critical care unit on day 15 was diagnosed as having a trachea-esophageal fistula. The cuff pressures were measured and were found to be 40 cmH₂O. Based on the findings of the case report, it suggests that measures to prevent tracheal stenosis and fistulas should include maintenance of cuff pressures at 25 cmH₂O, using properly sized tubes, and avoidance of excessive pressure of the tube tip on either the anterior or posterior tracheal wall.

Hung, Hsu, Huang and Yang (2007:676) reported a case of an 86-year old male who developed a TEF and a trachea-subclavian artery fistula after 12 days of critical care unit admission. On examination, it was found that the cuff pressures were over-inflated. It was speculated that mucosal necrosis might have resulted from long-standing high cuff pressures. Mucosal trauma from the tip of the tube and excessive tube movements during prolonged ventilation were other probable causes of TEF. In addition, excessive cuff pressure, prolonged intubation and the presence of a nasogastric tube might increase the risk of TEF. Recommendations from this study suggest that tracheal cuffs should not be inflated more than 22 mmHg in order to reduce the risk of mucosal necrosis.

A literature paper done by Yang (1995:625-627) confirms that factors like high cuff pressures, size of the tube, duration of intubation, cardiovascular status during intubation, movement of tube during the period of intubation, sex and age of the patient and material from which the cuff is manufactured could contribute to the development of tracheal stenosis, which can develop within 24 hours of intubation and mechanical ventilation.

In a quasi-experimental study done by Braz, Navarro, Takata and Nascimento (1999:243-247), it was proven that endotracheal tube cuff pressures in the intubated critically ill patient were routinely high, exposing these patients to tracheal injury. The study comprised of 86 patients who were intubated with cuffed endotracheal tubes ranging from 7.0 to 9.0 mm in internal diameter. The cuff pressures were measured by means of a manometer. The study results show high cuff pressures (>40 cmH₂O) in 90.6% of the patients. Recommendations from the study suggest that endotracheal tube cuff pressures be measured and monitored eight hourly by means of manometry to minimise trauma to the tracheal mucosa and surrounding structures.

In a survey done by Raynham, Lubbe and Fagan (2009: 645) in the critical care units in the Western Cape in South Africa, it was found that in 135 critically ill patients 30% of the patients surveyed had excessive and potentially high cuff pressures of more than 40 cmH₂O. In the group with high cuff pressures, 9% had cuff pressure monitors

that were not in use. Only 15% had cuff pressures monitored twice daily. A survey done in the Bloemfontein area revealed that 50% of the 112 nurses working in 11 different critical care units did not routinely practice endotracheal tube cuff pressures monitoring, while only 50% of the staff felt that they had sufficient knowledge regarding cuff care management. Tracheal stenosis was a common complication related to over-inflated endotracheal tube cuffs (Mol, De Villiers, Claassen and Joubert, 2004:14).

A literature paper by Rello, Sonora, Jubert, Artigas, Rue and Valles (1996:111-115) indicates that cuff pressures less than 20 cmH₂O (15 mmHg) are associated with an increased risk of aspiration and a 2.5 fold increase in ventilator-associated pneumonia. A descriptive study using a pneumatic device confirmed that cuff pressures greater than 30 cmH₂O (22 mmHg) may impede capillary blood flow to the area of the tracheal wall in contact with the cuff, resulting in damage to the tracheal wall mucosa. Total obstruction of the tracheal blood flow occurs at pressures greater than 50 cmH₂O. In patients with hypotension, cuff pressures of as little as 34 cmH₂O may exceed the perfusion pressures of the trachea resulting in significantly tracheal damage (Duguet, D'Amico, Biondi, Prodanvonic, Gonzalez-Bermejo and Similowski, 2007:128-132).

Derived from the above studies and the evidence found, it can be concluded that under-inflation and over-inflation of endotracheal tube cuff pressures might lead to the development of complications such as tracheal stenosis, TEF, aspiration and increased risk of VAP. The consequences of over- and under-inflation are related to incorrect or inadequate endotracheal tube cuff pressure monitoring. Professional nurses should thus not only implement correct cuff management practices but should be aware of the consequences of over- and under-inflation of the endotracheal tube cuff.

5.3.2.2.2 Normal range for endotracheal tube cuff pressure monitoring

In a conference paper, Make, Hill, Goldberg, Bach, Criner and Dunne (1998:289S) suggest that cuff pressures greater than 30 cmH₂O compress mucosal capillaries and impair blood flow, with total occlusion occurring at 50 cmH₂O. In order to avoid

tracheal stenosis, it is, therefore, recommended that cuff pressures do not exceed 30 cmH₂O.

Recommendations based on survey done in 32 critical care units by Spittle and Beavis (2001:344-354) suggest that endotracheal tube cuff pressures should be measured at least daily or once per shift and be maintained below or at 30 cmH₂O in order to avoid complications related to over-inflation of the cuff.

In a literature paper authored by Diaz, Rodriguez and Rello (2005:902), it is recommended that cuff pressures be maintained to balance the risk of mucosal damage and the risk of VAP. In patients on mechanical ventilation, the use of low-pressure cuffs may increase the risk of VAP whereas high-pressure cuffs may increase the risk of tracheal damage. Cuff pressures should be maintained at 25-30 cmH₂O. In a study done by Rello *et a* (1996:111-115) 83 intubated patients were evaluated. The study results found that there was a higher risk for pneumonia amongst patients with a cuff pressures lower than 20 cmH₂O. They confirm the recommendation that cuff pressures should be maintained at 25-30 cmH₂O or 18-22 mmHg. A literature review paper confirms this in stating that the pressure of the endotracheal tube cuff should be sufficiently high to avoid the loss of gas from the lower respiratory tract and the leakage of pathogen around the cuff into the lower respiratory tract. To achieve this goal, cuff pressures should not exceed 30 cmH₂O (Lorento, Blot and Rello, 2007:1194).

Based on the evidence found, it is thus recommended that the endotracheal tube cuff pressures be maintained at 25-30 cmH₂O or 18-22 mmHg.

5.3.2.2.4 Frequency of cuff pressure monitoring

In order to avoid the consequences of over- and under-inflation of the endotracheal tube cuff, professional nurses need to take cognisance of the nursing care management principles related to cuff pressures. As a point of departure, it is important to know when cuff pressures should be monitored.

Cuff pressure is a recognised factor in the pathogenesis of tracheal injury; even the high volume–low pressure cuff may cause mucosal damage within as little as two hours after intubation. Areas of ciliary and mucosal injury are seen as early as two hours after intubation. Measurement of cuff pressures at best recommended intervals represents a simple method of assessing the pressure exerted on the tracheal mucosal. Vyas, Inweregbu and Pittard (2002:276) conducted an observational study to measure endotracheal tube cuff pressures in 32 intubated patients in a cardio-thoracic unit. Their study findings reveal that 62% of all tracheal cuffs had cuff pressures above the recommended normal ranges. Part of the study included a telephone survey amongst 24 critical care units, which showed that 75% of critical care units never checked tracheal tube cuff pressures. The incidence of tracheal damage was evident in the patients studied. Due to the complications associated with high cuff pressures and inadequate monitoring of endotracheal tube cuff pressures, it was recommended that cuff pressures be measured regularly. However, despite the fact that the study highlights the significance of regular cuff pressure monitoring, no specific time interval is recommended.

Prolonged duration of intubation results in laryngeal damage and ulceration. In an observational study done by Tu, Saidi and Leiutaud (1999:187) investigating the effects of nitrous oxide on endotracheal tube cuff pressures and the incidence of tracheal lesions in patients receiving anaesthesia in the operating room, it was found that after as little as eight to ten hours of intubation, profound damage, for instance, epithelial disruption, basement membrane loss and the appearance of ischemic non-inflammatory necrosis are possible. Periods of intubation greater than ten days results in deeper ulcers, total disruption of the basement membranes and deep ischemic necrosis. It is thought that endotracheal tube cuff pressures of greater than 25 to 30 cmH₂O contribute to mucosal ischemia. The study findings recommend eight-hour interval checks because epithelial disruption can occur in as little as eight to ten hours.

According to the recommendations from three different surveys conducted in the critical care units, it is suggested that the most common frequency for measuring cuff pressure is every eight hours (Crimlisk, Horn, Wilson and Marino, 1996:225-235;

Sole, Byers, Ludy and Ostrow, 2002:363-368; Sole, Byers, Ludy, Zhang, Banta and Brummel, 2003:220-230). Failure to monitor cuff inflation at least once per shift, may place the patient at increased risk for aspiration and subsequent ventilator-associated pneumonia due to the under-inflation or tracheal mucosal damage in the presence of over-inflation (Rose and Redl, 2008(b):363).

Based on the evidence found, it can be concluded that endotracheal tube cuff pressures should be measured at least every 8 hours or once per shift, which can be 6 or 12 hourly in the context of the study.

5.3.2.2.4 Methods to measure cuff pressures

Four techniques are used to inflate and maintain endotracheal tube cuff pressures: the minimal leak technique (MLT), the minimal occlusive volume (MOV) technique, the cuff pressure measurement (CPM) technique and the palpation method. The MLT is when air is slowly injected into the cuff until the leak stops. A small amount of air is released to allow a slight air leak at peak inflation pressure. With the MOV technique, the cuff is slowly inflated until no leak is audible during a positive pressure ventilatory breath. This technique may be more effective than the MLT in reducing silent aspiration. CPM is performed with a manometer during the inspiratory phase. The fourth technique is the palpation method and involves subjective estimation of the cuff inflation based on gentle palpation of the pilot balloon (Rose and Redl, 2008(a):428). The pilot balloon is a small balloon that, when felt for air pressure, indicates the general inflation status of the cuff (Pierce, 2007:67). See Figure 2.2 for a schematic presentation.

A survey was done on the current practices of cuff management in adult critical care units in Australia and New Zealand. Of the 92 participants, it was reported that 54% (50/92) used a combination of MOV and CPM and a further 5.5% used these methods in combination with palpation of the pilot balloon. A total of 20 units (22%) used CPM as the sole method and 17.5% used MOV exclusively. Only one unit (1%) used MLT after intubation. According to Vyas *et al* (2002:275-277) and Crimlisket *al* (1996:225-235), the superiority of CPM over MOV or MLT has not been proven yet. CPM provides an objective measurement of cuff pressure that does not involve cuff

deflation, potentially decreasing the risk for aspiration. Rose and Redl (2008(a):434) conclude by saying that the MOV technique is more resource intensive than CPM. According to two literature papers (Ganner, 2001:1127-1134; St John, 2004:93-96), complications have been associated with MOV and MLT, including interruption of positive pressure and an increased risk of hypoxemia, aspiration and hyperinflation on cuff re-inflation. In addition, MLT might cause tracheal wall trauma, drying of tracheal mucosa and may result in hypoventilation due to the loss of tidal volume around the cuff.

In a descriptive survey conducted in a 24 bed adult medical-surgical critical care unit in Australia, using 80 nurse practitioners, it was found that MOV increases the risk of aspiration and VAP in the critically ill patient (Rose and Redl, 2008(a):364). In a survey conducted by Ganner (2001:1127-1134) assessing accurate measurements of cuff pressures post-cardiac surgery amongst theatre and critical care unit nursing staff, it was concluded that cuff pressures were too high using the minimal occlusion technique and that the cuffs are prone to leaking when using this technique.

An observational study to compare endotracheal cuff pressure obtained by estimation techniques with direct cuff pressure measurements by means of manometer was conducted using 40 anaesthesia providers. Pressures obtained by estimation techniques ranged from 6 to 60 cmH₂O. The authors conclude that estimation techniques for cuff inflation are inadequate and suggest direct measurements by means of using a manometer (Stewart, Secrest, Norwood and Zachary, 2004:443-447). The findings of the above study are supported by Fernandez, Blanch, Mancebo, Bonsoms and Artigas (1991:1328), who compare the accuracy of finger estimation with direct cuff pressure measurements in 20 participants in the critical care unit. Accuracy for the estimated method by finger palpation was 69% for high pressures, 58% for normal pressures and 73% for low pressures. It concludes that the palpation technique is inadequate for cuff pressure measurement and suggests that direct measurements by means of manometry be used.

The best practice evidence summary supports this in stating that direct measurements using a manometer could prevent over-inflation and under-inflation (Porritt, 2009). In an observational study done by Galinski, Treoux, Garrihue, Lapostolle, Barron and Adnet (2006:545-547), using 107 patients to assess the incidence of excessive cuff pressures, it was found that the majority of cuff pressures exceeded the normal recommended values and that frequent measurements with a manometer should be performed to correct the problem.

In a quasi-experimental control study comprising of three groups of anaesthesiologists, it was found that there is a tendency to overinflate endotracheal tube cuff amongst all the participants. The study findings suggest that cuff pressures should be done with a manometer routinely in order to avoid excessive or under-inflation of cuff (Wujtewics, Sawicka, Owczuk, Sommer and Wujtewics, 2009:166-169).

Recommendations from a quasi-experimental study conducted amongst 93 patients in three private hospitals in Kentucky suggest that endotracheal tube pressures be monitored with a manometer (Sengupta, Sessler, Maglinger, Wells, Vogt, Durrani and Wadhwa, 2004:6-10). In a prospective observational study done in 113 patients in two different critical care units, it was found that the incidence of tracheal tube over-inflation remained high. It was recommended that the use of manometry alone was not sufficient in reducing the incidence of over-inflation, but that a management protocol should be in place guiding practice (Morris, Zoumalan, Roccaforte, Amin, 2007:639).

Soleef *et al* (2009:133-143) conducted a single-group repeated measure design where they used ten critically ill patients who were intubated and mechanically ventilated. The study results show a total of 30% of the pressure measurements were less than 20 cmH₂O, which can expose the patients to a higher risk for aspiration. Another finding was that 16% of the cuff pressures were higher than 30 cmH₂O. It was recommended from this study that continuous monitoring of endotracheal tube cuff pressures should be used rather than intermittent monitoring with a manometer. However, this was a small sample size and findings should thus not be generalised.

Only one observational study was found providing information on continuous recording of cuff pressures. In this study, the cuff pressures were continuously recorded in nine intubated patients. Patients who spent 25% off continuous recording had cuff pressures more than 30 cmH₂O, thus suggesting that continuous cuff pressure monitoring reduces the risk for over-and under-inflation (Duguet *et al*, 2007:128).

Another more recent correlation study done by Efrati, Deutsch, Gurman, Noff and Conti (2010:984-990) suggest a new method for estimation of the percentage of endotracheal tube lumen obstruction during controlled mechanical ventilation. The estimation is based on the changes in the cuff pressure during peak inspiratory pressure. The axioms of the method are that the trachea is completely sealed by the endotracheal tube cuff and that the ventilator pressure is higher than the cuff pressure. This method proved to detect excessive cuff pressures early, but further studies are needed in order to evaluate the method as part of daily clinical practice in intubated patients.

5.3.2.2.5 Factors contributing to inadequate or incorrect cuff pressures

Various factors are thought to influence endotracheal tube cuff pressure variations. Change of tracheal muscle tone, hypothermia, hyperthermia, diffusion of anaesthetic gas into the tube, changes in endotracheal tube position and changes in the patient's position are some of the factors contributing to incorrect cuff pressures. Cuff pressure alterations in adult patients and the effect of changes in patient position were investigated in a randomised control trial conducted in 70 patients in the emergency room. The results of the study show that cuff pressures were higher (>22 mmHg) when patients were moved from the 35 degree semi-Fowlers position to the lateral decubitus position. It was recommended that in the routine care of intubated patients, regular endotracheal cuff pressures and adjustments after changes in body position should be encouraged (Gody, Vieira and Capitani, 2008:296).

In a quasi-experimental study done by Brimacombe, Keller, Giampalmo, Sparr and Berry (1999:708-710), using ten adult patients, it was found tracheal mucosal pressures were highest and that the rotated position caused a greater increase in

tracheal mucosal pressure that the extended or flexed position. This study highlights the fact that the patient's position does influence cuff pressures.

An observational study that was performed in a ten-bed critical care unit using 101 patients confirmed the findings that patients with cuff pressures less than 20 cmH₂O develop a risk for aspiration, while the incidence for tracheal stenosis was common in patients with cuff pressures more than 30 cmH₂O. In the study, 73% of the patients developed over-inflation, while 45% developed under-inflation when recording of cuff pressures was performed every eight hours. Absence of sedation and duration of intubation were associated with cuff under-inflation (Nseir, Brisson, Marquette, Chaud, Pompeo, Diarra and Durocher, 2009:229-234).

5.3.2.2.6 Management of cuff leaks

Management of a patient presenting with a leaking endotracheal tube should include a thorough physical examination. Cuff leaks are usually detected by sounds generated during lung inflation. When a cuff leak becomes audible, the volume of the leak can be determined by noting the difference between the desired inflation volume and the exhaled volume recorded by the ventilator. The endotracheal cuff should be inflated until cessation of an audible leak. However, the resultant cuff pressure should then be checked. If the cuff pressure is greater than 25 mm Hg, the patient may be allowed to continue ventilating with an air leak as long as adequate tidal volumes and appropriate ventilation are maintained or the endotracheal tube can be changed (Robert *et al.*, 2007:239). According to Sengupta *et al* (2004:6), injected volumes of 2 and 4 ml of air usually produce cuff pressures between 20 and 30 cm H₂O independent of tube size. However, when air is injected, it is recommended to measure cuff pressures rather than estimating the volume of air injected. Furthermore, it was recommended that if there is a need to inflate the cuff with more than ten ml of air, the practitioner should raise a concern about tracheal injury and investigate the cause for the leak (Hameed *et al*, 2008:23). The findings of an observational study done by Sridermma, Limtangturakool, Wongsurakait and Thamlikitkul (2007:74-78) concur when their study findings revealed that in 34 intubated adult patients in Siriraj Hospital, the volume of air required to inflate the

cuff adequately was 7,1 ml. If more air is required for inflation, the cause should be investigated.

5.3.3 SUMMARY FOR SYSTEMATIC REVIEW ON ENDOTRACHEAL TUBE CUFF PRESSURE MONITORING

The evidence found on the topic related to endotracheal tube cuff pressure monitoring highlighted the frequency of monitoring cuff pressure, the consequences related to over- and under-inflated cuffs, the methods and normal ranges required to measure endotracheal cuff pressures, factors contributing to incorrect or inadequate cuff pressures and management of cuff leaks.

Despite the fact that there was a paucity of Level I and II evidence, consistent and repetitive data were present in the evidence found. The review has highlighted the consequences related to incorrect endotracheal tube cuff pressure monitoring, which, if not practiced, might jeopardise the safety of the intubated mechanically ventilated patient.

5.4 SUMMARY OF THE CHAPTER

This chapter provided the findings of the systematic reviews done on the two of the four nursing care practices that were identified to be performed the least according to best recommended practices. A systematic review forms the core for the development of clinical guidelines. Derived from the data findings in this chapter, evidence-informed clinical guidelines were developed which will be presented in Chapter 6 and in Annexures V and Y of this study.

EVIDENCE-INFORMED CLINICAL GUIDELINES

6

“Man’s mind, stretched to a new idea, never goes back to its original dimensions.”

Oliver Wendell Holmes

“Clinical guidelines have been recognised as one of the most promising and effective advances for defining and improving the quality of care.” (Pearson et al)

IN THIS CHAPTER

In the previous five chapters, an overview of the research study was given, the research design and method were comprehensively discussed and the first stage of the study was completed.

This chapter discusses:

- The steps followed in the clinical guideline process. However note that a comprehensive description of the process of clinical guideline development was described in Chapter 3 of this study.
- The clinical algorithms
- The guidelines summary and the comments from the expert panel reviewers.

6.1 INTRODUCTION

According to Rees and Booth (2005:315), the development of guidelines must be supported by systematic, rigorous and explicit methods of evidence review and synthesis, thus supporting the fact that a systematic review is the essence and core of evidence-informed or evidence-based guidelines. Bazian (2005:270) states that the process for collecting, analysing and synthesizing the data must be valid and reliable, in order to make a sound evidence-based recommendation.

Four nursing care practices related to the artificial airway in the mechanically ventilated patient were initially identified to be explored and described. Derived from the data as analysed from the structured questionnaires on the four nursing care practices, two were done least according to the best recommended practices.

Systematic reviews were done on these two nursing care practices respectively, which formed the basis for the development of the evidence-informed clinical guidelines.

6.2 EVIDENCE-INFORMED CLINICAL GUIDELINE DEVELOPMENT PROCESS

The process in developing evidence-informed clinical guidelines were schematically illustrated in Figure 3.4 and described in Chapter 3 of this study. On completion of the systematic review, two draft clinical guidelines were developed, using the combined evidence-linked and formal consensus method as described in Chapter 3: step 2 of the guideline development process).

The expert panel members as selected (see step 6 in Chapter 3 on the expert panel selection) were contacted to confirm availability to participate in the study. Individual contact sessions were arranged to explain the purpose of the study, the objectives of the clinical guideline, as well as the process followed. Each panel member was issued with a participant information letter (see Annexure T). Consent was obtained from each member confirming voluntary participation in the study. In cases where personal sessions were not possible, e-mail or telephonic communication was used. The two draft evidence-informed clinical guidelines, namely endotracheal tube suctioning and cuff pressure monitoring, and the clinical algorithms were submitted, in hard copy or via e-mail, to the selected expert panel for review.

In order for the expert panel reviewers to assess the draft clinical guidelines, the researcher used a review sheet that was based on the AGREE appraisal instrument. For the purpose of this study, the AGREE tool was adapted (see Annexure U). The expert panel members were asked to complete the review sheet and to make comments, suggestion and/or recommendations as required. One week was granted for feedback from the expert panel reviewers. Apart from the written feedback, discussion sessions on the feedback were held with each panel member. In cases where personal sessions were not possible, telephonic and e-mail communication was used. Feedback from each reviewer was then considered to prepare the final clinical guidelines.

6.3 FORMAT OF THE CLINICAL GUIDELINES

The AGREE appraisal instrument was used as a guide for the development of the evidence-informed clinical guidelines. The instrument provides a standard framework for the development and implementation of clinical practice guidelines. The AGREE instrument is generic and can be applied to all types of clinical practice guidelines. A checklist of 23 items across six different quality domains provides a useful tool for generation and evaluation of clinical practice guidelines (Schmidt and Brown, 2009:324). See Chapter 3 for a description of the AGREE instrument as well as Annexure M.

The first part of the clinical guidelines aimed to define the scope and purpose of the guideline by introducing the reader to the objective, the systematic review question and defining the target population. The next section of the clinical guideline aimed to address stakeholder involvement. The third section in this guideline discusses the results of the systematic review findings. Best practice recommendations based on these findings are presented. The grades of recommendations were assigned to the best recommended practices. A description of the grades was available. Within the discussion section, the other domains of the AGREE instrument were applied, namely the rigour of development, clarity and presentation of the clinical guideline. Editorial independence, where any possible conflict of interest and independence of the recommendations were declared, was the last domain discussed in the guideline. Due to the scope of this research study, one domain, namely applicability, which addresses the behavioural, cost and organizational consequences of applying the guideline, was not addressed. A list of references used in the construction of the guideline was provided.

It is important to note that as this is evidence-informed guideline, recommendations with the applicable evidence to substantiate the recommendations formed the core of this guideline. Recommendations were based on the evidence found.

6.4 CLINICAL ALGORITHMS

Due to the comprehensiveness, length and scope of the evidence-informed clinical guidelines, it was decided to develop clinical algorithms derived from the guidelines.

Algorithms conveniently convey the scope of a guideline in a shorter version. Algorithms have shown to result in faster learning, higher retention and better compliance with established practice than standard text. The use of clinical algorithms at the patient's bedside can be used as part of the flow sheets and/or documentation and can assist in quick dissemination of information (Hardorn, 1999:93).

Based on the evidence-informed clinical guidelines, the following clinical algorithms were developed:

- Algorithm for the “ABCD” of endotracheal tube suctioning.
- Algorithm for “the when, how and what” of endotracheal tube cuff pressure monitoring.

The clinical algorithms were submitted with the clinical guidelines for review to the expert panel review members.

6.5 EVIDENCE-INFORMED CLINICAL GUIDELINE ON ENDOTRACHEAL TUBE SUCTIONING

Comments from the expert panel reviewers are provided in this section of the study. A guideline summary is provided in this section of the research study. Note that the final guideline is attached as Annexure V.

6.5.1 COMMENTS FROM THE EXPERT PANEL REVIEWERS

The comments and/or recommendations from the eight reviewers are presented according to the headings used in the review sheet. The scores as rated by the reviewers were calculated for each domain and are reflected in this section. The calculation for the domain score is explained in the first section, but thereafter only the final score is stated.

6.5.1.1 Scope and purpose of the clinical guidelines

The expert panel reviewers either agreed or strongly agreed that the objective and clinical question related to endotracheal tube suctioning is clearly described. However, two of the reviewers stated that the third item in this section, namely a

description of the patients to whom the guideline is meant to apply, must be described more explicitly. Based on the comments, the final guideline was adapted.

The calculation of the domain scores for this section was as follows:

	Item 1	Item 2	Item 3	Total
Reviewer 1	4	4	4	12
Reviewer 2	4	4	3	11
Reviewer 3	3	3	3	9
Reviewer 4	4	4	4	12
Reviewer 5	4	3	4	11
Reviewer 6	4	4	2	10
Reviewer 7	4	4	3	11
Reviewer 8	4	4	4	12
TOTAL	31	30	29	88

Maximum possible score = 4 x 3 items x 8 reviewers = 96

Minimum possible score = 2 x 3 items x 8 reviewers = 48

The scaled domain score will be:

Obtained score – Minimum possible score

Maximum possible score – minimum possible score

$88 - 48 / 96 - 48 \times 100 = 40 / 48 = 0.8333 \times 100 = 83\%$

The higher the score rating that is obtained per domain, the greater the consensus, related to the domain assessed, thus validating the content of the clinical guideline.

6.5.1.2 Stakeholder involvement

Two of the expert panel review members recommended that the items addressing the patient's views and preferences, as well as the target users of the guideline be stated more explicitly. Based on the comments the final guideline was adapted. The domain score for this section was 76.5%.

6.5.1.3 Rigour of development

This section of the clinical guideline was well accepted by all the members of the expert review panel who either agreed or strongly agreed. Two of the reviewers specifically commended on the high quality of rigour related to the development of the evidence-informed clinical guideline. The domain score for this section was 79%.

6.5.1.4 Clarity and presentation

All the members of the expert panel reviewers accepted this section well in stating that the recommendations are clear, unambiguous, user friendly and well substantiated. Of the eight reviewers, five accepted the content without making any suggestions. The remaining three reviewers made suggestions pertaining to the content of the clinical guideline. These suggestions are discussed under heading 6.5.2.5. The domain score for this section was 70.5%.

6.5.1.6 Editorial independence

Editorial independence, where any possible conflict of interest and independence of the recommendations were declared, was the last domain discussed in the guideline. This section was well accepted by the reviewers. The domain score for this section was 80.5%.

6.5.1.6 Other comments

The following general comments were noted from expert panel reviewers:

Reviewer one:

- Suggested that the reader must be made aware that although there are two types of suctioning, namely closed and open endotracheal tube suctioning, it should be explicitly stated that the guideline focuses on the practices of endotracheal tube suctioning and that these practices are the same despite of the types of suctioning. Following a consensus discussion with the reviewer, it was decided not to include this aspect in the final guideline.
- A brief description of evidence-informed clinical guideline and the rationale for the development of the clinical algorithm is required. None of the other reviewers

required an explanation. After a consensus discussion with the reviewer, it was decided not to include this aspect in the final guideline.

Reviewer two:

- Despite minor editorial comments, commented that the guideline content is relevant and reliable.

Reviewer three:

- Except for editorial comments, the guideline was well accepted.
- Guideline is factual, user friendly.
- Suggested that the grades of recommendations be discussed earlier in the guideline rather than placing them at the end of the document. This was done in the final clinical guideline.

Reviewer four:

- Overall guideline accepted.

Reviewer five:

- Except for comments related to the content, the overall guideline was accepted.
- Commented that the guideline proves to be a valuable tool for teaching and practice purposes.

Reviewer six:

- Despite editorial comments and comments made regarding the content, the overall guideline was accepted.

Reviewer seven:

- Except for the comments related to the content, the overall guideline was accepted.

Reviewer eight:

- The guideline was well accepted.

- Suggested that the grades be changed to 1,2, 3, etc, instead of A, B, C, D and I. After a telephonic consultation with the reviewer, consensus was reached to leave the grading system as indicated in the draft guideline as it was not developed by the researcher but has a definite scientific and rigorous process of development and was an established grading system.

6.5.2 GUIDELINE SUMMARY

This section provides the reader with a summary of the evidence-informed clinical guideline on endotracheal tube suctioning. A copy of the comprehensive final guideline is available as Annexure V.

6.5.2.1 Guideline title

Endotracheal tube suctioning in the adult mechanically ventilated patient in the critical care unit.

6.5.2.2 Scope and purpose

The objective of the guideline, the systematic review question and defining the target population are topics for discussion in this section.

6.5.2.2.1 Guideline objective

The objective of this evidence-informed clinical guideline is to provide professional nurses in the Nelson Mandela Metropole with the best practice recommendations in performing endotracheal tube suctioning in the intubated, adult mechanically ventilated patient in the critical care unit.

6.5.2.2.2 Review question

The systematic review question that was formulated in order to search for relevant literature pertaining to endotracheal tube suctioning was as follows:

- How should endotracheal tube suctioning in the adult, mechanically ventilated patient in the critical care unit be done in order to minimize and/or prevent the complications associated with the procedure?

6.5.2.2.3 Target group

The clinical guideline is intended for use amongst professional nurses performing endotracheal tube suctioning in the adult, intubated, mechanically ventilated patient in the critical care unit.

6.5.2.3 Stakeholder involvement

Due to the scope of this research study, the guideline was developed by the researcher and not by a recommended guideline development group. However, an expert review panel was consulted to comment on the guideline construction and content. The expert panel comprised of an intensivist, three professional nurses, a respiratory therapist, anaesthetist and a sales consultant for a respiratory equipment manufacturing company (who had previously worked in the critical care unit and holds an additional qualification in Critical Care Nursing). The eighth member of the group was a nursing lecturer at one of the local universities, teaching Critical Care Nursing.

Due to the disease process and presentation of the critically ill patients in the critical care units, the patients' views and preferences have not been considered in the development of this clinical guideline. Furthermore, no reference was made in the evidence found with regard to the patients' views and preferences, which are thus lacking in this guideline.

The guideline has not been piloted amongst the target users, namely the professional nurses in the critical care units in the Nelson Mandela Metropole as this was not part of the scope of this study. Implementation strategies thus have to be developed to enhance the use of this guideline in practice.

6.5.2.4 Rigour of development

This clinical guideline was developed and based on the data derived from a systematic review conducted. CINAHL, MEDLINE (via PubMed), EBSCO HOST, the JBI systematic review library, the Cochrane Library, clinical evidence from the British Medical Journal (BMJ), the National Guidelines Clearinghouse, Google Scholar, Highwire, Ingenta, and the online Worldviews on Evidence-Based Nursing were

searched for data. Search terms used for identifying literature pertaining to endotracheal tube suctioning were, for instance, “endotracheal suctioning AND Adult NOT neonate”; “tracheal* AND suctioning”; “ventilation AND suctioning”. The search was limited to articles pertaining to human, adult patients aged 18 and above, published in English up to date 1990. All animal and paediatric studies were excluded.

A total of 100 papers were initially identified to be included in the systematic review. After elimination of duplicate papers and those that did not adhere to the inclusion criteria, 42 papers were included for methodological assessment. Following the critical appraisal process, which was done independently by two reviewers, 36 papers were included in the systematic review. On completion of the literature searching process, critical appraisal, data extraction and synthesis were done, using the JBI SUMARI suite version 4.0. Recommendations were formulated based on the evidence collected and appraised. Furthermore, grades, which indicate the strength of recommendations, were used. The United States Preventive Services Task Force (USPSTF) grades of recommendations, accessed via the link www.ahcpr.gov/clinic/uspst-fix.htm, were used to rank recommendations in terms of hierarchy levels of evidence. Once the draft guideline was completed, it was submitted to the expert review panel for comments. The reviewers comments were considered and used to revised and complete the final clinical guideline.

6.5.2.5 Clarity and presentation of recommendations

The recommendations based on the evidence found and appraised are presented in this section. The comments from the reviewers on each section are highlighted.

6.5.2.5.1 Assessment

The following recommendations were made with regard to assessment of the critically ill, intubated patient prior to and after performing endotracheal tube suctioning.

- It is recommended that an assessment of the patient, which includes a chest auscultation, be done prior to performing endotracheal tube suctioning (Grade D).

- The need for suctioning should be determined by the clinical respiratory indicators for suctioning (Grade D).
- In the mechanically ventilated patient, the presence of a saw-tooth pattern on the volume and pressure flow-loop curve on the ventilator graphs is usually indicative of the need for performing endotracheal tube suctioning (Grade C).
- Routine endotracheal tube suctioning is not recommended and suctioning should only be performed when necessary (Grade A).
- Performing endotracheal tube suctioning every two hours does not appear to be beneficial in clearing airway secretions (Grade B).
- On completion of endotracheal tube suctioning, it is recommended that nurses perform a physical assessment, which should include a chest auscultation. Other assessment findings should include monitoring the vital signs data, perfusion status as well as the characteristics of the sputum. Re-assurance of the patient should be done to minimize and/or reduce anxiety produced by the endotracheal tube suctioning procedure (Grade D).

This section was well accepted by the panel of reviewers and no changes were thus made.

6.5.2.5.2 Best methods: no normal saline, hyperinflation and hyperoxygenation, suction pressure

This section refers to the best methods that should be practiced in order to ensure that endotracheal tube suctioning is performed safely. The best recommended methods include no normal saline instillation, the use of hyperinflation and hyperoxygenation and the use of adequate and correct suctioning pressures.

Normal saline instillation

It is recommended that:

- Normal saline instillation should not be used when performing endotracheal tube suctioning as it decreases the oxygenation levels of the patient (Grade A).
- The premise that the use of normal saline instillation to thin secretions should be discarded as it is unsupported and can be dangerous, thus jeopardising the safety of the intubated patient (Grade D).

- Normal saline instillation should not be practiced as it proves to dislodge bacterial colonies, thus contributing to lower-airway contamination and infections (Grade C and D).

This section of the guideline was well accepted by the reviewers and no changes were made to the final recommendations.

Hyperinflation and hyperoxygenation

The following recommendations can be made with regard to hyperinflation and hyperoxygenation practices.

- Hyperinflation used alone does not appear to be beneficial in the intubated, mechanically ventilated patient (Grade A).
- It is recommended that hyperinflation be used with caution in patients who present with increased intracranial pressure, vascular, cardiac surgery and those who are hemodynamically unstable (Grade D).
- Routine use of hyperinflation is not recommended due to the risk for barotrauma from large volumes, high peak pressures and patient discomfort. (This sentence was added at the request of the reviewers.)
- The use of hyperinflation combined with hyperoxygenation appears to be beneficial in improving the oxygenation level of intubated adult patients (Grade A and B).
- It is recommended that hyperinflation be delivered by the ventilator in order to control tidal volume and inspiration pressure (the rationale included at the request of the reviewers). The use of a manual resuscitation bag is not recommended (Grade D). Three of the reviewers strongly supported this recommendation, thus validating and increasing the reliability of the Grade D evidence.

Based on the comments of the reviewers, this section of the guideline was adapted. The changes were also indicated in the algorithm.

Suction pressures

It is recommended that suction pressure should be maintained at 80-120 mmHg during endotracheal tube suctioning (Grade D). One reviewer commented that the suction pressure of up to 200 mmHg can be used in performing suctioning. However,

this was based on expert opinion on practices used in the operating theatre and no referral to evidence was made. Therefore, this recommendation was not included in the final guideline.

6.5.2.5.3 Catheter size

It is recommended that suction catheters be as small possible, yet large enough to facilitate secretion removal. The external diameter of the suction catheter size should be less than half of the internal diameter of the endotracheal tube. The widely accepted formula for calculating catheter size is: suction catheter size [Fr] = (ET tube size [mm] -2) x 2 (Grade D). This recommendation was well accepted by all the reviewers and was thus not changed in the final guideline.

6.5.2.5.4 Depth of catheter insertion, duration of suctioning

With regard to the depth of the suction catheter insertion during endotracheal tube suctioning, it is recommended that:

- The suction catheter should be inserted to the length of the endotracheal tube only (Grade A).
- The suction catheter should be inserted to the carina. The suction catheter should be inserted until resistance is felt and then be retracted 1-2 cm before endotracheal tube suctioning is performed (Grade D).

Two of the reviewers questioned the practical application of inserting the suction catheter to the carina. No definite and clear specifications are given as where the carina is. However, literature papers suggest that the suction catheter be inserted until resistance is felt with the catheter, then it should be retracted 1-2 cm before endotracheal tube suctioning is performed. The recommendation in the guideline and in the algorithm was adapted to answer the query raised by the two reviewers

Duration of the suctioning procedure

It is recommended that the endotracheal tube suctioning procedure should not last longer than ten seconds (Grade D). This recommendation was accepted by all the reviewers and was thus not changed in the final guideline.

6.5.2.6 Editorial independence

The responses from the professional nurses completing the structured questionnaires formed the basis for the development of this evidence-informed guideline. The promoter of the study assisted in the conception and the design of the guideline. Although funding was received from the institution where the study was conducted, this guideline is editorially independent of the funding body. No funding was obtained from product manufacturers. No conflict of interest is applicable to the development of this guideline. No changes were made to this section as it was well accepted by the reviewers.

6.5.3 CLINICAL ALGORITHM FOR ENDOTRACHEAL TUBE SUCTIONING

The draft algorithm for the “ABCD” of endotracheal tube suctioning was well accepted by all the reviewers. Based on the feedback from the reviewers, changes were made to the recommendation on hyperinflation. The section on the depth of catheter insertion was adapted to emphasise the practical application of insertion of the suction catheter to the carina. The final clinical algorithm is illustrated in Figure 6.1 and Annexure W.

ALGORITHM FOR THE "ABCD" OF ENDOTRACHEAL TUBE SUCTIONING

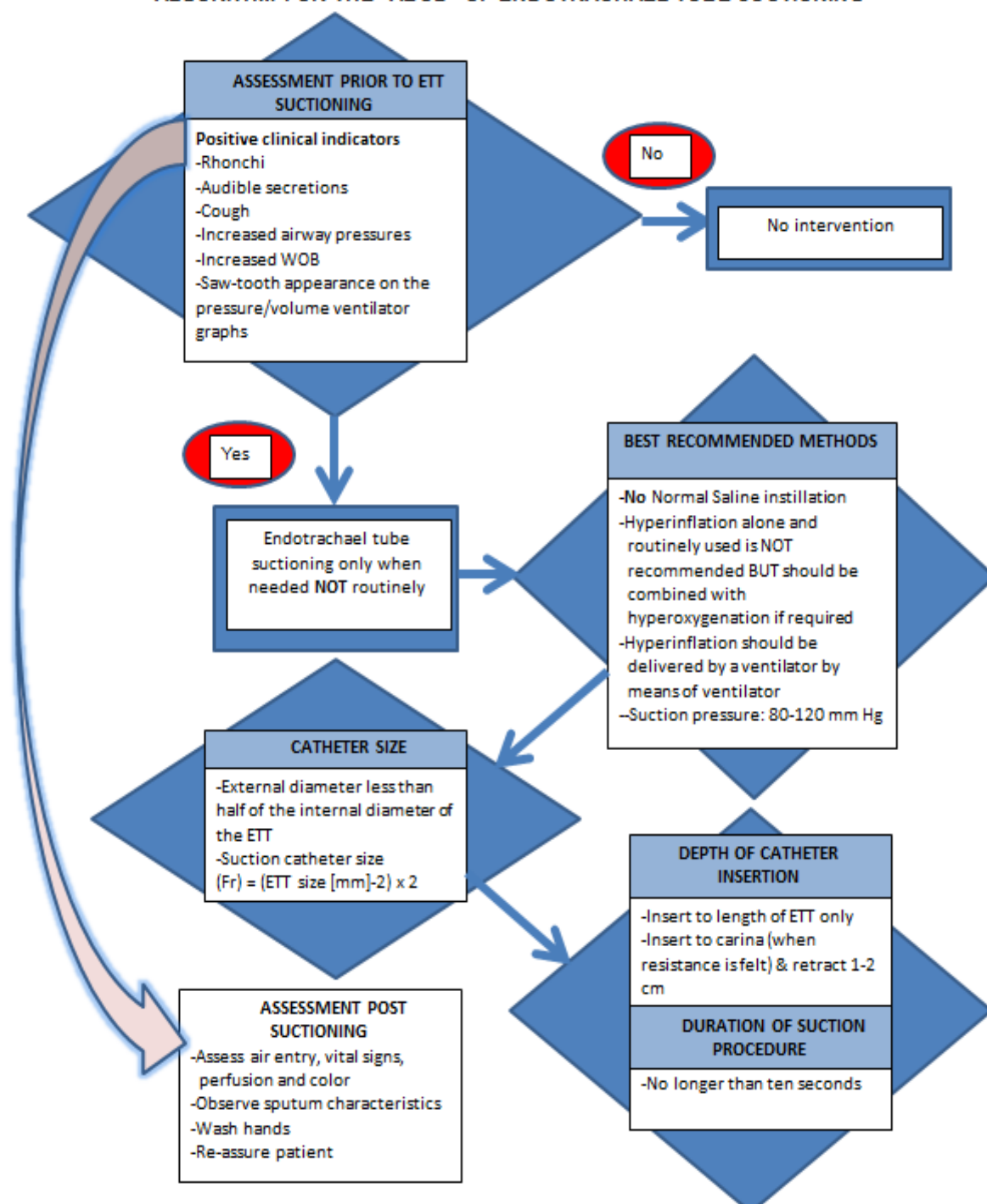


Figure 6.1 Algorithm for the "ABCD" of endotracheal tube suctioning

6.6 EVIDENCE-INFORMED CLINICAL GUIDELINE ON ENDOTRACHEAL TUBE CUFF PRESSURE MONITORING

Comments from the expert panel reviewers are provided in this section of the study. A guideline summary is provided in this section of the research study. Note that the final guideline is attached as Annexure X.

6.6.1 COMMENTS FROM THE EXPERT PANEL REVIEWERS

The comments and/or recommendations from the eight reviewers are presented according to the headings used in the review sheet.

6.6.1.1 Scope and purpose of the clinical guidelines

The expert panel reviewers either agreed or strongly agreed that the objective and clinical question related to endotracheal tube suctioning is clearly described. However, two of the reviewers felt that the third item in this section, namely a description of the patients to whom the guideline is meant to apply, as well as the target group be described more explicitly. Based on the comments, the final guideline was prepared. The domain score for this section was 78%.

6.6.1.2 Stakeholder involvement

This section was well accepted by the reviewers and no changes were thus made to the final guideline. The domain score for this section was 76.5%.

6.6.1.3 Rigour of development

This section of the clinical guideline was well accepted by all the members of the expert review panel. The domain score for this section was 84%.

6.6.1.4 Clarity and presentation

All the members of the expert panel reviewers accepted this section well in stating that the recommendations are clear and unambiguous. The domain score for this section was 78.5%. Other comments and the rating scores obtained in completing the review sheet are illustrated in Table 6.1.

Table 6.3 Comments from the expert panel reviewers on endotracheal tube cuff pressure monitoring

Reviewer	Comment
1	<ul style="list-style-type: none"> • It was recommended to state the target group more explicitly. • Commented that the content is relevant and updated.
2	<ul style="list-style-type: none"> • Guideline well accepted without any suggestions.
3	<ul style="list-style-type: none"> • Except for minor editorial comments, the clinical guideline was well accepted and no suggestions made.
4	<ul style="list-style-type: none"> • Guideline and algorithm well accepted.
5	<ul style="list-style-type: none"> • Overall guideline and algorithm well accepted. • Suggested that cuff pressure monitoring be done more frequently in the hemodynamically unstable patient.
6	<ul style="list-style-type: none"> • The overall guideline and algorithm was accepted.
7	<ul style="list-style-type: none"> • The guideline and the algorithm were well accepted without any suggestion or corrections.
8	<ul style="list-style-type: none"> • Recommended that the target group be stated more clearly.

6.6.1.5 Editorial independence

Editorial independence, where any possible conflict of interest and independence of the recommendations were declared, was the last domain discussed in the guideline. This section was well accepted by the reviewers. The domain score was 90%.

6.6.2 GUIDELINE SUMMARY

This section provides the reader with a summary of the evidence-informed clinical guideline on endotracheal tube suctioning. A copy of the comprehensive final guideline is available as Annexure X.

6.6.2.1 Guideline title

Endotracheal tube cuff pressure monitoring in the adult mechanically ventilated patient in the critical care unit.

6.6.2.2 Scope and purpose

The objective of the guideline, the systematic review question and defining the target population are topics for discussion in this section.

6.6.2.2.1 Guideline objective

The objective of this clinical guideline is to provide professional nurses with recommendations for clinical practice, which is based on evidence, for endotracheal tube cuff pressure monitoring in the intubated, mechanically ventilated patient in the critical care unit.

6.6.2.2.2 Review question

The following review question was formulated:

What nursing care interventions are the most effective in monitoring endotracheal tube cuff pressure to minimize the complications of over-inflation or under-inflation in the adult intubated patient in the critical care unit?

6.6.2.2.3 Target group

The clinical guideline is intended for use amongst professional nurses performing endotracheal tube cuff pressure monitoring in the adult, intubated, mechanically ventilated patient in the critical care unit.

6.6.2.3 Stakeholder involvement

Due to the scope of this research study, the guideline was developed by the researcher and not by a recommended guideline development group. However, an expert review panel was consulted to comment of the guideline construction and content. The expert panel comprised of the same group of individuals as discussed under heading 6.5.2.3.

Due to the disease process and presentation of the critically ill patients in the critical care units, the patients' views and preferences have not been considered in the development of this clinical guideline. Furthermore, no reference was made in the evidence found to with regard to the patients' views and preferences, which were thus lacking in this guideline.

None of the studies included cost information; therefore no information regarding cost is included in this guideline. The guideline has not been piloted amongst the target user, namely the professional nurses in the critical care units in the Nelson Mandela Metropole as this was not part of the scope of this study. Implementation strategies thus have to be developed to enhance the use of this guideline in practice.

6.6.2.4 Rigour of development

CINAHL, MEDLINE (via PubMed), the JBI systematic review library, the Cochrane Library, clinical evidence from the British Medical Journal (BMJ), the National Guidelines Clearinghouse and Google Scholar were searched. Search terms used for identifying literature pertaining to endotracheal tube cuff pressure were, for instance, “endotracheal tube AND cuff pressure AND monitoring”; “cuff pressures and tracheal care”; “cuff pressures and monitoring”; “tracheal damage”; “aspiration AND cuff pressures”; “aspiration OR ventilator-associated pneumonia AND cuff pressures”.

Inclusion criteria for studies to be considered in the systematic review comprised all studies that included human, adult patients aged 18 and above. Papers that were not published in English were excluded in the review. To ensure a comprehensive search, all papers that were published up to the year 1990 were included in the systematic review. Animal and pediatric studies were excluded.

The initial search for evidence identified 87 possible papers for inclusion into the systematic review. After eliminating duplications (n=15) and studies (31) that did not appear to answer the systematic review question and did not adhere to the inclusion criteria of the review, 41 papers were included in the critical appraisal process.

The methodological quality of papers was assessed using the critical appraisal tools in the JBI SUMARI software packages, Version 4.0. The JBI NOTARI and the MASTARI modules accessed via the CReMS in the SUMARI software package were used to critically appraise the evidence found. Two reviewers independently appraised the papers found.

The recommendations were formulated and based on the evidence found. The grade for recommendations as described earlier was used in the formulation of the recommendations. The draft clinical guideline was submitted to the expert panel for review.

6.6.2.5 Clarity and presentation of recommendations

The recommendations based on the evidence found and appraised are presented in this section. The comments from the reviewers on each section, where applicable are highlighted.

6.6.2.5.1 *Frequency of cuff pressure monitoring*

“When should endotracheal tube cuff pressure be monitored?”

Based on the papers found, which include Level III, IV and VII evidence, it is recommended that endotracheal tube cuff pressures be monitored at eight-hour intervals or at least once per shift, which can be 6 or 12 hourly in the context of the critical care units in the study (Grade B).

In a quasi-experimental study done by Brimacombe, Keller, Giampalmo, Sparr and Berry (1999:708-710), using ten adult patients, it was found tracheal mucosal pressures were highest and that the rotated position caused a greater increase in tracheal mucosal pressure than the extended or flexed position. This study highlights the fact that the patient’s position does influence cuff pressures.

The patient’s position does influence cuff pressure measurements. It is recommended that cuff pressures be re-checked after changes in the patient’s position (Grade D). Based on the expert opinion of one of the reviewers, it was suggested that cuff pressures be monitored and documented more frequently in the hemodynamically unstable patient. No other comments were added to this section of the final guideline.

6.6.2.5.2 Methods to maintain endotracheal tube cuff pressures

“How should endotracheal tube pressures be monitored?”

Cuff management practices include using the correct method and maintaining cuff pressures at the correct range. Literature describes four different methods to monitor cuff pressures. However, the question remains as to which of these methods is best recommended when monitoring endotracheal tube cuff pressures. According to the various pieces of evidence found, it is recommended that endotracheal tube cuff pressures be monitored by means of the cuff pressure measurement method performed with a manometer (Grade B). No suggestions were made and this section was thus unchanged in the final guideline.

6.6.2.5.3 Normal range for endotracheal tube cuff pressure monitoring

“What are the normal ranges at which endotracheal tube cuff pressures should be maintained?”

After establishing what is the best recommended method for measuring endotracheal tube cuff pressures, one needs to consider the best recommended normal ranges to maintain cuff pressures. Cuff pressures are monitored on the theory that high cuff pressures result in significant tracheal injury and reducing this pressure could prevent tracheal damage. A cuff pressure greater than 30 cmH₂O for 10 to 15 minutes is sufficient to induce histological evidence of mucosal lesions, which is the first step in development of mucosal damage or immediate complications, such as tracheal rupture (Galinski *et al*, 2006:545)

In order to prevent the complications related to over- and under-inflation, it is of utmost importance that the cuff pressure be maintained at the best recommended ranges of 25 to 30 cmH₂O or 18 to 22 mmHg (Grade B). This section was accepted by the reviewers.

6.6.2.5.4 Management of cuff leaks

It is recommended that when a cuff leak occurs, the endotracheal tube be inflated until cessation of the audible leak (Grade D). However, if more than 10 ml of air is injected, the practitioner should investigate and try to correct the cause (Grade D).

No comments were made by the reviewers on this section.

6.6.2.6 Editorial independence

The responses from the professional nurses completing the structured questionnaires formed the basis for the development of this evidence-informed guideline. The promoter of the study assisted in the conception and the design of the guideline. Although funding was received from the institution where the study was conducted, this guideline is editorially independent of the funding body. No funding was obtained from product manufacturers. No conflict of interest is applicable to the development of this guideline. No changes were made to this section as it was well accepted by the reviewers.

6.6.3 CLINICAL ALGORITHM FOR ENDOTRACHEAL TUBE CUFF PRESSURE MONITORING

Based on the clinical guideline, the algorithm was developed in order to disseminate data to allow for quicker access by professional nurses in the critical care unit. All the reviewers accepted the clinical algorithm. The clinical algorithm is presented in Figure 6.2.

**ALGORITHM FOR
“THE WHEN, HOW AND WHAT OF ENDOTRACHEAL TUBE CUFF PRESSURE
MONITORING”**

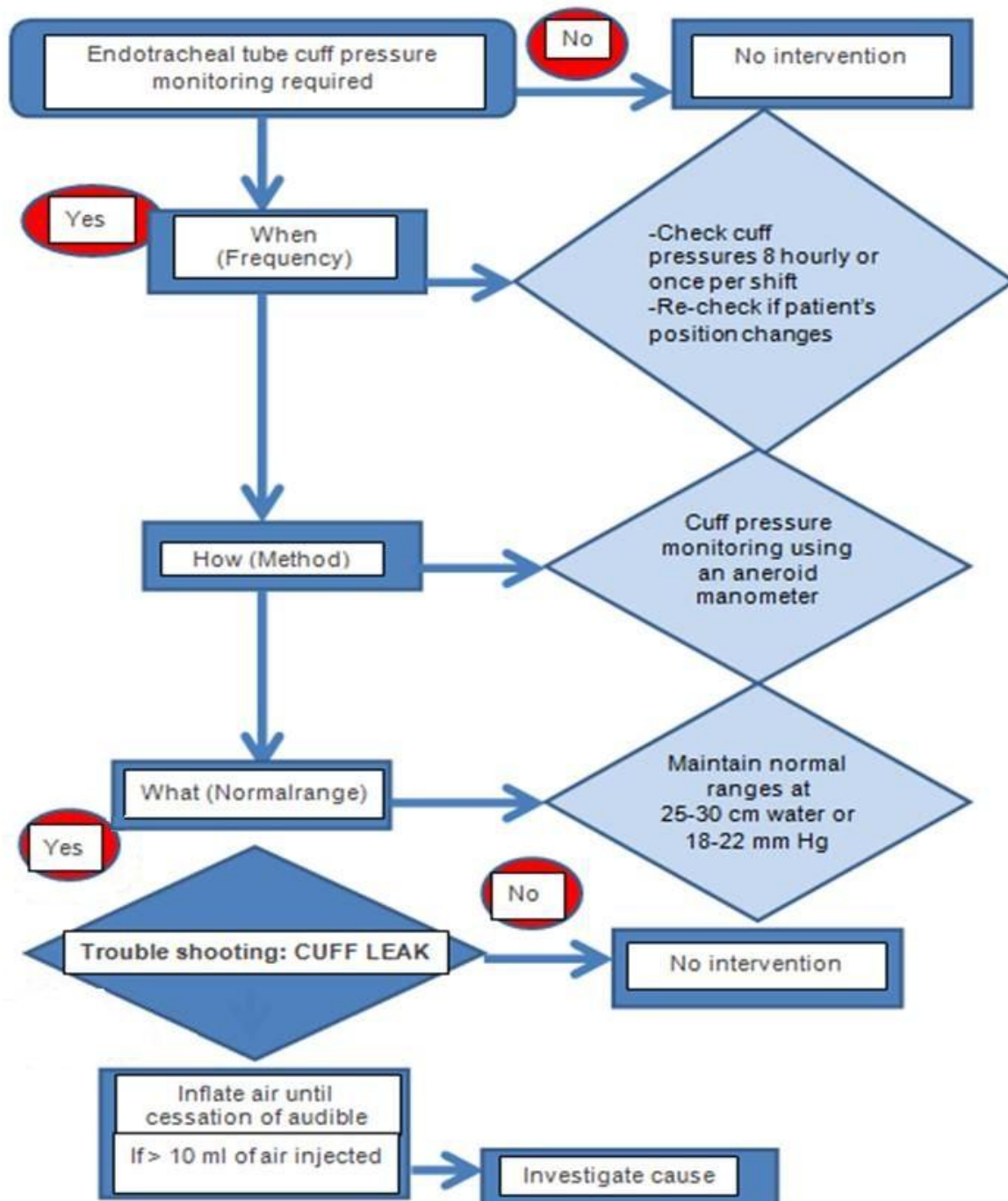


Figure 6.2 Algorithm for endotracheal tube cuff pressure monitoring

6.4 SUMMARY OF CHAPTER

The draft evidence informed clinical guidelines were submitted to the expert review panel. On completion of the review process, the necessary suggestions were considered and the final clinical guidelines were prepared. The guidelines summaries are presented in this chapter. However, the final, comprehensive guidelines are included as annexures. The clinical algorithms, as accepted by the expert review panel, are presented in this chapter.

The next chapter concludes the research study and includes the limitations and recommendations related to the study.

CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

7

“Start by doing what is necessary, then do what is possible, and then suddenly you are doing the impossible.” St Francis of Assisi

Thank you for exploring this journey with me!

IN THIS CHAPTER

This aim of this chapter is to discuss the limitations, conclusions and recommendations for the study.

7.1 INTRODUCTION

Evidence-informed nursing practice is the integration of professional judgement and research evidence about the effectiveness of interventions, and provides a sound and rational basis for the decisions taken about patient care by nurses (McSherry *et al*, 2002:3).

Evidence-informed clinical guidelines refer to systematically developed statements that are not only based on consensus, individual opinion and/or current practice, but on the best available evidence (Craig and Smyth, 2007:238). They are systematically developed to assist clinicians, consumers and policy makers in health care decisions and to provide critical summaries of available evidence on a particular topic (Elliot *et al*, 2007:63).

The purpose of the research study was to develop clinical guidelines that were based on the best available evidence. In this research study, the processes of data collection and analysis were described. The systematic review process and findings were discussed in Chapters 3 and 5 of this study. The process of clinical guideline development was discussed and the final evidence-informed clinical guidelines were presented. Clinical algorithms were developed in addition to the clinical guideline. The data was presented in Chapters 1- 6 of this research study.

This chapter addresses the conclusions, theoretical framework application, limitations and recommendations of the study.

7.2 CONCLUSIONS OF THE STUDY

Of all the patients admitted to the critical care units globally, approximately 75% of them require intubation and mechanical ventilation. However, it has been documented that although mechanical ventilation is a lifesaving treatment modality, it is associated with greater than 30% in-hospital mortality (Fenstermacher and Hong, 2004:258).

Due to the mortality rate and other complications related to mechanical ventilation, nursing care rendered to intubated patients in critical care units should be done in such a way to reduce the risk of adverse events in order to optimize patient safety. One way to ensure patient safety in the intubated mechanically ventilated patient is to base nursing care practices on the best available evidence. The development of clinical guidelines, based on evidence, is one of the initiatives that can ensure that the evidence found is transferred into practice.

All mechanically ventilated patients have an artificial airway *in situ* to enable the delivery of respiratory support and clearance of airway secretions. Four nursing care practices related to the care of the artificial airway were initially identified. These are endotracheal tube placement verification, endotracheal tube cuff pressure monitoring, suctioning and mechanical ventilator settings. The research study succeeded in reaching its overall purpose, which was to develop evidence-informed clinical guidelines for two identified nursing care practices related to the safety of the mechanically ventilated patient in the critical care unit.

The objectives of the research study were successfully reached. The research study was conducted in two stages. Stage One was divided into two steps. In step one of Stage One, the following objective was addressed:

-To explore and describe the four, identified nursing care practices related to the safety of the mechanically ventilated patient, as performed by professional nurses in critical care units in the Nelson Mandela Metropolitan area.

This objective was reached by the collection and analysis of data gathered by means of a structured questionnaire, completed by professional nurses in critical care units in both public and private health care institutions in the Nelson Mandela Metropole. The findings of this stage were presented in the form of tables and graphs in Chapter 4 of the research study.

Derived from the data analysis, it was possible to answer the second objective, namely to identify two of the four nursing care practices that are performed least according to best recommended practices. The two identified nursing care practices were endotracheal tube suctioning and cuff pressure monitoring.

Step two of Stage One was deemed necessary to reach the third objective namely: To explore and describe existing literature for the two identified nursing care practices related to the safety of the mechanically ventilated patient in a critical care unit. A systematic review on the two nursing care practices respectively was done. The findings of the systematic reviews were documented in Chapter 5 of the study. The process for conducting the systematic reviews was reported on in Chapter 3.

Stage Two of the research study was done to reach the last objective which is as follows: To formulate evidence-informed clinical guidelines to assist professional nurses in performing nursing care practices related to the safety of mechanically ventilated patients in critical care units. Based on the systematic review findings, two evidence-informed clinical guidelines were formulated. The aim of the guidelines was to provide professional nurses with recommendations for clinical practice, based on evidence, for endotracheal tube suctioning and cuff pressure monitoring in the mechanically ventilated patient in the critical care unit. The draft clinical guidelines were submitted to an expert panel for review, using the adapted AGREE tool. The comments and recommendations made by the panel were used to finalize the two evidence-informed clinical guidelines. Clinical algorithms for the two nursing care practices were developed in order to disseminate the information in these guidelines and to ensure easy access of the information to the professional nurses.

The research study findings revealed that there is a gap in practice with regard to basing nursing care practices related to the safety of the intubated mechanically ventilated patient in the critical care unit on the best available evidence. Data analysis clearly illustrated that practice variances exist amongst the professional nurses in the critical care units in the Nelson Mandela Metropole. No evidence-informed clinical guidelines existed for the four identified nursing care practices in the critical care units in the Nelson Mandela Metropole, thus making the development of the two evidence-informed clinical guidelines a unique contribution to the body of research and knowledge.

7.3 THEORETICAL FRAMEWORK

The research study was based on the JBI model, which describes the four major components of the evidence-based health care process as:

- Health care evidence generation;
- Evidence synthesis;
- Evidence transfer;
- Evidence utilisation.

In line with the JBI model of evidence-based health care, the following stages have been applied in this research study. However, it is important to note that not all the steps in this cyclic process have been applied in the research study, as some of the steps, for instance the implementation of the evidence-informed guidelines, are beyond this study's scope.

Health care evidence generation

Evidence for health care is generated through research, experience and formulation of opinion (Pearson *et al*, 2007:37). For the purpose of this study, evidence was generated by means of a quantitative approach using a structured questionnaire. Nursing care practices related to patient safety, as described in the problem statement, and performed by professional nurses in critical care units were explored and described by means of the structured questionnaire. Data collection and analysis allowed for evidence generation on the four identified nursing care practices. Evidence was furthermore generated by means of performing systematic

reviews on two of the four identified nursing care practices. A narrative literature review was done on all four identified nursing care practices.

Evidence synthesis

Evidence synthesis is the evaluation or analysis of research evidence on a specific topic to aid decision-making in health care. The second phase of the evidence synthesis involved the appraisal, data extraction and data analysis of the different types of evidence found (Pearson *et al*, 2007:23). After a literature search to locate the evidence available for the identified nursing care practises, the evidence had to be synthesized. The processes of evidence appraisal and synthesis were explained for the two identified nursing care practices that were included in the systematic review in Chapter 5 of this study.

Evidence transfer

Evidence transfer is considered to be more than the dissemination or distribution of knowledge. It includes writing up the systematic review report and developing clinical guidelines for utilisation in clinical practice (Pearson *et al*, 2007:24). The findings of the literature found were reported in the systematic review report for the two respective nursing care practices. Two evidence-informed clinical guidelines were formulated, which were based on the findings of the systematic reviews. These evidence-informed clinical guidelines will enhance nursing care practices related to the safety of the mechanically ventilated patient in a critical care unit.

Evidence utilisation

Evidence utilisation relates to the implementation of evidence in practice. The transfer of evidence into practice can be slow, and the process can be difficult for a range of complex reasons; thus, a strategy requiring appropriate skill, determination, time, money and planning is prudent for the success of any programme of implementation (Pearson *et al*, 2007:25). For the scope of this research study, evidence-informed clinical guidelines were developed by the researcher. An expert panel comprising of various members of the multi-disciplinary team reviewed the clinical guidelines, using a structured review sheet, thus validating the recommendations for practice.

7.4 LIMITATIONS

The limitations of the study were identified in the different stages and included the following:

Data Collection

- The low response rate from one of the critical care units in the public health care sector might have affected generalizations regarding the findings about professional nurses in the public health care sector.
- The lengthy questionnaire contributed to the low response rate in some of the critical care units. In analysing the data, it was found that the length of the questionnaire could have been shortened, thus reducing the data analysis chapter. However, at the time of doing the pilot study, participants did not find the length of the questionnaire problematic.

Systematic review

- Free access to electronic journals was limited and often articles had to be requested via the interlibrary loans or had to be purchased, thus increasing the cost of the research study.
- Due to the translation cost, non-English articles were not included in the systematic review. However, these articles could have enriched the findings of the study.
- The availability of independent reviewers to perform the critical appraisal independently of the researcher, who was the primary reviewer, was limited.

7.5 RECOMMENDATIONS

Recommendations for the research study are made for nursing research, education and practice.

7.5.1 RECOMMENDATIONS FOR NURSING RESEARCH

The data analysis revealed the absence of clinical guidelines for the other two nursing care practices, namely endotracheal tube verification and mechanical ventilator settings and monitoring. It is thus recommended that systematic reviews be done on these other two nursing care practices. Evidence-informed clinical

guidelines can be developed, thus enhancing quality and cost-effective care rendered by professional nurses to the critically ill, intubated, mechanically ventilated patient. In providing nursing care that is based on the best available evidence, decision-making will be reliable and relevant. Patient safety related to the care of the mechanically ventilated patient will thus be ensured.

The two evidence-informed clinical guidelines developed in this research study were not piloted or implemented for use amongst professional nurses in the critical care units. According to the JBI framework (as discussed in Chapter 1 of this study) evidence utilisation involves implementing the developed evidence-informed guidelines. However, initiatives that endeavour to disseminate and implement clinical guidelines have often faced significant barriers and opposition, such as restricted access to information, environmental factors, organizational factors and perceived degrees of usefulness or uselessness of the guideline (Pearson *et al*, 2007:119). Further research can be done on the barriers to change, which might include organisational, resource, psycho-social, patient or staff-related barriers. Acknowledging and understanding these barriers are important to successful implementation of the clinical guidelines. Further research can be done on the barriers to evidence-informed decision-making in critical care nursing.

Throughout the data analysis, it was clear that nursing care practices in the critical care units in the Nelson Mandela Metropole are based on tradition; own expertise or what has been taught in the unit, rather than on the best available evidence. Implementing an evidence-informed approach will thus require changes to health care. Further research can be done on evidence-informed health care and practice change (inclusive of the model for change), the process of change, factors influencing change, communication required for change and stakeholder analysis and involvement and environmental readiness for the implementation of the clinical guidelines.

Further research is required to explore the knowledge and understanding of the concepts related to evidence-based practices and the implementation and use of evidence in making clinical decisions in caring for patients.

Once the evidence-informed clinical guidelines are implemented for use, further research will be required to evaluate to what extent practice has changed and if any impact on patient care is evident. The compliance of professional nurses to the implementation of the evidence-informed clinical guidelines in practice is another possible research opportunity.

7.5.2 RECOMMENDATIONS FOR EDUCATION

It is recommended that more emphasis be placed on evidence-informed nursing care and evidence-based practices and decision-making related to nursing care practices in both under- and post-graduate programmes. Professional nurses will develop a culture to base their decisions on the best available evidence and not on tradition or ritual. Professional nurses can be encouraged to attend short learning programmes or workshops on evidence-informed decision-making in order to create a greater awareness for making clinical decisions that are based on the best available evidence. In these workshops, professional nurses can be taught how to formulate clinical questions pertaining to patient-care issues, search for literature, critically appraise and synthesise literature and make recommendations for patient care.

It is recommended that short learning programmes be developed to create a greater awareness amongst professional nurses, including those who are experienced, employed by nursing agencies or who hold additional qualifications in Critical Care Nursing regarding evidence-informed decision-making. A short learning programme, which specifically addresses the nursing care of an adult, intubated, mechanically ventilated patient in a critical care unit, can be developed. Various aspects of this nursing can be addressed. The evidence-informed clinical guidelines on endotracheal tube suctioning and cuff pressures, as well as the other two nursing care practises, can be presented as part of the short learning programme on the nursing care related to the safety of the mechanically ventilated patient in the critical care unit.

7.5.3 RECOMMENDATIONS FOR PRACTICE

For the scope of the research study, the evidence-informed clinical guidelines were not implemented for use amongst the target users. It is recommended that the use of

the clinical guidelines and the algorithms be piloted amongst professional nurses in the critical care units of one private and one public health care institution respectively.

The evidence-informed clinical guidelines can be used for implementation in the critical care units of both the private and public health care sectors in the Nelson Mandela Metropole. The guidelines and clinical algorithms can be incorporated into the unit policies, guidelines and in-service education programmes presented in the critical care units. Dissemination of the clinical guidelines amongst all professional nurses in the adult critical care units will reduce practice variances and aims to standardise the identified nursing care practices.

The clinical algorithms can be used at the patient's bedside as they will allow for easy access and dissemination of the information that is compiled in the clinical guideline. Based on the clinical algorithm, checklists can be developed or the information regarding endotracheal tube suctioning and cuff pressure monitoring can be incorporated into the patient's documents, for instance, the flow sheets, to form part of the daily nursing care practices. Audits done on patients' charts will reveal compliance to evidence-informed recommendations as indicated in the clinical guidelines.

The use of the evidence-informed approach can be encouraged amongst professional nurses for decision-making in the care of the critically ill patient. Small, bedside-group presentations can be encouraged in using the evidence-informed decision-making approach.

7.6 SUMMARY OF CHAPTER

According to McSherry *et al* (2002:1), nurses must be competent, able to justify what they do, active and autonomous in providing care to their patients. It is no longer acceptable for nurses to base care on ritual and tradition. They must be able to justify the decisions they have made about appropriate care and treatment on the basis of professional expertise, which includes using evidence, not necessarily research, to inform practice. Evidence-informed nursing care has to form the basis

for justifying nursing care practices (Adam and Osborne, 2005:512). Patient safety practices reduce the risk of adverse events related to exposure to medical care (Shojania *et al*, 2001:668). In using an evidence-informed approach and clinical guidelines to base clinical decisions upon, the safety of the mechanically ventilated patient in the critical care unit can be ensured.

This research study has succeeded in the development of two evidence-informed clinical guidelines, which can be used to enhance nursing care rendered by professional nurses in the critical care units in the Nelson Mandela Metropole. The use of the clinical guidelines and the algorithms will ultimately allow professional nurses to perform endotracheal tube suctioning and cuff pressure monitoring based on the best available evidence. In doing this, professional nurses in the critical care units will not only adhere to Sackett *et als'* (1996:71-72) belief that evidence-based medicine is the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients, but will adapt an evidence-informed approach in making decisions related to patient care by using the relevant evidence.

The study findings revealed the absence of evidence-informed clinical guidelines for the identified nursing care practices. This research study has made a unique contribution to the body of knowledge, research and nursing practice as evidence-informed clinical practice guidelines were developed, based on the best available evidence for two nursing care practices related to the safety of the intubated adult mechanically ventilated patient in the critical care unit.

NOTE: Three different reference lists are included in this research study and are divided as follows:

Reference list A: includes references for the completed study, except those used for the systematic reviews.

Reference list B: includes the references used for the systematic review on endotracheal tube suctioning.

Reference list C: includes the references used for the systematic review on endotracheal tube cuff pressure monitoring.

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ANNEXURE A
PARTICIPANT CONSENT LETTER



Faculty of Health Sciences
DEPARTMENT OF NURSING SCIENCE

Tel: +27 (0)41 504-4501

E-mail : portia.jordan@nmmu.ac.za

2010

Dear Madam/Sir

You are being requested to participate in a research study aimed at exploring and describing the nursing care practices related to the safety of the mechanically ventilated patient in the critical care unit. I will provide you with the necessary information to assist you to understand the study and explain what would be expected of you (participant). The information sheet would include the risks, benefits, and your rights as a research participant. Please feel free to ask me to clarify anything that is not clear to you.

To participate, it will be required of you to complete the provided written consent that will include your signature, date and initials to verify that you understand and agree to the conditions. You will be required to complete a structured questionnaire in order to collect data on the current nursing care practices as performed by you for the mechanically ventilated patients in the critical care unit. You have the right to query concerns regarding the study at any time. Immediately report any new problems during the study, to the researcher. The telephone number and e-mail correspondence of the researcher is provided. Please feel free to contact me. If required, you can contact the promoter of the research study, Prof RM van Rooyen at 041-5042122.

Furthermore, it is important that you are aware of the fact that the study was approved by the Research Committee of the Department of Nursing Science, as well as the Faculty of Health Sciences Research, Technology and Innovation Committee of the above university. The approval grants ethical clearance as well. Permission to conduct the study has also been granted by the hospital and nursing service manager of your institution.

Annexures

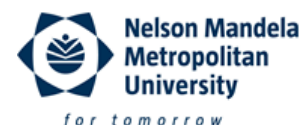
Participation in research is completely voluntary. You are not obliged to take part in any research. If you want to withdraw at any stage of the research study, you may do so. Although your identity will, at all times remain confidential the results of the research study may be presented at scientific conferences or in specialist publications. This informed consent statement has been prepared in compliance with current statutory guidelines of NMMU.

Yours sincerely

PORTIA JORDAN

RESEARCHER

ANNEXURE B
PARTICIPANT INFORMATION LETTER & CONSENT FORM
INFORMATION AND INFORMED CONSENT FORM



Title of the research project	Evidence-informed clinical guidelines for nursing care practices related to the safety of the mechanically ventilated patient.	
Reference number <i>(for official use)</i>		
Principal investigator	Portia Jordan	
Address	J Block, 2 nd Floor PO Box 77000 Department of Nursing Science North Campus Nelson Mandela Metropolitan University, Summerstrand Port Elizabeth 6031	
Postal Code		
Contact telephone number	041-504 4501	
A. DECLARATION BY OR ON BEHALF OF PARTICIPANT		<i>Initial</i>
I, the participant and the undersigned	<input type="text" value="(full names)"/>	
I.D. number	<input type="text"/>	
Address (of participant)	<input type="text"/>	
A.1 I HEREBY CONFIRM AS FOLLOWS:		
1. I, the participant, was invited to participate in the above-mentioned research project that is being undertaken by In the Faculty of <input type="text" value="Health Sciences"/>		
of the Department of <input type="text" value="Nursing Science"/>		
at the Nelson Mandela Metropolitan University.		
2. The following aspects have been explained to me, the participant:		

<p>2.1 Aim: The researcher is exploring: Nursing care practices related to safety in the mechanically ventilated patient.</p> <p>The information will be used to develop evidence-informed clinical guidelines to enhance nursing care practices related to safety of the mechanically ventilated patient in the critical care unit.</p>	
<p>2.2 Procedures: I understand that I am free to withdraw at any stage of the research study</p>	
<p>Risks: There are no risks pertaining to the study</p>	
<p>Possible benefits: As a result of my participation in this study nursing care practices related to the safety of the mechanically ventilated patient in the critical care unit will be enhanced.</p>	
<p>Confidentiality: My identity will not be revealed in any discussion, description or scientific publications by the researcher.</p>	
<p>Voluntary participation/refusal/discontinuation:</p> <p>My participation is voluntary <input type="checkbox"/> YES <input type="checkbox"/> NO</p> <p>My decision whether or not to participate will <input type="checkbox"/> YES <input type="checkbox"/> NO</p> <p>in no way affect my present or future <input type="checkbox"/> TRUE <input type="checkbox"/> FALSE</p> <p>care/employment/lifestyle <input type="checkbox"/> TRUE <input type="checkbox"/> FALSE</p>	
<p>The information above was explained to me/the participant by</p> <p><input type="text" value="(name of relevant person)"/></p> <p>in <input type="checkbox"/> Afrikaans <input type="checkbox"/> English <input type="checkbox"/> Xhosa <input type="checkbox"/> Other <input type="checkbox"/></p> <p>and I am in command of this language/it was satisfactorily translated to me by</p> <p><input type="text" value="(name of translator)"/></p> <p>I was given the opportunity to ask questions and all these questions were answered satisfactorily.</p>	
<p>No pressure was exerted on me to consent to participation and I understand that I may withdraw at any stage without penalisation.</p>	
<p>Participation in this study will not result in any additional cost to myself.</p>	

A.2 I HEREBY VOLUNTARILY CONSENT TO PARTICIPATE IN THE ABOVE-MENTIONED PROJECT

Signature or right thumb print of participant	Signature of witness		on		20
	Full name of witness				

B. STATEMENT BY OR ON BEHALF OF RESEARCHER

I, Portia Jordan declare that

I have explained the information given in this document to

(name of patient/participant)

and/or his/her representative

(name of representative)

he/she was encouraged and given ample time to ask me any questions;

this conversation was conducted in

Afrikaans		English		Xhosa		Other	
-----------	--	---------	--	-------	--	-------	--

and no translator was used / this conversation was translated into

(language) by

I have detached Section D and handed it to the participant

	YES		NO
--	-----	--	----

Signed/confirmed at

	on		20
--	----	--	----

Signature of researcher	Signature of witness
	Full name of witness

D. IMPORTANT MESSAGE TO PATIENT/REPRESENTATIVE OF PARTICIPANT

Dear participant/representative of the participant

Thank you for your/the participant's participation in this study. Should, at any time during the study:

an emergency arise as a result of the research, or
you require any further information with regard to the study, or
the following occur

You participate in the study against your free will
Subjected to revealing your identity
Revealing any information given by you

(indicate any circumstances which should be reported to the investigator)

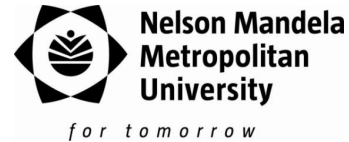
Kindly contact

at telephone number

Portia Jordan

072 653 2534

ANNEXURE C
LETTER TO THE HOSPITAL MANAGERS



Faculty of Health Sciences
DEPARTMENT OF NURSING SCIENCE
Tel: +27 (0)41 504-4501
E-mail : portia.jordan@nmmu.ac.za
2010

Nursing Service Manager
_____ Hospital
PORT ELIZABETH
6000

Dear Madam/Sir

Permission to conduct a research study

I hereby request permission to conduct a research study in the critical care unit of your institution. The focus of the research study is to explore and describe the nursing care practices related to patient safety for the mechanically ventilated patient in a critical care unit. The study will be conducted under the supervision on my promoter, Prof RM van Rooyen.

The participants will be required to complete a structured questionnaire exploring the nursing practices related to patient safety whilst caring for the mechanically ventilated patient. Participation in research study will be completely voluntary and participants can withdraw at any time during the study. The unit managers will aid in the process of handing out the questionnaires to the participants. Once data is collected, analysed and the systematic review process has been completed, evidence-informed clinical guidelines will be formulated. A copy of the research findings will be available, if required for dissemination in the critical care unit.

Furthermore, I would like to assure you that ethical principles will be maintained throughout the study, as the study will be approved by the Faculty of Health Sciences Research and Innovation Committee (FRTI) of the University prior embarking on the data collection phase.

Should you have any queries, please do not hesitate to contact me on the above stated contact details. Alternatively you can contact my promoter at 041-504 2112.

Yours sincerely

PORTIA JORDAN

**ANNEXURE D
LETTER TO THE UNIT MANAGERS**



**Faculty of Health Sciences
DEPARTMENT OF NURSING SCIENCE**
Tel: +27 (0)41 504-4501 Fax: +27 (0)41-504-2616
E-mail : portia.jordan@nmmu.ac.za
2010

Unit Manager
Critical Care Unit
_____ Hospital

Dear Madam

Permission to conduct a research study

I hereby request permission to conduct a research study in the critical care unit of your institution. The focus of the research study is to explore and describe the nursing care practices related to patient safety for the mechanically ventilated patient in a critical care unit.

The participants will be required to complete a structured questionnaire. Participation in research study will be completely voluntary and participants can withdraw at any time during the study. Once data is collected, analysed and the systematic review process has been completed, clinical guidelines will be formulated. I would like to assure you that ethical principles will be maintained throughout the study, as the study will be approved by the Faculty of Health Sciences Research and Innovation Committee (FRTI) of the University prior embarking on the data collection phase. Furthermore, I would like to request your availability, as a unit manager, to co-ordinate the process of handing out the questionnaires to the participants.

Should you have any queries, please do not hesitate to contact me on the above stated contact details.

Yours sincerely
PORTIA JORDAN
RESEARCHER

ANNEXURE E
QUESTIONNAIRE

QUESTIONNAIRE TO EXPLORE AND DESCRIBE THE FOUR IDENTIFIED NURSING CARE PRACTICES RELATED TO THE SAFETY OF THE MECHANICALLY VENTILATED PATIENT

Please complete the following questionnaire to explore and describe the current nursing-care practices related to the safety of the mechanical ventilated patient in the critical care unit. Where indicated, mark the relevant answer to indicate your response, for example:

Indicate which of the following do you do:

I enjoys walking	
I plays sport once a week	
I prefer to gym twice a week	X
I do not like any form of exercises	
I enjoy dancing	

If a question requires a response, please indicate that on the space provided if you are able to answer the specific question.

Thank you for your time and co-operation

Portia Jordan
Department of Nursing Science
Nelson Mandela Metropolitan University
041-504 4501

A reference number will be allocated to this questionnaire, therefore your name will not appear on this questionnaire and its contents will remain confidential. Please answer all questions as honest as possible.

REF NUMBER	
------------	--

QUESTIONNAIRE TO EXPLORE AND DESCRIBE THE FOUR IDENTIFIED NURSING CARE PRACTICES RELATED TO THE SAFETY OF THE MECHANICALLY VENTILATED PATIENT

SECTION A – DEMOGRAPHIC DATA

Read each item below and place an X at the correct answer or fill in the correct response where required.

1. Indicate your gender.

Male	
Female	

2. Indicate how old you are.

< 25 years	
25-30 years	
31-40 years	
41-50 years	
51-60 years	
61-65 years	

3. Indicate the years you have been working in a critical care unit.

< 1 year	
1-5 years	
6-10 years	
11-15 years	
>15 years	

Annexures

4. As a professional nurse what position do you hold in the critical care unit?

Permanent employed professional nurse working in a shift	
Agency worker	
Unit manager	
Shift leader	
Clinical facilitator/mentor	

5. As a professional nurse do you hold an additional qualification with SANC?

Yes	
No	

6. If the answer to question 5 is yes, indicate which qualification(s):

SECTION B – ENDOTRACHEAL TUBE VERIFICATION

Read each item below and place an X at the correct answer or fill in the correct response where required.

7. How often do you verify the endotracheal tube placement in the mechanically ventilated patient?

2 hourly	
4 hourly	
6 hourly	
12 hourly	
Never	

8. Which method do you use in verifying endotracheal tube placement in the mechanically ventilated patient?

Direct laryngoscopy	
Chest radiography (CXR)	
Pulse oximetry	
Identification of carbon dioxide in exhaled gas	
Palpation of the cuff on each side of the trachea	
Inspection of the chest movements	
Auscultation of bilateral breath sounds	

9. When using inspection to verify the endotracheal tube, indicate what you would do:

Observe for symmetrical chest movement	
Observe for unilateral chest movement	
Assess for bilateral breath sounds	
Perform a epigastric auscultation	

10. When auscultating the breath sounds in order to verify the endotracheal tube placement which of the following will indicate correct placement?

Unilateral breath sounds	
Bilateral breath sounds	
Diminished breath sounds	
Rhonchi	

11. If you use chest radiography to verify the correct endotracheal tube placement, which of the following indicators will ensure proper placement?

Endotracheal tube is at the level of the right bronchus	
Endotracheal tube is at the level of the left bronchus	
Endotracheal tube is at the level of the carina	
Endotracheal tube is 2 -3 cm above the carina with the head in a neutral position	

Annexures

12. If you would use identification of carbon dioxide in exhaled gas as a method in verifying ET tube placement, which method is the best recommended.

Capnography	
Calometric detection of carbon dioxide	

13. The normal range for carbon dioxide in exhaled gas indicating correct endotracheal tube placement will be:

35-45 mmHg	
50-80 mmHg	
80-100 mmHg	
> 100 mmHg	

14. How would you know if the endotracheal tube is correctly verified when using calometric detection of carbon dioxide?

If the indicator paper changes to beige	
If the indicator paper remains purple	
If the indicator paper turns yellow	

15. Does your unit have an institutional guideline in place on how to verify the endotracheal tube placement in the mechanically ventilated patient?

Yes	
No	

16. If you answered yes to question 15, indicate who developed the guideline.

17. If you answered yes to question 15, indicate how often do you use the guideline.

Often	
Seldom	
Never	

18. If the answer is no to question 15, indicate on what do you base your decision-making in verifying the endotracheal tube placement in the mechanically ventilated patient.

Own expertise	
The most recent literature	
What you have been taught in the unit	

19. Would you like to receive in-service education regarding ET tube verification methods in order to ensure the safety of the mechanically ventilated patient in the critical care unit?

Yes	
No	

SECTION C – ENDOTRACHEAL CUFF PRESSURE MONITORING

Read each item below and place an X at the correct answer or fill in the correct response where required.

20. How often do you measure and record ET tube cuff pressures while caring for the mechanically ventilated patient.

Every 2 hours	
Every 4 hours	
Every 6 hours	
Every 12 hours	
When a leak occurs	
Never	

21. How would you position your patient when measuring the endotracheal tube cuff pressures?

Supine	
Supine to 45 degrees	
30 to 45 degrees	
30 to 90 degrees	
Left lateral	
Do not change patient position	

Annexures

22. Indicate the method you use to monitor the ET tube cuff pressure?

By listening for air leaks	
Use of minimal occlusive volume technique	
Use of the minimal leak technique	
Estimating the cuff pressure by feeling the cuff	
By means of an aneroid manometer	

23. Indicate which endotracheal tube cuff pressure you maintain in the mechanically ventilated patient.

18-22 mmHg	
23-25 mmHg	
26-30 mmHg	
>31 mmHg	
Do not know	

24. Do you deflate and re-inflate the cuff prior and after performing endotracheal tube suctioning?

Yes	
No	

25. If an audible leak is noticed, indicate how you would manage it?

Continue cuff inflation to obtain a seal irrespective of volume of air inserted	
Continue cuff inflation and notify physician	
Manipulate patient's ETT and position	
Assess cuff pressures	
Monitor on-going cuff leak	

Annexures

26. If a cuff leak is detected indicate how much air you will use to inflate the cuff.

2 ml	
5 ml	
10 ml	
20 ml	
Continued inflation till audible leak disappears irrespective of amount of air used	

27. Under inflation of the endotracheal cuff cause:

Aspiration of secretions into the lower airway.	
Increasing the risk for ventilator associated pneumonia	
All of the above	
None of the above	

28. Over inflation of the endotracheal cuff contributes to:

Tracheal erosion	
Tracheal stenosis	
Tracheal rupture	
Tracheal innominate artery fistulas	
All of the above	
None of the above	

29. Does your unit have an institutional guideline in place on how to monitor and record endotracheal cuff pressures?

Yes	
No	

30. If you answered yes to question 29, indicate how often do you use the guideline?

Often	
Seldom	
Never	

Annexures

31. If you answered yes to question 29, indicate who developed the guideline.

32. If the answer is no to question 29, indicate on what do you base your decision-making in ensuring the correct endotracheal cuff pressure in the mechanically ventilated patient.

Own expertise	
The most recent literature	
What you have been taught in the unit	

SECTION D: ENDOTRACHEAL TUBE SUCTIONING

Read each item below and place an X at the correct answer or fill in the correct response where required.

33. How often do you perform endotracheal tube suctioning in the mechanically ventilated patient?

1-2 hourly	
4 hourly	
6 hourly	
12 hourly	
Only when necessary	

34. When do you perform endotracheal tube suctioning in the mechanically ventilated patient?

If the patient cough	
Visible or audible secretions	
If desaturation occurs	
Increased airway pressure	
All of the above	

Annexures

35. The external diameter of the suction catheter should be half the size of the internal diameter of the ET tube.

Agree strongly	
Agree	
Neither agree or disagree	
Disagree	
Disagree strongly	

36. Do you perform a respiratory assessment prior endotracheal tube suctioning?

Yes	
No	

37. If you answered yes, which of the following assessment findings will indicate that your patient needs suctioning?

Rhonchi	
Crackles	
Wheezes	
Normal breath sounds	

38. How would you position the patient prior performing endotracheal tube suctioning?

High Fowlers	
Semi-Fowlers	
Supine	

39. What suction pressure you do use when performing endotracheal tube suctioning?

80-120 mmHg	
150-180 mmHg	
200 mmHg	
250 mmHg	
300 mmHg	

Annexures

40. Do you hyper-oxygenate your patient prior endotracheal tube suctioning?

Yes	
No	

41. If you answered yes to question 40, indicate what percentage of oxygen you use.

60 % for at least 30 seconds prior suctioning	
50% for at least 30 seconds prior suctioning	
100% for at least 30 seconds prior suctioning	
55 % for at least 30 seconds prior suctioning	

42. Hyper-oxygenation is performed to minimize hypoxia and related complications induced by endotracheal tube suctioning.

Agree strongly	
Agree	
Neither agree or disagree	
Disagree	
Disagree strongly	

43. Do you practice hyperinflation prior to endotracheal tube suctioning?

Yes	
No	

44. If you answered yes to question 43, indicate what method you use for hyperinflation.

Manually with a ambubag	
Manually by means of the ventilator	

45. Saline instillation loosens the secretions prior to endotracheal tube suctioning.

Agree strongly	
Agree	
Neither agree or disagree	
Disagree	
Disagree strongly	

Annexures

46. Do you instil normal saline when performing endotracheal tube suctioning?

Yes	
No	

47. How much normal saline do you instill?

48. When do you instill the normal saline?

Prior to suctioning	
During suctioning	
After suctioning	

49. Normal saline instillation have adverse effects e.g. bronchoconstriction, decreased saturation and excessive fluid volume in the mechanically ventilated patient.

True	
False	

50. When do you wash/spray your hands in performing endotracheal tube suctioning?

Prior to suctioning	
After suctioning	
Before and after suctioning	
Don't wash hands	

51. Indicate the duration of the suction procedure when performing endotracheal tube suctioning in the mechanically ventilated patient

10 seconds	
18 seconds	
20 seconds	
25 seconds	

Annexures

52. How far do you insert the suction catheter when performing endotracheal tube suctioning?

To the level of the carina	
Until resistance is felt	
Until the patient cough	
Past the length of the endotracheal tube	

53. Which of the following complications can occur as result of endotracheal tube suctioning?

Hypoxia	
Infection	
Bradycardia	
Tracheal bleeding	
All of the above	
None of the above	

54. A comprehensive respiratory assessment must be done after performing endotracheal tube suctioning and should include chest auscultation.

True	
False	

55. To evaluate the effectiveness of the tracheal suctioning, the following must be observed:

Increased oxygen saturation	
Decreased rhonchi on auscultation	
Decrease peak inspiratory pressure	
Decrease secretions	
All of the above	

56. Does your unit have an institutional guideline in place on endotracheal tube suctioning practices for the mechanically ventilated patient?

Yes	
No	

Annexures

57. If you answered yes to question 56, indicate who developed the guideline?

58. If the answer is no to question 56, indicate on what do you base your current endotracheal suctioning practices

Own expertise	
The most recent literature	
What you have been taught in the unit	

59. Would you like to receive in-service education regarding ET tube verification methods in order to ensure the safety of the mechanically ventilated patient in the critical care unit?

Yes	
No	

SECTION E: MECHANICAL VENTILATOR SETTINGS

Read each item below and place an X at the correct answer or fill in the correct response where required.

60. Which of the following mechanical ventilator modes would allow lung protective strategies?

Airway pressure release ventilation (APRV)	
Volume-assured pressure support ventilation (VAPSV)	
Pressure support ventilation (PSV)	
Synchronized intermittent mandatory ventilation (SIMV)	

61. Patients on volume controlled continuous mandatory ventilation (VC-CMV) is at risk for:

Volutrauma	
Atelectrauma	
Biotrauma	
Barotrauma	

Annexures

62. Pressure-support ventilation is used to limit barotrauma.

True	
False	

63. What recommended tidal volumes would you use to ensure safety in the mechanical ventilated critically ill patient?

Tidal volumes of 6-8 ml/kg	
Tidal volumes of 4-6 ml/kg	
Tidal volumes of 8-10 ml/kg	
Tidal volumes of 10-12 ml/kg	

64. Indicate the peak airway pressure that you will maintain in the critically ill patient:

< 45 cmH ₂ O	
50-55 cmH ₂ O	
30 cmH ₂ O	
< 35 cmH ₂ O	

65. High tidal volumes and high airway pressures can cause a syndrome of ventilator-induced lung injury.

Agree strongly	
Agree	
Neither agree or disagree	
Disagree	
Disagree strongly	

66. What levels of PEEP would be safe to use in the mechanically ventilated patient?

0-5 cmH ₂ O	
6-8 cmH ₂ O	
9-10 cmH ₂ O	
11-15 cmH ₂ O	
16-20 cmH ₂ O	
>20 cmH ₂ O	

Annexures

67. Indicate which of the following might be complications related to PEEP.

Volutrauma	
Increased cardiac output	
Decreased afterload	
Atelectrauma	

68. In order to prevent oxygen toxicity in the mechanical ventilation patient you should set the FiO₂ at the following level:

0.6%	
0.1%	
Enough to keep the SaO ₂ > 90% and the Po ₂ > 60 mmHg	
0.4%	

69. Oxygen toxicity results in one of the following:

Barotrauma	
Pneumothorax	
Pulmonary edema	
Acute lung injury	

70. Setting a low respiratory rate on the mechanical ventilator leads to one of the following:

Acidosis	
Alkalosis	
Barotrauma	
Volutrauma	

71. Setting a high respiratory rate on the mechanical ventilator (over-ventilation) leads to one of the following:

Acidosis	
Alkalosis	
Barotrauma	
Volutrauma	

Annexures

72. Indicate the average flow rate that you will set in order to ensure decrease peak inspiratory pressure in the mechanically ventilated patient in the critical care unit.

20-39 L/min	
40-60 L/min	
61-80 L/min	
81-100 L/min	

73. How often do you monitor the ventilator alarms parameters?

2 hourly	
4 hourly	
6 hourly	
12 hourly	
Never	

74. Indicate what values do you considers in setting the peak pressure alarm limit in order ensure safety in the mechanically ventilated patient?

5-10 cmH ₂ O above peak inspiratory pressure	
10-20 cmH ₂ O above peak inspiratory pressure	
21-30 cmH ₂ O above peak inspiratory pressure	
31-35 cmH ₂ O above peak inspiratory pressure	

75. If you have set a respiratory rate of 14 breaths per minute, mode, SIMV for patient A. What respiratory rate alarm limits would you set?

A. Upper alarm limits of 30 bpm	
B. Upper alarm limits of 40 bpm	
C. Lower alarm limits of 12 bpm	
D. Lower alarm limit of 8 bpm	
A & C	
A & D	
B & C	
B & D	

Annexures

76. If you have set the ventilator on a tidal volume of 500 ml and a respiratory rate of 10, what minute ventilation alarm limits would you set?

A .Upper alarm limits of 10	
B. Upper alarm limits of 15	
C. Lower alarm limits of 2	
D. Lower alarm limit of 3	
A & C	
A & D	
B & C	
B & D	

77. Does your unit have an institutional guideline in place on how to monitor ventilator settings and the alarm settings in the critical care unit?

Yes	
No	

78. If you answered yes to question 77, indicate who developed the guideline.

79. If the answer is no to question 77, indicate on what do you base your monitoring principles.

Own expertise	
The most recent literature	
What you have been taught in the unit	

THANK YOU FOR YOUR TIME AND CO-OPERATION IN ANSWERING THIS QUESTIONNAIRE

ANNEXURE F**LIST OF HAND SEARCHED JOURNALS**

JOURNAL TITLE
Accident and Emergency Nursing
American Journal of Nursing
American Journal of Respiratory and Critical Care Medicine
Anaesthesia
British Journal of Nursing
British Journal of Anaesthesia
British Medical Journal
Canadian Nurse
CHEST
Critical Care Medicine
Continuing Medical Education (CME)
Emergency Medicine Journal: South African Edition (EMJ)
Heart and Lung
Intensive Care Medicine
Journal of Advanced Nursing
Journal of American Medical Association (JAMA)
Journal of Nursing Care Quality
LANCET
New England Journal of Medicine
North Clinics of Critical Care
Medical Clinics of North America
Nursing Outlook
Nursing Research
Nursing RSA
Nursing Science Quarterly
Nursing Standard
Respiratory Care
South African Medical Journal (SAMJ)
Southern African Journal of Critical Care (SAJCC)

ANNEXURE G

SYSTEMATIC REVIEW PROTOCOL: ENDOTRACHEAL TUBE SUCTIONING

TITLE OF THE REVIEW

Endotracheal tube suctioning in the adult mechanically ventilated patient in the critical care unit.

BACKGROUND

Endotracheal tube suctioning is one of the most common procedures performed in the care of the mechanical ventilated patient in the critical care unit. It is used to enhance clearance of respiratory tract secretions, improve oxygenation and prevent atelectasis. As an essential part of care for intubated patients, the major goals of endotracheal tube suctioning are to ensure adequate ventilation, oxygenation and airway patency. These goals should be obtained while patient discomfort and adverse hemodynamic effects are minimized and hypoxemia related to suctioning is prevented (Pierce, 2007:159). Potential complications related to endotracheal suctioning include cardiac arrhythmias, hypoxemia, cardiac arrest, vagal stimulation, mucosal trauma, and atelectasis, contamination of the lower airway and the development of pneumonia, bronchospasm, pulmonary bleeding and increased intracranial pressure (Morton and Fontaine, 2009:578). Considering the complications that can occur while performing endotracheal tube suctioning, it is imperative that nursing care practices related to this procedure are done correctly and in accordance with the latest and best evidence-informed recommendations.

REVIEW QUESTION

The following review question will be posed:

“How should endotracheal tube suctioning in the adult mechanically ventilated patient in the critical care unit be done in order to minimise and/or prevent the complications associated with the procedure?”

SEARCH STRATEGY

The search strategy designed in order to access all relevant studies will comprise of three phases, namely:

- Searching MEDLINE (via PubMed), CINAHL, EBSCO HOST, the JBI systematic review site and the Cochrane Library to identify and become familiar with relevant keywords contained in the title, abstract and subject descriptors.
- Searching all databases using the identified search terms

- Searching the reference lists and bibliographies of all papers for additional studies

Search terms can include: “ventilation AND suctioning”; “artificial respiration”; “mechanical ventilation AND suctioning”; “tracheal suctioning”; “endotracheal tube suctioning”; “suctioning AND normal saline”; “suctioning AND methods AND adults NOT neonates”; “suction*”

SELECTION OF EVIDENCE

Studies for inclusion in the review were selected according to inclusion and exclusion criteria which will be discussed as below.

Inclusion criteria

The inclusion criteria include the types of studies, types of participants, interventions and outcome measures.

Types of evidence

The review will consider any randomised controlled trials; in the absence of RCTs other research designs, such as non-randomised controlled trials, cohort, descriptive studies, opinion papers as well as literature papers will be considered for inclusion to enable the identification of current best evidence. The hierarchy of evidence as stated in LoBiondo-Wood and Haber (2010:16) will be used to rank evidence.

Types of participants

The review will consider all studies that comprise of human, adult patients, aged 18 years and above who are intubated with an artificial airway namely an endotracheal tube or tracheostomy. Studies does not need to be contextualized to the critical care unit only, but can include other high acuity areas for instance the emergency care unit, high care and operating theatre, as patient might initially be intubated in these areas and require endotracheal tube suctioning.

Types of interventions or activity

Interventions of interest include those related to endotracheal tube suctioning, irrespective of whether it is closed or open suctioning. Specific interventions include suctioning methods, techniques and instillation of normal saline.

Types of outcome measures

The primary outcome is reduced suctioning-related complications. Secondary outcomes include reduced duration of mechanical ventilation, duration of stay in the critical care unit,

increased patient safety and decrease the risk for adverse effects related to the complications of suctioning.

Language of publications

No language restrictions will be applied to the initial search.

Time period

Studies dated back to 1990 will be included in the review. However, if due to the paucity of literature, it deemed necessary to include older studies, it will be done.

Exclusion Criteria

The following would be excluded in the review

- All animal studies
- All studies conducted in the neonatal or pediatric settings

CRITICAL APPRAISAL

Identified studies that meet the inclusion criteria will be grouped into the different categories as indicated by the hierarchy for the levels of evidence. These studies will then be assessed for validity by two reviewers. Critical appraisal tools from the SUMARI suite developed by JBI will be used to critically appraise the various studies included. (Electronic access were granted by JBI to use these tools)

DATA EXTRACTION

Following assessment of the methodological quality, the papers will be grouped according to the study design. The JBI data extraction tools will be used to extract data.

DATA SYNTHESIS

For quantitative data, where possible, odds ratio or standardised mean differences and their 95% confidence intervals will be calculated from the data generated by each included randomised control trial. If appropriate with available data, results from comparable groups of studies will be pooled into statistical meta-analysis. Heterogeneity between combined studies will be tested using standard chi-square test. Where statistical pooling is not possible the findings will be presented in a narrative form.

ANNEXURE H

SYSTEMATIC REVIEW PROTOCOL: ENDOTRACHEAL TUBE CUFF PRESSURE MONITORING

TITLE OF THE REVIEW

Endotracheal tube cuff pressure monitoring in the adult mechanically ventilated patient in the critical care unit.

BACKGROUND

The purpose of endotracheal cuffs on the airway is to allow for the application of positive-pressure ventilation without a loss of tidal volume and to prevent aspiration of oral and gastric secretions. Exposure of the tracheal mucosa to the pressure of the tracheal cuff has been implicated as one of the most important predisposing factors for mucosal injury. Over-inflation and under-inflation of the endotracheal cuff are associated with subsequent complications such as tracheal stenosis, tracheomalacia and ventilator-associated pneumonia. The measurement of cuff pressure is therefore one mechanism advocated to prevent complications related to excessive or inadequate cuff pressures in the intubated patient (Morton and Fontaine, 2009:603).

REVIEW QUESTION

This review seeks to establish, through the available literature, what is best practice for performing endotracheal tube suctioning in the patient with an artificial airway in situ. The specific review question to be addressed is:

What nursing care interventions are the most effective in monitoring endotracheal tube cuff pressure to minimize the complications of over-inflation or under-inflation in the adult intubated patient in the critical care unit?

SEARCH STRATEGY

The search strategy designed in order to access all relevant studies will comprise of three phases, namely:

- Searching MEDLINE (via PubMed), CINAHL, EBSCO HOST and the Cochrane Library to identify and become familiar with relevant keywords contained in the title, abstract and subject descriptors.
- Searching all databases using the identified search terms
- Searching the reference lists and bibliographies of all papers for additional studies

Search terms can include: “mechanical ventilation AND cuff pressures” ; “ventilation AND cuff pressures”; “endotracheal tube”; “endotracheal cuff pressures”; “tracheal cuff”; “measurement AND cuff pressures”; “aspiration AND cuff pressures”; “aspiration OR ventilator-associated pneumonia AND cuff pressures”.

SELECTION OF EVIDENCE

Studies for inclusion in the review were selected according to inclusion and exclusion criteria.

Inclusion criteria

The inclusion criteria will be according to the type of studies, participants, interventions, publication, outcomes and time period.

Types of evidence

All types of studies will be included in the review and will be ranked according to the different levels of evidence as stated in LoBiondo-Wood and Haber (2010: 16).

Types of participants

The review will consider all studies comprising of human, adult patients, aged 18 years and above who are intubated with an artificial airway namely an endotracheal tube or tracheostomy. Although the review is to be focused on patients in critical care units, studies conducted in the emergency room, operating theatre and recovery room will be included as an endotracheal tube or tracheostomy is the most widespread artificial airway used in these settings.

Types of interventions or activity

Interventions of interest include those related to endotracheal tube cuff pressures in the intubated, adult patient.

Types of outcome measures

The primary outcome is reduced complications related to under-and over-inflation of the endotracheal tube cuff. Secondary outcomes include reduce risk for aspiration, reduced risk for ventilator-associated pneumonia, reduced stay on the mechanical ventilator.

Language of publications

No language restrictions will be applied initially.

Time period

Studies dated back to 1990 will be included in the review.

Exclusion Criteria

The following would be excluded in the review

- All animal studies
- All studies conducted in the neonatal or paediatric settings

CRITICAL APPRAISAL

Identified studies that meet the inclusion criteria will be grouped into the different categories as indicated by the hierarchy for the levels of evidence. These studies will then be assessed independently for methodological validity by two reviewers, prior to inclusion in the review. The critical appraisal tools from the SUMARI suite developed by JBI will be used to critically appraise the various studies included. (Electronic access were granted by JBI to use these tools)

DATA EXTRACTION

Following assessment of the methodological quality, the papers will be grouped according to the study design. The JBI data extraction tools will be used to extract data.

DATA SYNTHESIS

For quantitative data, where possible, odds ratio or standardised mean differences and their 95% confidence intervals will be calculated from the data generated by each included randomised control trial. If appropriate with available data, results from comparable groups of studies will be pooled into statistical meta-analysis. Heterogeneity between combined studies will be tested using standard chi-square test. Where statistical pooling is not possible the findings will be presented in a narrative form.

ANNEXURE I**SEARCH TERMS: ENDOTRACHEAL TUBE SUCTIONING**

Database	Search terms
MEDLINE (via PubMed)	<p>#1 ventilation AND suctioning</p> <p>#2 ventilated AND suctioning</p> <p>#3 mechanical ventilation AND (suctioning) OR (suction*)</p> <p>#4 respiration, artificial AND suctioning</p> <p>#5 (((suction* OR suctioning) AND (randomised controlled trial) OR (randomi?ed trail) OR (controlled trail) OR (random*) OR (comparative study) OR (cross-over study) OR (follow-up study) OR (systematic review) OR (clinical guideline) OR (practice guideline)))</p> <p>#6 ventilation AND suctioning AND normal saline</p> <p>#7 suctioning AND normal saline</p> <p>#8 endotracheal tube suctioning AND adult NOT neonate</p> <p>#9 methods OR techniques AND suctioning</p> <p>#10 NOT (animal) NOT (human)</p> <p>#11 #1 AND #5</p> <p>#12 #5 AND#7</p>
CENTRAL (The Cochrane Library, Issue 2, 2009)	<p>#1 suctioning</p> <p># 2 tracheal suctioning</p> <p>#3 endotracheal tube suctioning</p> <p>#4 mechanical ventilation</p> <p>#5 artificial respiration</p>
HIGHWIRE	<p>#1 ventilation and suctioning</p> <p>#2 suctioning</p> <p>#3 endotracheal tube suctioning</p>
OVID	<p>#1 (suctioning OR tracheal suctioning OR endotracheal tube suctioning OR mechanical ventilation OR normal saline OR methods)</p>

Annexures

CINAHL	#1 (suctioning OR tracheal suctioning OR endotracheal tube suctioning OR mechanical ventilation OR normal saline OR methods)
JBI	#1 suctioning #2 tracheal suctioning #3 artificial airway #4 #2 AND #3

ANNEXURE J**SEARCH TERMS: ENDOTRACHEAL TUBE CUFF PRESSURE MONITORING**

Database	Search Strategy
MEDLINE (via PubMed)	#1 ventilation AND cuff pressure #2 ventilated AND cuff pressures #3 mechanical ventilation AND (cuff pressures) OR (tracheal* pressures) #4 respiration, artificial AND cuff pressures #5 (((cuff * OR cuff pressures) AND (randomised controlled trial) OR (randomi?ed trail) OR (controlled trial) OR (random*) OR (comparative study) OR (cross-over study) OR (follow-up study) OR (systematic review) OR (clinical guideline) OR (practice guideline))) #6 ventilation AND cuff pressures AND tracheal care #7 endotracheal tube AND cuff monitoring #8 aspiration OR ventilation-associated pneumonia AND cuff pressures #9 NOT (animal) NOT (human) #10 #1 AND #5 #11 #5 AND#7
CENTRAL (The Cochrane Library, Issue 2, 2009) & DARE	#1 cuff pressures and monitoring # 2 tracheal cuff pressures #3 endotracheal tube cuff pressure monitoring #4 mechanical ventilation #5 cuff pressure care
HIGHWIRE	#1 ventilation and cuff pressures #2 cuff pressure monitoring #3 endotracheal tube cuff pressures
CINAHL	#1 (cuff pressures OR tracheal cuffs OR endotracheal tube cuff pressures OR mechanical ventilation OR complications OR monitoring)

Annexures

JBI	#1 cuff pressures monitoring #2 tracheal tube cuff pressures #3 artificial airway #4 #2 AND #3
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ANNEXURE K**CHARACTERISTICS OF EXCLUDED STUDIES FOR REVIEW ON ENDOTRACHEAL TUBE SUCTIONING (N=33)**

No	Study	Reason for exclusion
ANIMAL STUDIES (2)		
1	Almgren B, Wickerts C, Heinonen E and Hogman M. 2004. Side-effect of endotracheal suction in pressure and volume controlled ventilation. <u>Chest</u> . Vol.125 No.3:1077-1080.	Animal study
2	Copnell B, Tingay DG, Mills JF and Dargaville PA. 2009. Endotracheal suction techniques that effectively remove secretions do not preserve lung volume [Abstract]. Access via doi:10.1016/j.aucc.2008.12.053.	Animal study
NON-ENGLISH (3)		
3	Ganzalez A, Martinez MA, Sagardoy E, Coscojueala MA and Asiain MC. 2004. [Assessment of practice competence and scientific knowledge of ICU nurses in the tracheal suctioning]. <u>Enferm Intensiva</u> . Vol.15 No.3: 101-111.	Article in Spanish
4	Lerga C, Zapata MA, Herce A, Martinez A, Margall MA and Asiain MC. 1997. [Endotracheal suctioning of secretions: effects of instillation of normal serum]. <u>Enferm Intensiva</u> . Vol.8 No.3:129-137.	Article in Spanish
5	Weitl J and Bettstetter H. 1994. [Indications for the use of closed endotracheal suction. Artificial respiration with high positive end-expiratory pressure]. <u>Anaesthesist</u> . Vol.43 No.6: 359-363.	Article in German
THE INCIDENCE OF VAP RELATED TO SUCTIONING (8)		
6	Cook D, de Jonghe B and Bourchard L. 1998. Influence of airway management on ventilator-associated pneumonia: evidence from randomised control trials. <u>JAMA</u> . Vol.279.No.10:781-787.	VAP and suctioning, but study does not answer the review question

7	De Pew CL and Noll ML. 1994. Inline closed-system suctioning: a research analysis. <u>Dimension Critical Care Nursing</u> . Vol.13 No.2:73-83.	Not addressing the review question
8	Gujadhur R, Helme BW, Sanni A and Dunning J. 2005. Continuous subglottic suction is effective for prevention of VAP. <u>Interactive Cardiovascular and Thoracic Surgery</u> . Vol.4:110-115.	Focused on VAP reduction
9	Niel-Wiese BS, Snoeren RL and van Broek PJ. 2008. Policies for endotracheal suctioning of patients receiving mechanical ventilation: A systematic review of RCT's. Database for Abstracts for Review of Effects (DARE). http://www.crd.yourk.ac.uk . Accessed 29 August @11:50 am.	Related to policies on open versus closed endotracheal suctioning and VAP. Not addressing review question
10	Peter JV, Chacko B and Moran JL. 2007. Comparison of closed endotracheal suction versus open suction in the development of VAP in ICU. <u>Indian Journal of Medical Science</u> . Vol.61 No.4: 201-211.	Focused on the effect of suctioning on VAP, not answering the review question.
11	Smulders K and van der Hoeven H. 2002. A randomised clinical trial of intermittent subglottic secretion drainage in patients receiving mechanical ventilation. <u>Chest</u> . Vol.121 No.3: 858-862.	Focus on the reduction of VAP
12	Sole ML, Poalilio E, Byers JF and Ludy JE. 2002. Bacterial growth in secretions and on suctioning equipment of orally intubated patients: a pilot study. <u>American Journal of Critical Care</u> . Vol.11 No.2: 141-149.	VAP and not directly related to suctioning methods and techniques
13	Vonberg RP, Eckmanns, Welte T and Gastmeier P. 2006. Impact of suctioning on the incidence of VAP. <u>Intensive Care Medicine</u> . Vol.32 No.9:1329-1335.	Open and closed suctioning techniques and VAP. Not answering review question.
PAEDIATRICS (10)		
14	Christensen RD, Rigby G, Schmutz N, Lambert DK, Weidmeier SE, Burnett J, Scofield SH and Snow GL. 2007. ET care: a randomised controlled masked trial	Pediatrics

	comparing two solutions for upper airway care in the NICU. <u>Journal of Perinatology</u> . Vol. 27:479-484.	
15	Maggiore SM, Lacobone E, Zito G, Conti C, Antenelli M and Proietti R. 2003. Deep versus shallow suction of endotracheal tubes in ventilated neonates and young infants. <u>Cochrane Database Systematic Review</u> . Issue (3) CD 003309.	Review on neonates
16	Ireton J. 2000. Tracheostomy suction: a protocol for practice. <u>Paediatric Nursing</u> . Vol.19 No.10:14-18.	Pediatrics
17	Gilbert M. 1999. Assessing the need for endotracheal suction. <u>Paediatric Nursing</u> . Vol. 11 No.1: 14-17.	Pediatrics
18	McKinley D and Kinney S. 2008. The challenges of completing a randomised control trial evaluating the use of saline during endotracheal suctioning in the pediatric intensive care unit. Accessed via doi:10.1016/j.aucc.2008.12.054.	Use of normal saline in pediatrics
19	Morrow BM, Futter MJ and Argent AC. 2006. Effect of endotracheal suction on lung dynamics in mechanically ventilated pediatric patients. <u>Australian Journal of Physiotherapy</u> . Vol.52:121-126.	Pediatrics
20	Morrow BM, Futter MJ and Argent AC. 2004. Endotracheal suctioning: from principles to practice. <u>Intensive Care Medicine</u> . Vol.30.No.3:1167-1174.	Pediatrics
21	Punyoo J. 2007. A comparison of the effects of endotracheal suctioning with and without normal saline instillation. Conference paper.	Pediatrics
22	Pritchard MA, Flenady V and Woodgate P. 2003. Systematic review of the role of pre-oxygenation for tracheal suctioning in ventilated newborn infants. <u>Journal of Paediatric Child Health</u> . Vol.39 No.3:163-165.	Pediatrics
23	Ridling DA, Martin LD and Bratton SL. 2003. Endotracheal suctioning with or without instillation of isotonic sodium chloride in critically ill children. <u>American Journal of Critical Care</u> . Vol.12 No.3:212-219.	Pediatrics

NOT ANSWERING THE REVIEW QUESTION (10)		
24	Briassoulis G, Briassoulis P. 2009. The effects of endotracheal suctioning on accuracy of oxygen consumption and carbon dioxide production measurements and pulmonary mechanics calculated by a compact metabolic monitor. <u>Anesthesia and Analgesia</u> . Vol.109:873-879.	No direct comparison to methods and techniques of endotracheal tube suctioning
25	Bourgalt AM, Brown CA, Hains SMJ and Parlow JL. 2006. Effects of endotracheal tube suctioning on arterial oxygen tension and heart rate variability. <u>Biological Research for Nursing</u> . Vol.7 No.4:268-278.	Focus on the physiological parameters and effects rather than on the suctioning-induced effects.
26	Fry M and Ruperto K. 2009. A 12 month retrospective study of airway management practices. <u>International Emergency Nursing</u> . Vol.17 No.11: 108-112.	Not answering the review question
27	Johnson KL, Kearney PA, Johnson SB, Niblett JB, McMillian NL and McClain RE. 1994. Closed versus open endotracheal suctioning: cost and physiological consequences. <u>Critical Care Medicine</u> . Vol.22 No.4:658-666.	Not addressing the clinical review question.
28	Isea JO, Poyant D, O'Donnel C, Faling J, Karlinsky J and Celli BR. 1993. Controlled trial of continuous irrigation suction catheter vs conventional intermittent suction catheter in clearing bronchial secretions from ventilated patients. <u>Chest</u> . Vol.103 No.4:1227-1230.	Not quite answering the review question
29	Niel-Wiese BS, Daha TJ and van den Broek PJ. 2006. Is there evidence for recommending needleless closed catheter access systems in guidelines? <u>Journal of Hospital Infection</u> . Vol.62:406-413.	Not answering the review question
30	Novoa CMA, Ramos MIF, Puntillillo KA, Stanik-Hutt J, Thompson CL, White C and Wild LR. 2008. Pain related to tracheal suctioning in awake acutely and critically ill adults. <u>Intensive and Critical Care Nursing</u> . Vol. 24 No.5:20-27.	Not answering the review question
31	Paul-Allen J and Ostrow CL. 2000. Survey of nursing practices with closed-system suctioning. <u>American</u>	Closed-suction system

	<u>Journal of Critical Care</u> . Vol.9 No.1: 9-17.	
32	Schwenker D, Ferrin M and Gift AG. 1998. A survey of endotracheal suctioning with instillation of normal saline. <u>American Journal of Critical Care</u> . Vol.7 No.4:255-260.	Included the respiratory therapists, which might affect conclusive generalizations as the population is different.
33	Sole M, Byers JF, Ludy JE, Zhnag Y, Banta C and Brummel K. 2003. A multi-survey of suctioning techniques and airway management practices. <u>American Journal of Critical Care</u> . Vol.12 No.3:220-232.	Not answering the review question
PAPERS EXCLUDED AFTER CRITICAL APPRAISAL (6)		
1	AARC Clinical Practice Guideline: Endotracheal suctioning of mechanically ventilated adults and children with artificial airways. 1993. <u>Respiratory Care</u> . Vol.38 No.5:500-504.	Outdated, clinical guideline.
2	Brooks D, Anderson CM, Carter MA, Downes LA, Keenan SP, Kelsey CJ and Lacy JB. 2001. <u>Canadian Respiratory Journal</u> . Vol.8 No.3:163-182.	Focus on adult, non-intubated, intubated and children.
3	Perrie H and Scribante J. 2007. Nesibopho Best Practice Guideline on endotracheal tube suctioning of adults. <u>Nesibopho Health Care</u> . (Pty) Ltd. (Endorsed by the Critical Care Society of Southern Africa).	No rigorous process in the guideline development process stated, thus implicating on reliability.
4	Kelleher S and Andrews T. 2008. An observational study on open-system endotracheal suctioning practices of critical care nurses. <u>Journal of Clinical Nursing</u> . Vol.17 No.12:360-369.	Not adhering to the critical appraisal tool elements
5	Day T, Farnell S, Haynes S and Wainwright S. 2002. Tracheal suctioning: an exploration of nurses' knowledge and competence in acute and high dependency ward areas. <u>Journal of Advanced Nursing</u> . Vol.39 No.1:35-45.	Inadequate information for critical appraisal tool. Focus more on the knowledge base of nurses.
6	Wood CJ. 1998. Endotracheal suctioning: a literature review. <u>Intensive and Critical Care Nursing</u> .	Address the review question, but the literature used in this

Annexures

	Vol.14: 124-136. (Please note that although this is the same author, year of publication and journal, it is not this article that has been used in the systematic review).	paper is outdated (earlier than the year 1990) and updated literature is available.
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ANNEXURE L**CHARACTERISTICS OF EXCLUDED STUDIES FOR REVIEW ON ENDOTRACHEAL TUBE CUFF PRESSURE MONITORING (N=31)**

No	Study	Reason for exclusion
ANIMAL STUDIES (5)		
1	Touzot-Jourde G, Stedman NL, Trim CM. 2005. The effects of two endotracheal tube cuff inflation pressures on liquid aspiration and tracheal wall damage in horses. <u>Vet Anesthetics Analogue</u> . Vol. 32 No.1:23-9.	Animal study
2	Hoffman RJ, Dahlen JR, Lipovic D and Sturman KM. 2009. Linear correlation of endotracheal tube cuff pressure and volume. <u>Western Journal of Emergency Medicine</u> . Vol. 8 No.3:137-139.	Animal study
3	Nseir S, Duguet A, Copin M, De Jonkheere D, Zhang M, Similowski T and Marquette C. 2007. Continuous control of endotracheal cuff pressure and tracheal wall damage. <u>Critical Care</u> . Vol. 11 No.5: 109-115.	Animal study
4	Hsu CC, Lee WJ, Wu YL, Guo HR and Lin HJ. 2005. Assessment of new method to distinguish esophageal from tracheal intubation by measuring endotracheal cuff pressures in a porcine model. <u>Acad Emergency Medicine</u> . Vol. 12.No.12: 1153-1157.	Animal study
5	Ferrer M and Torres A. 2008. Maintenance of tracheal tube cuff pressures: where are the limits? <u>Critical Care</u> . Vol.12 No.1:106-108.	Animal study
PEDIATRICS (7)		
6	Erb T and Frei FJ. 2001. The use of cuffed endotracheal tubes in infants and small children. <u>Anaesthesist</u> . Vol. 50 No.6:395-400.	Pediatrics
7	Khine HH, Corddry DH, Kettrick RG, Martin TM, McCloskey JJ, Rose JB, Theroux MC and Zagnoev	Pediatrics

	M. 1997. Comparison of cuffed and uncuffed endotracheal tubes in young children during general anesthesia. <u>Anesthesiology</u> . Vol.86 No.3: 627-31.	
8	Ashtekar CS, Wardhaugh A. 2005. Do cuffed endotracheal tubes increase the risk of airway mucosal injury and post-extubation stridor in children? <u>Arch Dis Child</u> . Vol. 90 No.11:1198-9.	Pediatrics
9	Bernet V, Dullenkopt A, Maino P and Weiss M. 2005. Outer diameter and shape of pediatric tracheal tube cuffs at higher inflation pressures. <u>Anaesthesia</u> . Vol.60 No.5:1123-1128.	Pediatrics
10	Bernet V, Dullenkopt A, Cannizzaro V, Stutz K and Weiss M. 2006. An in vitro study of the compliance of pediatric tracheal cuffs and tracheal wall pressure. <u>Anaesthesia</u> . Vol.61 No.6:978-983.	Pediatrics
11	Clements RS, Steel AG, Bates AT, Mackenzie R. 2007. Cuffed endotracheal tube use in pediatric pre-hospital intubation: challenging the doctrine? <u>Emergency Medicine Journal</u> .Vol.24 No.1:57-8.	Pediatrics
12	Flynn PE, Black AE and Mitchell V. 2008. The use of cuffed tracheal tubes for pediatric tracheal intubation, a survey of specialist practice in the United Kingdom. <u>European Journal of Anaesthesiology</u> . Vol. 25 No.8:685-8.	Pediatrics
NON-ENGLISH (8)		
13	Otani S, Fujii H and Kurasako N. 1998. [Recurrent nerve palsy after endotracheal tube intubation]. <u>Masui</u> . Vol. 47 No.3: 350-355.	Article in Japanese
14	Terashima H, Sakurai T, Takahashi S, Saitoh M and Hirayama K. 2002. [Post-intubation tracheal stenosis: problems associated with choice of management]. <u>Kyoba Geka</u> . Vol. 55 No.10:837-842.	Article in Japanese
15	Suzuki N, Kooguchi K, Mizobe T, Hirose M, Tikano Y and Tanaka Y. 1999. [Post-operative hoarseness	Article in Japanese

	and sore throat after tracheal intubation: effect of low intracuff pressure of endotracheal tube and the usefulness of cuff pressure indicator]. <u>Masui</u> . Vol. 48 No.10:1091-1095.	
16	Wutjewicz MA, Sawicka W and Sein Anand J. 2004. [Monitoring of tracheal tube cuff pressures in patients in intensive therapy unit and intensive care units]. <u>Przegel Lek</u> . Vol. 61 No.4: 353-355.	Article in Polish
17	Hähnel J, Treiber H and Konrad F. 1993. [A comparison of different endotracheal tubes: tracheal cuff seal, peak centering and the incidence of post-operative sore throat]. <u>Anaesthetist</u> . Vol.42 No.4:232-237.	Article in German
18	Kunitz O, Jansen R, Ohnsorge E, Haff-vonBelow S, Schulz-Stubner S and Rossaint R. 2004. Cuffdruckmessung and regelung im Erwachsenenalter. <u>Anaesthetist</u> . Vol. 43 No.24:334-340.	Article in Dutch
19	Garcia C, Guerrero-Romero F and Rodriguez-Moran M. 2001. [Cuff pressures in endotracheal intubation: should it be routinely measured?]. <u>Gac Medical Mex</u> . Vol.137 No.2:179-182.	Article in Spanish
20	Granja C, Faraldo S, Languan P and Gois L. 2002. [Control of endotracheal cuff balloon pressure as a method of preventing laryngotracheal lesions in critically ill intubated patients]. <u>Rev Esp Anesthesiology Reanim</u> . Vol.49 No.3: 137-140.	Article in Spanish
NOT RELEVANT (11)		
21	Conway DH and Mackie C. 2004. The effects of tracheostomy cuff deflation during continuous positive airway pressure. <u>Anaesthesia</u> . Vol.59 No.2:652-657.	Not relevant to the review question
22	Dullenkopt A, Smchitz A, Frei M, Gerber AC and Weiss. 2004. Air leakage around endotracheal tube cuffs. <u>European Journal of Anaesthesiology</u> . Vol.21 No.6:448-453.	Not relevant to the review question

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23	Elrich-Pur H, Hrska F, Kraft P, Friehs H, Wulkersforfer B, Kostler WJ, Rabitsh W. 2006. Comparison of mucosal pressure induced by cuffs of different airway devices. <u>Anaesthesiology</u> . Vol.104 No.5:933-938.	Focus not relevant to the review question
24	Farre R, Rotger M, Ferrer A, Torres A and Navajas D. 2002. Automatic regulation of cuff pressures in endotracheal intubated patients. <u>European Respiratory Journal</u> . Vol.20:1010-1013.	Not relevant to the review question
25	Fuchs J, Schummer S, Giesser J, Bayer O and Schummer W. 2007. Detection of tracheal mal-positioning of nasogastric tubes using endotracheal cuff pressure measurements. <u>Acta Anaesthesiologica Scandinavica</u> . Vol.51 No.9:1245-1249.	Primary outcomes not relevant to cuff pressure monitoring
26	Griesdale DE, Bosma TL, Kurth T, Isac G and Chittock DR. 2008. Complications of endotracheal intubation in the critically ill. <u>Intensive Care Medicine</u> . Vol.38:1835-1842.	Focus on the success of intubations and not on the cuff related complications
27	Guyton DC, Barlow MR and Besselievre TR. 1997. Influence of airway pressure on minimum occlusive endotracheal tube cuff pressures. <u>Critical Care Medicine</u> . Vol.25 No.1:91-94.	Focus on the linear relationship between occlusive and inflation pressures
28	Hofstetter C, Scheller B, Hoegl S, Mack MG, Zwissler B, Byhahn C. 2010. Cuff over-inflation and endotracheal tube obstruction: case report and experimental study. <u>Scand J Trauma Resuscitation Emergency Medicine</u> . Vol. 8 No.18:18-22.	Not relevant to the review question
29	Kriner E, Shafazand S and Colice GL. 2005. The endotracheal tube cuff leak test as a predictor for post-extubation stridor. <u>Respiratory Care</u> . Vol.50 No.12:1632-1638.	Not relevant to the review question
30	Lorente L, Lecuona M, Jimenez A, Maro M and Sierra A. 2007. Influence of an endotracheal tube with polyurethane cuff and subglottic secretion drainage in pneumonia. <u>American Journal of</u>	Addressing the effect of the different ETT cuffs on the reduction of VAP with no reference to cuff pressure

Annexures

	<u>Respiratory and Critical Care Medicine.</u> Vol.176:1079-1083.	monitoring.
31	Nseir S, Zerimech F, De Jonkheere J, Alves I, Balduyck M and Durocher A. 2010. Impact of polyurethane on variations in tracheal cuff pressures in critically ill patients: a prospective observational study. <u>Intensive Care Medicine.</u> Vol.36:1156-1163.	Not relevant to the review question
PAPERS EXCLUDED AFTER CRITICAL APPRAISAL (1)		
1	Perrie H. 2010. Nesibopho Best practice guideline on tracheal tube cuff pressure monitoring. <u>Nesibopho Healthcare (Pty) Ltd.</u>	Does not adhere to the rigorous process of a literature review and the development of best practice guidelines.

ANNEXURE M
COPY OF THE AGREE INSTRUMENT

Citation information				
SECTION A: SCOPE AND PURPOSE				
ITEM	Strongly agree(4)	Agree(3)	Disagree(2)	Strongly disagree(1)
The overall objectives(s) of the guideline is (are) specifically described				
The clinical question(s) covered by the guideline is (are) specifically described				
The patients to whom the guideline are meant to apply are specifically described				
SECTION B: STAKEHOLDER INVOLVEMENT				
The guideline development group includes individuals from all relevant professional groups				
The patient's views and preferences have been sought				
The target users of the guideline are clearly defined				
The guideline has been piloted amongst target user.				
SECTION C : RIGOUR OF DEVELOPMENT				
Systematic methods were used to search for evidence				
The criteria selecting the evidence are clearly described				
The methods used for formulating the recommendations are clearly described				
The health benefits, side effects and risks have been considered in formulating the recommendations				
There is an explicit link between the				

recommendations and the supporting evidence				
The guideline has been externally reviewed by experts prior to its publication				
A procedure for updating the guideline is provided				
SECTION D: CLARITY AND PRESENTATION				
The recommendations are specific and unambiguous				
The different options for management of the condition are clearly presented				
The key recommendations are easily identifiable				
The guideline is supported with tools for application				
SECTION E: APPLICATION				
The potential organizational barriers in applying the recommendations have been discussed				
The possible cost implications of applying the recommendations have been considered				
The guideline presents key review criteria for monitoring and/or audit purposes				
SECTION F: EDITORIAL INDEPENDENCE				
The guideline is editorial independent from the funding body				
Conflicts of interest of guideline development members have been recorded				

Overall appraisal:

Section A: Scope and purpose: /12
Section B: Stakeholder involvement: /16 =
Section C: Rigor of development: /28 =
Section D: Clarity and presentation: /16 =
Section E: Application: /12 =
Section F: Editorial Independence: /8 =
TOTAL: /92=

Comments:

Included

Excluded

ANNEXURE N**JBI CRITICAL APPRAISAL TOOL FOR EXPERIMENTAL STUDIES (MAStARI)**

Citation information			
Type of evidence			
Description of context			
Description of methods	Yes	No	Unclear
Was the assignment to treatment groups random?			
Were participants blinded to treatment allocation?			
Was allocation to treatment groups concealed from the allocator?			
Were the outcomes of people who withdrew described and included in the analysis?			
Were those assessing outcomes blind to the treatment allocation?			
Were the control and treatment groups comparable at entry?			
Were groups treated identically other than for the named interventions?			
Were outcomes measured in the same way for all groups?			
Were outcomes measured in a reliable way?			
Was appropriate statistical analysis used?			
Overall appraisal:			
Include <input type="checkbox"/>	Exclude <input type="checkbox"/>	Seek further information <input type="checkbox"/>	
Comments			

ANNEXURE O**JBI CRITICAL APPRAISAL TOOL FOR COHORT STUDIES (MAStARI)**

Citation information			
Description of context			
Description of methods	Yes	No	Unclear
Is the sample representative of patients in the population as a whole?			
Are the patients at a similar point in the course of their condition?			
Was follow-up carried out over a sufficient period of time?			
Were the outcomes of people who withdrew described and included in the analysis?			
Were the outcomes measured in a reliable way?			
Was the appropriate statistical analysis used?			
Overall appraisal:			
Include	<input type="checkbox"/>	Exclude	<input type="checkbox"/> k further information <input type="checkbox"/>
Comments			

ANNEXURE P**JBI CRITICAL APPRAISAL TOOL FOR OBSERVATIONAL STUDIES (MAStARI)**

Citation information			
Description of context			
Description of methods	Yes	No	Unclear
Is the study based on a random or pseudorandom sample?			
Are the criteria for inclusion in the sample clearly defined?			
Were outcomes assessed using objective criteria?			
If comparisons are being made was there sufficient description of the groups?			
Was the appropriate statistical analysis used?			
Overall appraisal:			
Include	<input type="checkbox"/>	Exclude	<input type="checkbox"/> k further information <input type="checkbox"/>
Comments			

ANNEXURE Q**JBI CRITICAL APPRAISAL TOOL FOR NARRATIVE, TEXTUAL OR OPINION PAPERS
(NOTARI)**

Citation information			
Type of evidence			
Description of context			
Description of methods	Yes	No	Unclear
Is the source of opinion clearly identified			
Does the source of opinion have a standing in the field of expertise			
Are the interest of patients the central focus of opinion			
Is the opinion's basis in logic/experience clearly argued			
Is there reference to the extant literature/evidence and any incongruence with it logically defended?			
Is the opinion supported by peers?			
Overall appraisal:			
Include	<input type="checkbox"/>		
Exclude	<input type="checkbox"/>		
Seek further information	<input type="checkbox"/>		
Comments			

ANNEXURE R
JBIMAStARI DATA EXTRACTION TOOL

Review date: _____

Author: _____

Journal: _____

Year: _____

Study method:

RCT	Quasi-RCT	Cohort	Observational	Retrospective
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Other: _____

Method of randomization: _____

Allocation of concealment: _____

Blinding of outcome: _____

Participants:

Setting: _____

Population: _____

Sample Size: _____

Time period of study: _____

Interventions: _____

Outcomes:

Primary: _____

Secondary: _____

If study excluded state reasons: _____

Summary of main results _____

ANNEXURE S

JBI NOTARI DATA EXTRACTION TOOL

Review date: _____
Author: _____
Journal: _____
Year: _____
<u>Study description:</u>
Type of text: _____
Stated: _____
Allegiance/position: _____
Intervention: _____
Setting: _____
Geographical: _____
Cultural: _____
Logic of argument: _____
Data Analysis: _____

Author's conclusions: _____

Comments _____ :

Findings: _____
Illustration from publication: _____
Extraction of findings complete: Yes _____ No

ANNEXURE T
LETTER TO THE EXPERT PANEL



Faculty of Health Sciences
DEPARTMENT OF NURSING SCIENCE
Tel: +27 (0)41 504-4501/ +27 (0) 72 653 2534
E-mail : portia.jordan@nmmu.ac.za

2010

Dear Madam/Sir

I am currently engaged in a research study related to the development of evidence-informed clinical guidelines for nursing care practices with regard to the safety of the mechanically ventilated patient in the critical care unit. Draft clinical guidelines on two nursing care practices namely: endotracheal tube suctioning and endotracheal tube cuff pressure monitoring were developed and were based on a systematic review.

You are being requested to participate in an expert panel review for the two clinical guidelines and clinical algorithms that were developed during the research study. To participate, it will be required of you to complete the provided, attached clinical guideline review form and give comments where necessary. The evidence-informed clinical guideline was based on the AGREE clinical appraisal tool. Therefore it is important to note that the format of the guideline comprise of the evidence found and recommendations for practice.

Anonymity as a participant will be ensured, if required. You are under no obligation to participate in this research study. However, your valuable input will be appreciated and will be used in finalizing the clinical guidelines. Please complete the attached consent form indicating your willingness to participate in the review panel. Should you have any queries please do not hesitate to contact me or my promoter, Prof RM van Rooyen.

Yours sincerely
PORTIA JORDAN
RESEARCHER

CONSENT TO PARTICIPATE IN THE EXPERT PANEL

I _____ hereby agree to participate in the expert panel for the assessment of the draft evidence-informed clinical guidelines on endotracheal tube suctioning and endotracheal tube cuff pressure monitoring.

Signature _____

Date _____

ANNEXURE U
REVIEW SHEET FOR EVIDENCE-INFORMED CLINICAL GUIDELINES (ADAPTED FROM
THE AGREE INSTRUMENT)

Please tick the most relevant response in the blocks as indicated below.

Citation information	Evidence-informed clinical guideline for endotracheal tube suctioning in the adult mechanically ventilated patient in the critical care unit. PJ Jordan and RM van Rooyen, Department of Nursing Science, NMMU, 2010.			
Description of context	The evidence informed guideline was developed for professional nurses who perform endotracheal tube suctioning in the adult mechanically ventilated patient in the critically care unit. The guideline was based on the data derived from the systematic review conducted.			
SECTION A: SCOPE AND PURPOSE				
ITEM	Strongly agree(4)	Agree(3)	Disagree(2)	Strongly disagree(1)
The overall objective of the guideline is specifically described.				
The clinical question covered by the guideline is specifically described.				
The patients to whom the guideline is meant to apply are specifically described.				
SECTION B: STAKEHOLDER INVOLVEMENT				
The expert panel reviewing the clinical guideline includes individuals from all relevant professional groups.				
The patient's views and preferences have been sought.				
The target users of the guideline are clearly defined.				
The guideline has been piloted amongst target users, namely				

Annexures

professional nurses in the critical care units in the Nelson Mandela Metropole.				
SECTION C : RIGOUR OF DEVELOPMENT				
Systematic methods were used to search for evidence.				
The inclusion and exclusion criteria selecting the evidence are clearly described.				
The methods used for formulating the recommendations are described.				
There is an explicit link between the recommendations and the supporting evidence.				
The guideline has been externally reviewed by experts prior to its finalization.				
SECTION D: CLARITY AND PRESENTATION				
The recommendations are specific and unambiguous.				
The key recommendations are easily identifiable.				
Comments:				

ANNEXURE V

EVIDENCE-INFORMED CLINICAL GUIDELINE FOR ENDOTRACHEAL TUBE SUCTIONING IN THE ADULT MECHANICALLY VENTILATED PATIENT IN THE CRITICAL CARE UNIT

Portia Janine Jordan (MCUR, BCUR, Dip Nursing Ed, Dip Nephrology)

Department of Nursing Science, NMMU

Dalena van Rooyen (DCUR, MCUR, BCUR Hons, BCUR, Dip Nursing Ed)

Department of Nursing Science, NMMU

Objective: The objective of this evidence-informed clinical guideline is to provide professional nurses in the Nelson Mandela Metropole with best practice recommendations when performing endotracheal tube suctioning in the mechanically ventilated patient in critical care units.

Design: This clinical guideline was developed and based on the data derived from a systematic review. CINAHL, MEDLINE (via PubMed), EBSCO HOST, the JBI systematic review library, the Cochrane Library, clinical evidence from the British Medical Journal (BMJ), the National Guidelines Clearinghouse, Google Scholar, Highwire, Ingenta, and the online Worldviews on Evidence-Based Nursing were searched for data. Hand searching was done in order to maximize the search for inclusion of all possible literature relevant to the topic. In order to draw on all types of evidence, all studies that described endotracheal tube cuff pressure monitoring were included in the systematic review. Therefore, best practice information sheets, randomised controlled trials, quasi-experimental studies, cohort studies, prospective, surveys, case reports, observational, descriptive studies and literature review papers were included in the systematic review. On completion of the literature searching process, critical appraisal, data extraction and synthesis were done. Summaries were made in the form of recommendations, to which the grades of recommendation were assigned.

Setting: The clinical guideline is intended for use amongst professional nurses performing endotracheal tube suctioning in the adult, intubated, mechanically ventilated patient in the critical care unit. The aim is that the guideline be used for critical care units in the public and private health care institutions in an attempt to standardise nursing care amongst professional nurses in the Nelson Mandela Metropole.

Population: The clinical guideline aims to address endotracheal tube suctioning in adult, intubated, mechanically ventilated patients in the critical care units.

Results and conclusion: The recommendations addressed the following aspects related to endotracheal tube suctioning: patient assessment, frequency of endotracheal tube suctioning, hyperinflation, hyperoxygenation, normal saline instillation, suction catheter size, depth of suction catheter insertion, the duration of the suctioning procedure and suction pressure to be used during endotracheal tube suctioning.

Keywords: suctioning, intubation, critical care unit, clinical guidelines, evidence-informed, mechanical ventilation.

1.1 INTRODUCTION

Endotracheal tube suctioning is one of the most common procedures performed in the care of the mechanically ventilated patient in a critical care unit. It is used to enhance clearance of respiratory tract secretions, improve oxygenation and prevent atelectasis. As an essential part of care for intubated patients, the major goals of endotracheal tube suctioning are to ensure adequate ventilation, oxygenation and airway patency. These goals should be obtained while patient discomfort and adverse hemodynamic effects are minimized and hypoxemia related to suctioning is prevented (Pierce, 2007:159). Potential complications related to endotracheal suctioning include cardiac arrhythmias, hypoxemia, cardiac arrest, vagal stimulation, mucosal trauma, atelectasis, contamination of the lower airway and the development of pneumonia, bronchospasm, pulmonary bleeding and increased intra-cranial pressure (Day, Farnell and Wilson-Barnett, 2002:79). Considering the complications that can occur while performing endotracheal tube suctioning, it is imperative that nursing care practices related to this procedure are done correctly and in accordance with the latest and best evidence-informed recommendations.

1.2 SCOPE AND PURPOSE

The scope and purpose of the guideline pertains to the objective, review question and the target group.

1.2.1 Objective of the clinical guideline

The objective of this clinical guideline is to provide professional nurses with recommendations for clinical practice, which are based on evidence, for endotracheal tube suctioning in the mechanically ventilated patient in the critical care unit. Based on data derived from the structured questionnaires completed by professional nurses in the Nelson Mandela Metropole, it was found that endotracheal tube suctioning was done least according to best recommended practice. Furthermore, it was found that practice variances existed amongst professional nurses in the critical care units of public and private health care institutions when performing endotracheal tube suctioning. In order to enhance the safety of the mechanically ventilated patient in the critical care unit, an evidence-informed clinical guideline was developed to guide nurses in performing endotracheal tube suctioning.

1.2.2 Review question

The systematic review question that was formulated in order to search for relevant literature pertaining to endotracheal tube suctioning was as follows:

How should endotracheal tube suctioning in the adult, mechanically ventilated patient in the critical care unit be done in order to minimize and/or prevent the complications associated with the procedure?

1.2.3 Target group

The evidence-informed clinical guideline is intended for use amongst professional nurses performing endotracheal tube suctioning in the adult intubated, mechanically ventilated patient in the critical care unit.

1.3 STAKEHOLDER INVOLVEMENT

The draft guideline was submitted to an expert panel for review. The expert panel comprised of three professional nurses, one from the public and two from the private sector respectively, who hold an additional qualification in Critical Care Nursing. An intensivist, respiratory therapist, anaesthetist were included as members of the multi-disciplinary team. A sales consultant for a respiratory equipment manufacturing company who previously worked in the critical care unit and holds an additional qualification in Critical Care Nursing were also included in the expert panel. The eighth member of the group was a nursing lecturer at one of the local universities, teaching Critical Care Nursing.

Due to the disease process and the fact that critically ill patients are often sedated and unable to communicate while connected to the mechanical ventilator, the patient's views and preferences have not been considered in the development of this clinical guideline.

The target users of this evidence-informed clinical guideline are the professional nurses caring for the intubated adult mechanically ventilated patients in the critical care unit. For the scope of this research study, the guideline has not been piloted amongst the target users as yet.

1.4 RIGOUR OF DEVELOPMENT

Electronic and hand-searched data bases included CINAHL, MEDLINE (via PubMed), EBSCO HOST, the JBI systematic review library, the Cochrane Library, clinical evidence from the British Medical Journal (BMJ), the National Guidelines Clearinghouse, Google Scholar, Highwire, Ingenta, the online Worldviews on Evidence-Based Nursing and various journals pertaining to critical care, respiratory care and anaesthesia.

Search terms used for identifying literature pertaining to endotracheal tube suctioning were, for instance, “endotracheal suctioning AND adult NOT neonate”; “tracheal* AND suctioning”; “ventilation AND suctioning”.

Inclusion and exclusion criteria for the systematic review were considered. The review considered all papers that comprise of human, adult patients, aged 18 years and above, who are intubated with an artificial airway, namely an endotracheal tube or tracheostomy, and mechanically ventilated. All searches were limited to English. The search was limited by the year 1990 of publication. Studies was not contextualized to the critical care unit only, but included other high acuity areas, for instance, the emergency care unit, high care and operating theatre, as patients might initially be intubated in these areas and require endotracheal tube suctioning. Included papers were best-practice information sheets, clinical practice guidelines, randomised controlled trials, non-randomised control trials, cohort studies, observational and descriptive studies, expert opinion and literature review papers. Excluded papers consisted of those that were not in English, studies that addressed the pediatric population, animal studies or studies that were irrelevant to the topic of discussion.

A total of 100 papers were initially identified to be included in the systematic review. After elimination of duplicate papers and those that did not adhere to the inclusion criteria, 42 papers were included for methodological assessment. Critical appraisal and data extraction was done by means of the JBI SUMARI software package, using the MASTARI and the NOTARI modules for the different hierarchies of evidence found. Following the critical appraisal process, which was done independently by two reviewers, 36 papers were included in the systematic review. Detailed summaries of each paper appraised were composed. The summaries were used to formulate recommendations based on the grades of evidence. Due to the heterogeneity in the various studies, no meta-analysis was performed.

The United States Preventive Services Task Force’s (USPSTF), grades of recommendations, accessed via the link www.ahcpr.gov/clinic/uspst-fix.htm, have been used to rank recommendations in terms of hierarchy levels of evidence. See Table 1.1

Table 1.1 GRADES OF RECOMMENDATION	
Grade	Explanation
A	Strongly recommended that clinicians adopt this. Good evidence found to suggest that this intervention improves health outcomes and benefits the patient.
B	Recommended that clinicians adopt this. At least fair evidence found to suggest that the intervention or activity improves health outcomes and benefits the patient.
C	No recommendation for or against adoption. At least fair evidence that the activity or intervention improves health outcomes, but the benefits and harms are too close to justify a general recommendation.
D	Recommend against routinely adopting this activity or intervention. At least fair evidence found that suggest that it is ineffective or that harms outweigh benefits
I	The evidence is insufficient to recommend for or against routinely adopting this. Evidence that is effective is lacking, of poor quality or conflicting and the balance of benefits and harms cannot be determined.

Due to the scope of this research study, the guideline was developed by the researcher and not by a recommended guideline development group. However, an expert review panel (as described earlier) was consulted to comment of the guideline construction and content.

1.5 RECOMMENDATIONS

The data pertaining to endotracheal tube suctioning in the adult, mechanically ventilated patient in the critical care unit were categorised as illustrated in Table 1.2.

Table 1.2 SYNTHESIZED DATA FROM EVIDENCE FOUND ON ENDOTRACHEAL TUBE SUCTIONING	
Aspects related to endotracheal tube suctioning	Nursing intervention
Assessment prior to endotracheal tube suctioning	Patient assessment
	Frequency of endotracheal tube suctioning
	Hyperinflation and hyperoxygenation
	Normal saline instillation
Implementation of endotracheal tube suctioning	Suction catheter size selection
	Depth of suction catheter insertion
	Duration of the suctioning procedure
	Suction pressure
Evaluation following endotracheal tube suctioning	Patient assessment

In order to simplify the clinical guideline, it was decided by the researcher to group the data in Table 1.2 into the “ABCD of endotracheal tube suctioning”, which is set out as follows:

A Assessment;

B Best methods: No normal saline instillation, Hyperinflation and hyperoxygenation, suction pressure;

C Catheter size;

D Depth of insertion, duration of suctioning procedure.

1.5.1 Assessment

The following recommendations can be made with regard to the assessment of the critically ill, intubated patient prior to and after performing endotracheal tube suctioning:

- It is recommended that an assessment of the patient, which includes a chest auscultation, be done prior to performing endotracheal tube suctioning (Grade D);
- The need for suctioning should be determined by the clinical respiratory indicators for suctioning (Grade D);
- In the mechanically ventilated patient, the presence of a saw-tooth pattern on the volume and pressure flow-loop curve on the ventilator graphs is indicative of the need for performing endotracheal tube suctioning (Grade C);

- Routine endotracheal tube suctioning is not recommended and suctioning should only be performed when necessary (Grade A);
- Performing endotracheal tube suctioning every two hours does not appear to be beneficial in clearing airway secretions (Grade B);
- On completion of endotracheal tube suctioning, it is recommended that nurses perform a physical assessment, which should include a chest auscultation. Other assessment findings should include monitoring the vital signs data, perfusion status as well as the characteristics of the sputum. Re-assurance of the patient should be done to minimize and/or reduce anxiety produced by the endotracheal tube suctioning procedure (Grade D).

Rationale

Evidence derived from four literature review papers (Level VII), one best-practice information sheet (Level VII) and one observational study (Level IV) confirmed that the purpose of suctioning is to remove secretions and to maintain a clear airway. Endotracheal tube suctioning should be performed following a comprehensive assessment of the patient's respiratory status, which should include a chest auscultation (Glass and Grap, 1995:51; Day *et al*, 2002:86; Branson, 2007:1334; Jelic, Cunningham and Factor, 2008:210; Pedersen, Rosendahl-Nielsen, Hjermind and Egerod, 2009:23). It is further argued that suctioning should be done when auscultation findings reveal rhonchi, or when the airway pressure increases or when the oxygenation levels decrease. Individualized assessment is essential prior to performing suctioning. Clinical respiratory assessment indicators for suctioning include coarse breath sounds, noisy breathing, and prolonged expiratory breath sounds (Glass and Grap, 1995:51; Thompson, 2000:2).

In an observational study by Guglielminotti, Alzieu, Maury, Guidet and Offenstadt (2000:1095), the need to use the mechanical ventilator pressure and flow curves that might suggest the need for suctioning was revealed. The authors found that if respiratory breath sounds were present over the trachea area on auscultation, the presence of secretions to be greater than 0.5 ml was more likely. The most common finding in their study was a saw-tooth pattern in the expiratory flow signal on the mechanical ventilator graphs that suggests airway secretions in the large airways, thus necessitating endotracheal tube suctioning.

Traditionally, nurses were taught to perform endotracheal tube suctioning on patients routinely, perhaps every two hours. However, it has been documented in several of the literature and opinion papers found, that routine endotracheal tube suctioning might increase

the risk for complications and adverse effects, for instance, increasing the production of airway secretions, possible trauma to the airway, infection, hypertension and cardiac arrhythmias. Therefore, it is recommended that endotracheal tube suctioning should not be done routinely but rather on the individualized patient assessment (Glass and Grap, 1995:51; Thompson, 2000:2; Day *et al*, 2002: 87; Branson, 2007:1334; Jelic *et al*, 2008:210; Pedersen *et al*, 2009:23).

A quasi-experimental study was done to compare if there were any differences in endotracheal tube suctioning outcomes between patients receiving routine two-hourly suctioning and endotracheal tube suctioning performed on the basis of the nurse's clinical judgement following training in clinical assessment. The study results showed that if endotracheal tube suctioning was performed when needed and only after doing a physical assessment, accumulated secretions were successfully cleared. Furthermore, it was proven that if a minimum frequency is deemed necessary to maintain a clear airway then, unless indicated, every two hours is too frequent as no secretions were cleared for 46% of the time it was performed. The study also proved that endotracheal tube suctioning performed only when necessary appears to be less distressing to the patients. However, the study showed no statistically significant difference in complications related to the frequency of suctioning, namely decreased saturation, peak airway pressure, heart rate, heart rhythm and mean arterial pressure (Wood, 1998:176).

A randomised control clinical trial done by Van de Leur, Zwaveling, Loef and van der Schans, 2003 (426-432), assessed the effects of routine versus minimally invasive suctioning. The study included 380 patients requiring endotracheal intubation for more than 24 hours. Of these patients, (n=197) received routine suctioning while the control group (n=186) received minimally invasive suctioning only when needed. It was found that suction-related complications occurred more frequently with routine suctioning. These events included decreased saturation (p=0.010); increased systolic blood pressure (p<0.001); increased pulse rate (p=0.007) and blood in mucus (p<0.001). Conclusively, the study thus supported the fact that endotracheal tube suctioning should only be done when needed, as per assessment findings and clinical indicators, and not routinely.

Thompson (2000:2) states in the best practice information sheet that suctioning should only be done when clinically necessary. Practitioners should use the clinical assessment indicators as a guide for performing endotracheal tube suctioning. These clinical indicators

includes coarse breath sounds, noisy breathing, crackles, wheezes and prolonged expiratory breath sounds, which can be heard when doing a chest auscultation.

In a literature review paper by St John (2004:93), it was stated that suctioning frequency should be based on the clinical need of the patient and not on a fixed schedule. The clinical indications include secretions in the endotracheal tube, frequent or sustained coughing, adventitious breath sounds on auscultation, e.g., rhonchi, desaturation related to airway secretions, increased peak airway pressures and sudden onset of respiratory distress. A physical assessment is thus necessary prior to performing endotracheal tube suctioning as it can aid in determining the need for suctioning rather than doing it routinely.

Limiting the frequency of suctioning may prevent the adverse effects and suctioning-induced complications, as stated by (Jelic *et al*, 2008:209). However, apart from the adverse events associated with more frequent suctioning, Wood (1998:177) states that it is expensive, inefficient and wasteful use of valuable resources when endotracheal tube suctioning is applied routinely and without clear indications. Therefore, it is recommended that health care practitioners use their physical assessment skills to determine if a patient requires endotracheal tube suctioning, rather than performing the procedure on a routine basis.

In reviewing the literature found, no definite recommendation was made for the intervals when endotracheal tube suctioning should be done. The literature review paper authored by Pedersen *et al* (2009:23) states there is no evidence to support maximum suction intervals but it may be advisable to perform suctioning at least every eight hours to reduce the risk of partial occlusion of the endotracheal tube and the accumulation of secretions. However, it is recommended that the frequency of performing endotracheal tube suctioning be guided by the clinical indicators and the physical assessment data as done by the health care practitioner.

According to literature review papers by Day *et al* (2002:87) and St John (2004:94), it is recommended that a comprehensive respiratory assessment be undertaken following endotracheal tube suctioning. The assessment should include chest auscultation to assess the air entry and breath sounds. Monitoring of the patient's heart rate, colour, perfusion and oxygenation levels must be done. Sputum should be observed for colour, consistency and the findings should be documented. Hand-washing should be emphasized to avoid contamination and infection. In order to minimise stress and anxiety induced by the

suctioning procedure, reassurance should be given to the patient after endotracheal tube suctioning.

1.5.2 Best recommended methods

This section refers to the best methods that should be practiced in order to ensure that endotracheal tube suctioning is performed safely. The best recommended methods include no normal saline instillation, hyperinflation and hyperoxygenation and adequate and correct suction pressures to use.

1.5.2.1 Normal saline instillation

It is recommended that:

- Normal saline instillation should not be used when performing endotracheal tube suctioning as it decreases the oxygenation levels of the patient (Grade A);
- The premise that the use of normal saline instillation to thin secretions should be discarded as it is unsupported and can be dangerous, thus jeopardising the safety of the intubated patient (Grade D);
- Normal saline instillation should not be practiced as it proves to dislodge bacterial colonies, thus contributing to the lower airway contamination and infection (Grade C and D).

Rationale

Normal saline instillation has adverse effects. In a randomised control trial performed by Ackerman and Mick (1998:261-266) it was found that instillation of normal saline prior to endotracheal tube suctioning had a detrimental effect on oxygen saturation. The findings confirm that the practice of instilling normal saline prior to endotracheal tube suctioning compromises oxygenation and should thus be abandoned as a routine intervention. Other studies done by Ackerman (1993:326-330); Ackerman and Gugerty (1990:14-17); Ji, Kim and Park (2002:607-612) and Akgül and Akyolcu (2002:826-830) confirmed that the SaO₂ levels was lower in patients where normal saline instillation was used prior to endotracheal tube suctioning than in patients where it was not used, thus further strengthening the argument that normal saline instillation has a detrimental effect on oxygenation.

A literature review paper by Branson (2007:1328-1347) states that normal saline instillation does cause the patient to cough, which may aid in the secretion removal process. However, the properties of mucus are unlikely to change with the addition of water unless some physical means of mixing the two is accomplished. Based on the premise, saline instillation

to thin secretions is unsupported and can be dangerous, thus jeopardising the safety of the intubated patient.

A study by O'Neal, Grap, Thompson and Dudley (2001:356-363) documented no beneficial effects of normal saline. But it did demonstrate that normal saline might precipitate a significantly increased level of dyspnea for up to ten minutes after suctioning in patients older than 60 years of age. Recommendations based on the results of this study would be to avoid the use of normal saline instillation prior to endotracheal tube suctioning.

An observational study done by Kinloch (1999:231-242) aimed to investigate the effects of 5 ml of normal saline instillation during endotracheal suctioning on mixed venous saturation. The participants were 35 cardiothoracic surgical patients, where one group had 5 ml of normal saline instilled at the beginning of the endotracheal suctioning procedure, while the other group had the same endotracheal suctioning procedure without the normal saline instillation. The findings of the study revealed that normal saline instillation at the beginning of endotracheal suctioning had significantly lowered the mixed venous saturation values.

Other detrimental effects of normal saline instillation include infection-control issues and bacterial contamination. The findings from an experimental study done by Hagler and Traver, (1994:444-447) illustrated that normal saline instillation dislodged up to 310,000 viable bacterial colonies, supporting the fact that normal saline instillation has the potential for producing airway infection by dislodging bacteria into the lower airway. Another study by Freytag, Thies, Konig and Welte (2003:31-37) found that normal saline instillation with endotracheal tube suctioning may lead to a dispersion of micro-organisms into the lower respiratory tract. Several literature review papers support the fact that normal saline increase the release of viable bacteria into the lower airway (Glass and Grap, 1995:53; Blackwood, 1999:930; Thompson, 2000:3; Celik and Kanan, 2006:11-14; Branson, 2007:1334; Halm and Kristo-Hagel, 2008:470, Jelic *et al*, 2008:300; Rauen, Chulay, Bridges, Vollman and Arbour, 2008:101).

Collectively, the studies demonstrated that normal saline instillation has adverse effects. It was illustrated that normal saline instillation adversely affects arterial and global tissue oxygenation, increases the heart rate and stimulates the cough reflex. Furthermore, it dislodges bacterial colonies, thus contributing to the lower airway contamination and infections. Based on the findings of studies, it can be recommended that normal saline instillation should not be used prior to endotracheal tube suctioning.

1.5.2.2 Hyperinflation and hyperoxygenation

The following recommendations can be made with regard to hyperinflation and hyperoxygenation practices:

- Hyperinflation alone does not appear to be beneficial to the intubated, mechanically ventilated patient (Grade A);
- It is recommended that hyperinflation be used with caution in patients who present with increased intracranial pressure, vascular, cardiac surgery and those who are hemodynamically unstable (Grade D);
- Routine use of hyperinflation is not recommended due to the risk for barotrauma from large volumes, high peak pressures and patient discomfort;
- The use of hyperinflation combined with hyperoxygenation appears to be beneficial in improving the oxygenation level of intubated adult patients (Grade A and B);
- It is recommended that hyperinflation be delivered by the ventilator in order to control tidal volume and inspiration pressure. The use of a manual resuscitation bag is not recommended (Grade D).

Rationale

In an RCT done by Barker and Adams (2002:157) using 17 patients with acute lung injury requiring mechanical ventilation, the use of hyperinflation had no effect on oxygenation, heart rate, blood pressure and dynamic lung compliance. The above study results were supported by a RCT done by Stone (1990:289-299). The author of the study used 26 post-cardiac surgery, intubated and mechanically ventilated patients. Hyperinflation was done using five different inspiratory volumes by means of the mechanical ventilator. The heart rate and the oxygenation levels were assessed during the use of manual hyperinflation. The study results showed no clinical significant difference in the oxygenation and heart-rate parameters. In reviewing the above two studies, it appears that the use of hyperinflation alone with a reservoir ventilation bag, or even when using different volumes by means of a mechanical ventilator, does not have any effect on the oxygenation, hemodynamic parameters or lung compliance when used prior to endotracheal tube suctioning.

From the various pieces of evidence found, it can be concluded that hyperinflation alone is associated with the risk of barotrauma, cardiovascular instability and increased intracranial pressure. Therefore, it should be used with caution in patients who have raised intracranial pressure, those patients who are in the post-operative period following vascular or cardiac surgery and those who are hemodynamically unstable (Thompson, 2000:3; Day *et al*, 2002:80). Large variations in peak inspiratory pressure, tidal volume, respiratory rate and I:E

(inspiratory:expiratory) ratio have been shown during manual hyperinflation. These can have detrimental effects on cardiac output and oxygen delivery (Singer, Vermaat and Hall, 1994:1182; Clark, Kelly, Convery and Free, 1999:936). However, studies were found that investigated the combined effect of hyperinflation with suctioning, positioning change and hyperoxygenation.

In a randomised control trial study conducted to demonstrate an additional mechanical benefit to the respiratory system, hyperinflation and suction techniques were combined. This study findings suggest that hyperinflation, in conjunction with suction, induces beneficial changes in respiratory mechanics in mechanically ventilated patients with ventilator-associated pneumonia (Choi, Jones, 2005:25). The study findings were supported by a quasi-experimental study that was designed to assess the safety and short-term effectiveness of hyperinflation in mechanically ventilated patients. Eighteen patients from the intensive care units of two tertiary institutions were included and acted as their own control. Hyperinflation treatment involved patient positioning (side-lying), suctioning and hyperinflation. Side-lying treatment involved patient positioning and suctioning alone. Patients received both treatments on the day of data collection. Results demonstrated significant improvement for static respiratory system compliance ($p=0.001$) with hyperinflation treatment compared to side-lying treatment. Hyperinflation treatment also cleared a significantly greater wet weight of sputum ($p=0.039$). There were no differences between hyperinflation and side-lying treatment for gas exchange (PaO_2/FIO_2 and $PaCO_2$), mean arterial pressure or heart rate. In conclusion, total static respiratory system compliance and sputum clearance were improved by the addition of hyperinflation to a physiotherapy treatment of positioning and suctioning in mechanically ventilated patients without compromise to cardiovascular stability or gas exchange (Hodgson, Denehy, Ntoumenopoulos, Santamaria and Carroll, 2000:255-61).

Two studies were found that investigated the effects of using hyperinflation combined with hyperoxygenation prior to endotracheal tube suctioning. A quasi-experimental study by Paratz, Lipman and McAuliffe (2002:317) investigated the effects of hyperinflation in patients on mechanical ventilation on hemodynamics and gas exchange. The study results revealed that there was an improvement in gas exchange evident by the increase in the PaO_2 , which was sustained 20 minutes after using hyperinflation. There was no significant change in the $PaCO_2$. The diastolic arterial blood pressure increased significantly when using hyperinflation ($p<0.001$). However, all the other hemodynamic parameters, including heart rate and pulmonary artery pressure, did not alter during or after hyperinflation. The results in

this study thus highlight the fact that hyperinflation improves oxygenation. However, in this study, hyperinflation was used in combination with hyperoxygenation, thus explaining the improvement in the oxygenation status. The sample size of the study and the fact that it was limited to septic and acute lung injury patients should be noted when using the study results in formulating recommendations for practice.

Lookinland and Appel (1991:133-139) did a study on 24 non-head injured,intubated trauma patients, who were divided into four groups. In the first group of patients, no hyperinflation or hyperoxygenation was used, whereas in group 2, only hyperoxygenation was used. In group 3, only hyperinflation was used, while hyperoxygenation and hyperinflation were used in group 4 prior to endotracheal tube suctioning. The study results showed no difference noted in the mean arterial pressure and cardiac output between the four groups. An increase in the PaO₂ in groups 2 and 4 was noted, implying that the use of hyperinflation with hyperoxygenation is more beneficial when used prior to endotracheal tube suctioning. One literature review paper (Glass and Grap, 1995:52) supports this by stating that hyperinflation and hyperoxygenation should be combined, but if after the use of hyperoxygenation, the patient's oxygen tension saturation remains stable during suctioning, hyperinflation is deemed unnecessary.

Hyperinflation can be done by means of using a manual ventilation bag or it can be delivered via a mechanical ventilator. Two literature review papers support the use of manual hyperinflation by means of a mechanical ventilator and recommend it as a superior method in delivering hyperinflation. Pedersen *et al*(2009:25) state that using a hyperinflation volume of 1.5 x the baseline tidal volume on the mechanical ventilator is the most common for hyperinflation prior to endotracheal tube suctioning. The use of a ventilator for hyperinflation results in less hemodynamic alterations than using a manual resuscitation bag (Thompson, 2000:4).

1.5.2.3 Suction pressures

It is recommended that suction pressure should be maintained at 80-120 mmHg during endotracheal tube suctioning (Grade D).

Rationale

To prevent the suction catheter from adhering to the tracheal mucosa, negative pressure should only be applied during catheter withdrawal. However, the application of excessive negative pressure during endotracheal tube suctioning may cause trauma to the mucosa.

Using high negative pressures does not mean that more secretions will be aspirated. Therefore, the use of the lowest possible suction pressure, namely 80-120 mmHg, is recommended in order to reduce the risk of atelectasis, hypoxia and damage to the tracheal mucosa (Glass and Grap, 1995:52; Day *et al*, 2002:85; St John 2004:94; Pedersen *et al*, 2009:24).

1.5.3 Catheter size

It is recommended that suction catheters be as small possible, yet large enough to facilitate secretion removal. The external diameter of the suction catheter should be less than half of the internal diameter of the endotracheal tube. The widely accepted formula for calculating catheter size is: suction catheter size [Fr] = (ET tube size [mm] -2) x 2 (Grade D).

Rationale

Glass and Grap (1995:53) state that using a suction catheter with an external diameter less than half the internal diameter of the endotracheal tube will allow air to enter the lungs while oxygen is being removed by suctioning. This will help to prevent excessive negative pressure and atelectasis. Thompson (2000:3) supports this by stating that the internal diameter of the endotracheal tube may be directly related to the negative pressure within the lungs. The size of the suction catheter should be less than half of the internal diameter of the artificial airway to avoid greater negative pressures in the airway and to potentially minimize a decrease in the arterial oxygenation. According to a literature paper authored by St John (2004:94), the selection of an appropriately sized suction catheter for a given tube inner lumen diameter should be done correctly in avoiding complications during the suctioning. When a suction catheter occludes less than half the lumen of the endotracheal tube, the negative pressure in the lungs is minimized because the space in the tube that allows air to pass to the lungs during suctioning correlates with the tube lumen (Pedersen *et al*, 2009:23).

There is consensus in the four literature papers found that suction catheters should be small as possible, yet large enough to facilitate secretion removal. It is recommended that the external diameter of the suction catheter size be less than half of the internal diameter of the endotracheal tube. No clinical trials were found to support this recommendation.

1.5.4 Depth of catheter insertion, duration of suctioning

With regard to the depth of the suction catheter insertion during endotracheal tube suctioning, it is recommended that:

- The suction catheter should be inserted to the length of the endotracheal tube only (Grade A);
- The suction catheter should be inserted to the carina, until resistance is felt, and then retracted 1-2 cm before endotracheal tube suctioning is performed (Grade D).

Rationale

The effect of deep suctioning is tracheal mucosal damage, including epithelial denudement, hyperemia, loss of cilia, edema, fibrosis and granuloma formation. This damage occurs when the tissue is pulled into the catheter tip holes and increases the risk of infection and bleeding for the patient. The purpose of suctioning is to remove secretions that are not accessible to bypassed cilia. Therefore, insertion of suction catheters only as far as the end of the placed endotracheal tube has been recommended. Passing suction catheters no further than 1cm past the length of the endotracheal tube can avoid contact with the trachea and carina. Resistance should not be met. If resistance is met, the suction catheter should be withdrawn at least 0.5 cm-1cm before applying suction. The suction catheter should be inserted to the carina and retracted 1-2 cm before applying suctioning (Wood, 1998:80 Celik and Elbas, 2000:192, Day *et al*, 2002:80; Pate and St John, 2004:13; Pedersen *et al*, 2009:25).

In a single randomised control trial done by Van der Leur *et al* (2003:426-432) it was found that suction-related adverse events occurred more frequently with routine deep suctioning versus shallow suctioning where the suction catheter is inserted to the length of the endotracheal tube only.

1.5.2.6 Duration of the suctioning procedure

It is recommended that endotracheal tube suctioning procedure should not last longer than ten seconds (Grade D).

Rationale

The duration of the suctioning procedure affects the severity of adverse effects related to endotracheal tube suctioning. The three literature review papers found suggest that a maximum of ten seconds be recommended. Performing endotracheal tube suctioning for durations longer than ten seconds is associated with an increased risk of mucosal damage and hypoxia, thus compromising the safety of the intubated, mechanically ventilated patient (Wood, 1998:172; Thompson, 2000:3; Pedersen *et al*, 2009:24). No clinical trials or other pieces of evidence were found to support this recommendation.

1.6 SUMMARY OF RECOMMENDATIONS

The recommendations formulated can be used to guide professional nurses to provide safe and consistent care, while reducing the complications and risks associated with endotracheal tube suctioning in the critically ill patient. Table 1.3 provides a summary of the recommendations.

Table 1.3 BEST PRACTICE RECOMMENDATIONS FOR ENDOTRACHEAL TUBE SUCTIONING

- It is recommended that an assessment, which includes a chest auscultation, be done prior to performing endotracheal tube suctioning.
- It is recommended that the need for suctioning should be determined by clinical respiratory indicators and the presence of a saw-tooth pattern on the volume and pressure flow-loop curve on the ventilator graphs.
- It is recommended that endotracheal tube suctioning be performed only when necessary.
- Routine instillation of normal saline prior to endotracheal tube suctioning is not recommended.
- It is recommended that hyperinflation be used with caution in patients with increased intracranial pressure, vascular and cardiac surgery and those who are hemodynamically unstable.
- Hyperinflation combined with hyperoxygenation prior to endotracheal tube suctioning is recommended. Hyperinflation must be done by means of a ventilator rather than using a manual resuscitation bag.
- It is recommended that the lowest suction pressures, namely 80-120 mmHg be used during endotracheal tube suctioning.
- It is recommended that the external diameter of the suction catheter be less than half of the internal diameter of the endotracheal tube.
- It is recommended that the suction catheter be inserted to the length of the endotracheal tube or to the carina, where resistance is felt and then retracted 1-2 cm before endotracheal tube suctioning is performed.
- It is recommended that endotracheal tube suctioning should not last longer than ten seconds.
- It is recommended that an assessment, which includes chest auscultation, monitoring of vital signs, perfusion status and characteristics of sputum be done on completion of endotracheal tube suctioning. Re-assurance of the patient should be done throughout and after the procedure.

1.7 EDITORIAL INDEPENDENCE

The responses from the professional nurses completing the structured questionnaires formed the basis for the development of this evidence-informed guideline. The promoter of the study assisted in the conception and the design of the guideline. Although funding was received from the institution where the study was conducted, this guideline is editorially independent of the funding body. No funding was obtained from product manufacturers. No conflict of interest is applicable to the development of this guideline.

1.8 CONCLUSION

A wide variety of evidence was found to assist in the formulation of the recommendations. However, the lack of randomised control trials related to each aspect of the endotracheal tube suctioning was considered when recommendations were made. While there is a paucity of good quality evidence regarding the many aspects of endotracheal tube suctioning, the synthesis of the research is in providing the best available evidence to address the gaps and variances in practices that were found amongst registered nurses in the Nelson Mandela Metropole.

None of the studies included cost information; therefore no information regarding cost is included in this guideline. No reference was made in the evidence found to with regard to the patient's views and preferences, which was thus lacking in this guideline. The guideline has not been piloted amongst the target users, namely the professional nurses in the critical care units in the Nelson Mandela Metropole as this was not part of the scope of this study. Implementation strategies thus have to be developed to enhance the use of this guideline in practice.

ANNEXURE W

ALGORITHM FOR THE “ABCD” OF ENDOTRACHEAL TUBE SUCTIONING

ALGORITHM FOR THE “ABCD” OF ENDOTRACHEAL TUBE SUCTIONING

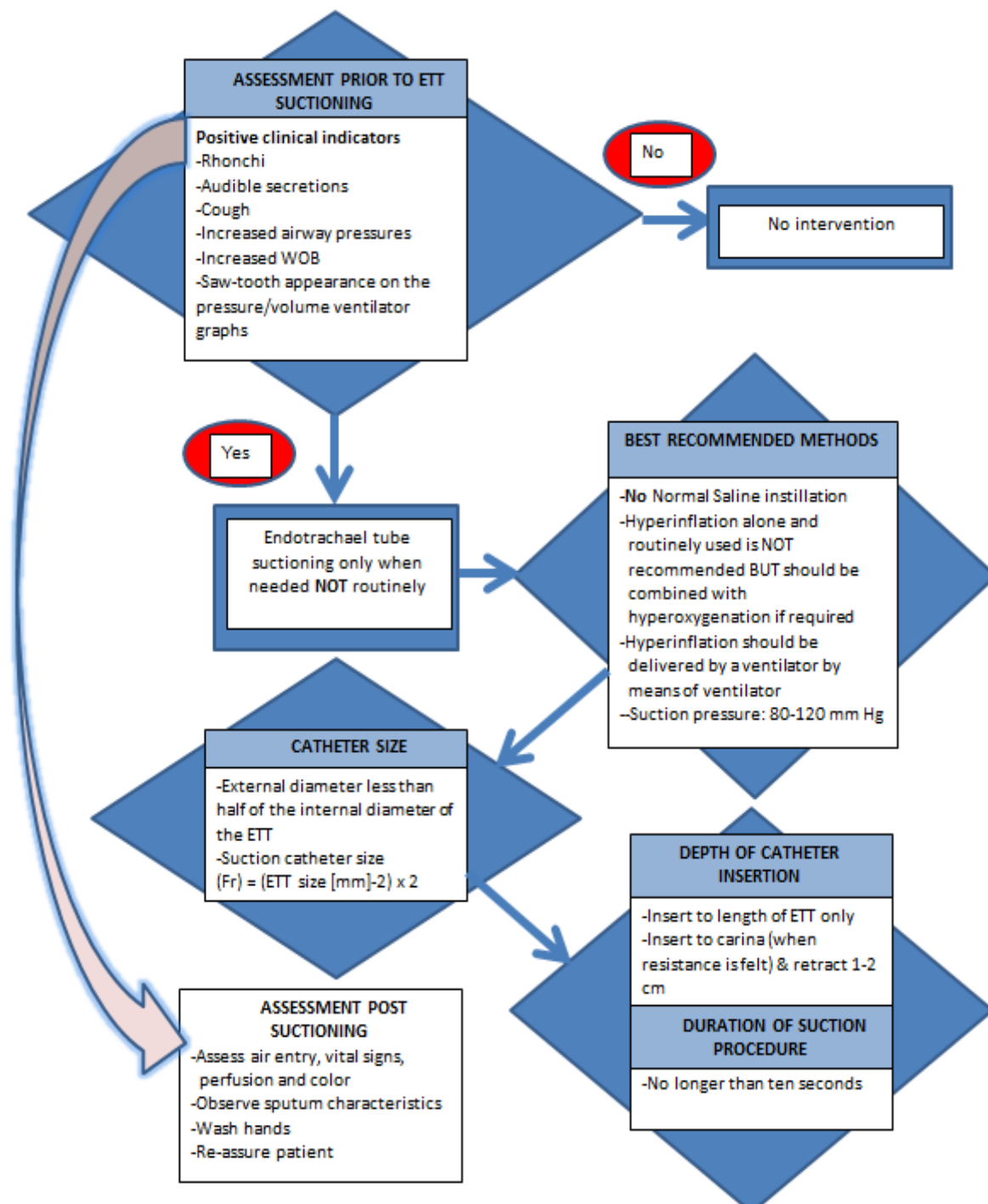


Figure 6.1 Algorithm for the “ABCD” of endotracheal tube suctioning

ANNEXURE X

EVIDENCE-INFORMED CLINICAL GUIDELINE FOR ENDOTRACHEAL TUBE CUFF PRESSURE MONITORING IN THE ADULT MECHANICALLY VENTILATED PATIENT IN THE CRITICAL CARE UNIT

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Objective: The objective of this evidence-informed clinical guideline is to provide professional nurses in the Nelson Mandela Metropole with best practice recommendations for endotracheal tube cuff pressure monitoring in the mechanically ventilated patient in the critical care unit.

Design: This clinical guideline was developed and based on the data derived from a systematic review. CINAHL, MEDLINE (via PubMed), the JBI systematic review library, the Cochrane Library, clinical evidence from the British Medical Journal (BMJ), the National Guidelines Clearinghouse, Google Scholar, Highwire, Ingenta, and the online Worldviews on Evidence-based Nursing were searched for data. Hand searching was done in order to maximize the search for inclusion of all possible literature relevant to the topic. In order to draw on all types of evidence, all studies that described endotracheal tube cuff pressure monitoring were included in the systematic review. Therefore, best practice information sheets, randomised controlled trials, quasi-experimental studies, cohort studies, prospective, surveys, case reports, observational, descriptive studies and literature review papers were included in the systematic review. On completion of the literature searching process, critical appraisal, data extraction and synthesis were done. Summaries were made in the form of recommendations, to which the grades of recommendation were assigned.

Setting: The clinical guideline is intended for use by professional nurses performing endotracheal tube cuff pressure monitoring of adult, intubated, mechanically ventilated patients in critical care units. The aim is that the guideline be used for critical care units in the public and private health care institutions in an attempt to standardize nursing care amongst professional nurses in the Nelson Mandela Metropole.

Population: The clinical guideline aims to address endotracheal tube cuff pressure monitoring in adult, intubated, mechanically ventilated patient in critical care units.

Results and conclusion: A systematic review was done on endotracheal tube cuff pressure monitoring. Based on the results of the systematic review, recommendations for practice were formulated. The recommendations include the following: frequency of endotracheal tube cuff pressure monitoring, methods on how to perform endotracheal cuff pressure monitoring and the management of cuff leaks.

Keywords: clinical guidelines, mechanical ventilation, endotracheal tube, tracheal cuff pressures, cuff pressure monitoring.

1.1 INTRODUCTION

Cuffed endotracheal tubes are one of the aspects of airway management designed to ensure safety, yet patients might be at risk for injury from under-inflated and over-inflated endotracheal tube cuffs. The endotracheal tube's inflatable cuff seals the airway, thus preventing aspiration of pharyngeal contents into the trachea and it should ensure that there are no leaks past the cuff during positive pressure ventilation. At the same time, the pressure exerted by the inflated cuff on the trachea should not be so high that capillary circulation is compromised (Stewart, Screst, Norwood and Zachary, 2003:443).

Ongoing cuff management involves interventions to ensure appropriate inflation of the endotracheal tube cuff. Potential injuries from over-inflation of the cuff include tracheal rupture, tracheal necrosis, trachea-oesophageal fistula, tracheal stenosis and recurrent laryngeal nerve palsy. More commonly, over-inflation of the cuff can result in stridor and sore throats after extubation. Under-inflation can lead to bronchial aspiration of secretions, particularly during inspiration. Importantly, aspiration of pharyngeal secretions has been associated with ventilator-associated pneumonia (Rose and Redl, 2008:429). Cuff pressures of more than 30 cmH₂O compress mucosal capillaries and impair blood flow, with total occlusion occurring at 50 cmH₂O (Hameed, Mohamed and Al-Mansoori, 2008:23). Health care practitioners should thus monitor endotracheal tube cuff pressures regularly in order to avoid tracheal injury and the risk of aspiration. Cuff management practices include the monitoring of endotracheal tube cuff pressure and cuff leaks and using the correct method at the recommended intervals.

1.2 SCOPE AND PURPOSE

The scope and purpose of the guideline pertains to the objective, review question and the target group.

1.2.1 Objective of the clinical guideline

Data analysed from a structured questionnaire completed by professional nurses in the critical care units in the Nelson Mandela Metropole revealed that endotracheal tube cuff pressure monitoring was least done according to best recommended practice. Following the data analysis phase, a systematic review was done on endotracheal tube cuff pressures, which formed the basis for the development of an evidence-informed clinical guideline.

The objective of this clinical guideline is to provide professional nurses with recommendations for clinical practice, which are based on evidence, for endotracheal tube

cuff pressure monitoring in the adult, intubated, mechanically ventilated patient in the critical care unit.

1.2.2 Review question

The following review question was formulated:

What nursing care interventions are the most effective in monitoring endotracheal tube cuff pressure to minimize the complications of over-inflation or under-inflation in the adult, intubated patient in a critical care unit?

1.2.3 Target group

The evidence-informed clinical guideline is intended for use amongst professional nurses performing endotracheal tube cuff pressure monitoring in the adult intubated, mechanically ventilated patient in the critical care unit.

1.3 STAKEHOLDER INVOLVEMENT

The draft guideline was submitted to an expert panel for review. The expert panel comprised of three professional nurses, one from the public and two from the private sector respectively, who hold an additional qualification in Critical Care Nursing. An intensivist, respiratory therapist, anaesthetist were included as members of the multi-disciplinary team. A sales consultant for a respiratory equipment manufacturing company who previously worked in the critical care unit and holds an additional qualification in Critical Care Nursing were also included in the expert panel. The eighth member of the group was a nursing lecturer at one of the local universities, teaching Critical Care Nursing.

Due to the disease process and the fact that critically ill patients are often sedated and unable to communicate while connected to the mechanical ventilator, the patient's views and preferences have not been considered in the development of this clinical guideline.

The target users of this evidence-informed clinical guideline are the professional nurses caring for the intubated adult mechanically ventilated patients in the critical care unit. For the scope of this research study, the guideline has not been piloted amongst the target users as yet.

1.4 RIGOUR OF DEVELOPMENT

CINAHL, MEDLINE (via PubMed), the JBI systematic review library, the Cochrane Library, clinical evidence from the British Medical Journal (BMJ), the National Guidelines

Clearinghouse and Google Scholar were searched. Search terms used for identifying literature pertaining to endotracheal tube cuff pressure were, for instance, “endotracheal tube AND cuff pressure AND monitoring”; “cuff pressures and tracheal care”; “cuff pressures and monitoring”; “measurement AND cuff pressures”; “tracheal damage”; “aspiration AND cuff pressures”; “ventilator-associated pneumonia AND cuff pressures”.

The reference lists and bibliographies of all papers were further searched for identification of additional studies. Furthermore, hand searching for articles in critical care, respiratory, emergency care and anaesthetic journals was done to ensure that all possible evidence was included. The local university and health care institution libraries were used to access these journals. Abstracts on the topic were also identified. The librarian aided in obtaining the full articles if the abstracts proved to be relevant to the topic. The librarian and interlibrary loan facility assisted in obtaining articles that could not be accessed via the local university. A search for conference papers, unpublished dissertations and thesis was done but none was found. The Critical Care Society of Southern Africa was contacted to find out if any literature was available on national level. One best practice guideline on endotracheal tube cuff pressure monitoring was available and was included in the appraisal of evidence.

Inclusion criteria for studies to be considered in the systematic review comprised all studies that included human, adult patients aged 18 and above. Furthermore, the participants in the included studies had to be intubated with an artificial airway namely an endotracheal tube or tracheostomy. Interventions of interest included those related to endotracheal tube cuff pressure monitoring. The primary outcomes measured in the different types of evidence included the reduction of complications related to over- and under-inflation of the endotracheal tube cuff. Secondary outcomes include reduce risk for aspiration, reduced risk for ventilator-associated pneumonia and reduced stay on the mechanical ventilator. Papers that were not published in English were excluded in the review. To ensure a comprehensive search, all papers that were published up to the year 1990 were included in the systematic review. Due to the anatomical and physiological differences noted between adults and neonates or pediatric patients, all studies that focused on pediatrics were excluded. Animal studies were excluded for the same reasons.

The initial search for evidence identified 87 possible papers for inclusion in the systematic review. After eliminating duplications (n=15), and studies (31) that did not appear to answer the systematic review question and not adhering to the inclusion criteria of the review, 41 papers were included in the critical appraisal process.

The methodological quality of papers was assessed using the critical appraisal tools in the JBI SUMARI software packages, Version 4.0. The JBI NOTARI and the MASTARI modules accessed via the CReMS in the SUMARI software package were used to do critically appraise the evidence found, which were independently appraised by two reviewers. The primary reviewer collated the results in order to make the final appraisal. When discrepancies were detected between the appraisal results of the two reviewers, consensus discussions were held to establish the reasons for the discrepancies. After consensus was reached between the two reviewers, the final selection of papers was done for inclusion in the systematic review.

On completion of data extraction, detailed summaries of each paper were composed. The summaries were used to formulate recommendations based on the grades of evidence. Due to the type of evidence found and the heterogeneity of the various studies, no meta-analysis was performed.

The United States Preventive Services Task Force's (USPSTF), grades of recommendations, accessed via the link www.ahcpr.gov/clinic/uspst-fix.htm, have been used to rank recommendations in terms of hierarchy levels of evidence. See Table 1.1.

Table 1.1 GRADES OF RECOMMENDATION	
Grade	Explanation
A	Strongly recommended that clinicians adopt this. Good evidence found to suggest that this intervention improves health outcomes and benefits the patient.
B	Recommended that clinicians adopt this. At least fair evidence found to suggest that the intervention or activity improves health outcomes and benefits the patient.
C	No recommendation for or against adoption. At least fair evidence that the activity or intervention improves health outcomes, but the benefits and harms are too close to justify a general recommendation.
D	Recommend against routinely adopting this activity or intervention. At least fair evidence found that suggest that it is ineffective or that harms outweigh benefits
I	The evidence is insufficient to recommend for or against routinely adopting this. Evidence that is effective is lacking, of poor quality or conflicting and the balance of benefits and harms cannot be determined.

Due to the scope of this research study, the guideline was developed by the researcher and not by a recommended guideline development group. However, an expert review panel (as described earlier) was consulted to comment of the guideline construction and content.

1.5 RECOMMENDATIONS

Cuff management strategies need to include various aspects related to endotracheal tube cuff pressure care. These aspects as summarized from the data appraisal, extraction and synthesis of evidence form the core of this evidence-informed clinical guideline and include the following:

- When should endotracheal tube cuff pressure monitoring be done (Frequency)?
- How should endotracheal tube cuff pressure monitoring be done (Method)?
- What normal ranges are required to maintain endotracheal tube cuff pressures?
- Troubleshooting (Management of cuff leaks).

1.5.1 Frequency of cuff pressure monitoring

“When should endotracheal tube cuff pressure be monitored?”

Based on the papers found, which include Levels III, IV and VII evidence, it is recommended that endotracheal tube cuff pressures be monitored at eight-hour intervals or once per shift, which can be 6 or 12 hourly in the context of the critical care units in the Nelson Mandela Metropole. Failure to monitor endotracheal tube cuff pressures at the recommended intervals can result in tracheal injury or aspiration, thus jeopardising the safety of the intubated, mechanically ventilated patient.

Rationale

According to the evidence found, it was highlighted that incorrect cuff pressures can contribute to the development of tracheal stenosis, tracheal injury, laryngeal injuries, tracheoesophageal fistulas, aspiration and an increased risk for VAP Braz *et al* (1999:243-247); Tadie *et al* (2010, 991-998); Rumbak *et al* (1999, 1092-1095); Duguet *et al* (2007:128-132); Robert *et al* (2007, 237-240); Hung *et al* (2007:676); Hamed *et al* (2008:23); De (2008:195); Mol *et al* (2004:14) Raynham *et al* (2009:645); (Epstein, 2005:544); Yang (1995:625-627); Rello *et al* (1996:111-115) and Diaz *et al* (2005:902).

Based on the data found, it is thus important that cuff pressures be monitored at the best recommended intervals as stated above. Professional nurses should thus not only implement correct cuff management practices but should be aware of the consequences of over- and under-inflation of the endotracheal tube cuff.

An observational study (Level IV) by Vyas, Inweregbu and Pittard (2002:276) shows that 75% of critical care units in their study never checked tracheal tube cuff pressures. Furthermore, the study found that 62% of all tracheal cuffs in the 32 critically ill patients studied were over-inflated. Tracheal damage was evident in patients where cuff pressures were not checked. Although the study findings recommend that cuff pressures should be measured regularly, no time intervals were indicated.

Prolonged duration of intubation results in laryngeal damage and ulceration. In a prospective study by Tu, Saidi and Leiutaud (1999:187), investigating the effects of nitrous oxide on endotracheal tube cuff pressures and the incidence of tracheal lesions in patients receiving anaesthesia in the operating room, it was found that after as little as ten hours of intubation, profound damage, for instance, epithelial disruption, basement membrane loss and the appearance of ischemic non-inflammatory necrosis are possible. Periods of intubation greater than ten days result in deeper ulcers, total disruption of the basement membranes and deep ischemic necrosis. It is thought that endotracheal tube cuff pressures of greater than 20 to 30 cmH₂O contribute to mucosal ischemia. The study findings recommended eight-hour intervals endotracheal tube cuff pressure monitoring because epithelial disruption can occur as little as eight to ten hours.

A literature paper by Epstein (2005:544) states that over-inflation of endotracheal cuff can lead to ischemic airway injury. With prolonged ischemia, mucosal ulceration can occur, leading to formation of granulation tissue. Tracheal stenosis may present while the patient is still undergoing mechanical ventilation. Tracheal stenosis may produce no symptoms until the lumen has been reduced by 50 to 75%. Derived from the findings of these studies, it is recommended that cuff pressures should be monitored at eight-hour interval checks because epithelial disruption can occur in as little as ten hours.

According to the recommendations from three different surveys conducted in the critical care units, it was suggested that the most common frequency for measuring cuff pressure is every eight to 12 hours (Crimlisk, Horn, Wilson and Marino, 1996:225-235; Sole, Byers, Ludy and Ostrow, 2002:363-368; Sole, Byers, Ludy, Zhang, Banta and Brummel, 2003:220-230). Failure to monitor cuff inflation at least once per shift, which can be 6 or 12 hourly may place the patient at increased risk from aspiration and subsequent ventilator-associated pneumonia due to under-inflation or tracheal mucosal damage in the presence of over-inflation (Rose and Redl, 2008(b):363).

Apart from using the correct method to measure and monitor cuff pressures, it is important to have insight into the factors that influence endotracheal tube cuff pressure variations. Change of tracheal muscle tone, hypothermia, hyperthermia, diffusion of anaesthetic gas into the tube, changes in endotracheal tube position and changes in the patient's position are some of the factors contributing to incorrect cuff pressures. Cuff pressure alterations in adult patients and the effect of changes in patient position were investigated in a randomised control trial conducted in 70 patients in an emergency room. The results of the study show that cuff pressures were higher (>22 mmHg) when patients were moved from the 35 degree semi-Fowlers position to the lateral decubitus position. It was recommended that in the routine care of intubated patients, regular endotracheal cuff pressures and adjustments after changes in body position should be encouraged (Gody, Vieira and Capitani, 2008:296).

In a quasi-experimental study done by Brimacombe, Keller, Giampalmo, Sparr and Berry (1999:708-710), using ten adult patients, it was found tracheal mucosal pressures were highest and that the rotated position caused a greater increase in tracheal mucosal pressure than the extended or flexed position. This study highlights the fact that the patient's position does influence cuff pressures. Cuff pressures should thus be checked after position changes.

A case report presented by Robert *et al* (2007:237-240) illustrates that the incidence of trachea-esophageal fistula (TEF) increases if endotracheal tube cuff pressures are not correctly measured and maintained. Recognising that poorly managed endotracheal tube cuff pressure was likely the cause of trachea-esophageal fistula (TEF), the case report emphasises the importance of maintaining endotracheal tube cuff pressure of not greater than 25 mmHg. It suggests that endotracheal tube cuff pressures be monitored and documented every eight hours.

1.5.2 Methods to maintain endotracheal tube cuff pressures

“How should endotracheal tube pressures be monitored?”

Cuff management practices include using the correct method and maintaining cuff pressures at the correct range. Literature describes four different methods to monitor cuff pressures. However, the question remains as to which of these methods is best recommended when monitoring endotracheal tube cuff pressures. According to the various pieces of evidence found, it is recommended that endotracheal tube cuff pressures be monitored by means of the cuff pressure measurement method performed with a manometer.

Rationale

The four techniques described to inflate and maintain endotracheal tube cuff pressures include the minimal leak techniques (MLT), minimal occlusive volume (MOV), cuff pressure measurement (CPM) performed with a manometer during the inspiratory phase and using the palpation method. MLT is a technique where air is slowly injected into the cuff until the leak stops. A small amount of air is released to allow a slight air leak at peak inflation pressure. With the MOV technique, the cuff is slowly inflated until no leak is audible during a positive pressure ventilatory breath. This technique may be more effective than the minimal leak technique in reducing silent aspiration. CPM is performed with a manometer during the inspiratory phase and provides an objective measurement of cuff pressures that does not involve cuff deflation. The fourth technique is the palpation method and this involves the subjective estimation of the cuff inflation based on gentle palpation of the pilot balloon (Rose and Redl, 2008(a):428).

A survey was done on the current practices of cuff management in adult critical care units in Australia and New Zealand. Of the 92 participants, it was reported that 54% (50/92) used a combination of MOV and CPM and a further 5.5% used these methods in combination with palpation of the pilot balloon. A total of 20 units (22%) used CPM as the sole method and 17.5% used MOV exclusively. Only one unit (1%) used MLT after intubation. According to Vyas *et al* (2002, 275-277) and Crimlisk *et al* (1996:225-235) the superiority of CPM over MOV or MLT has not been proven yet. CPM provides an objective measurement of cuff pressure that does not involve cuff deflation, potentially decreasing the risk for aspiration. However readings may be influenced by a patient's body position, head alignment, coughing and lung compliance. Rose and Redl (2008(a):434) conclude by saying that the MOV technique is more resource-intensive than CPM. According to two literature papers (Ganner, 2001:1127-1134; St John, 2004:93-96), MOV and MLT are less likely to be affected by these factors. However, complications have been associated with MOV and MLT, including interruption of positive pressure and an increased risk of hypoxemia, aspiration and hyperinflation on cuff re-inflation. In addition, MLT could cause tracheal wall trauma, drying of tracheal mucosa and may result in hypoventilation due to the loss of tidal volume around the cuff.

In a descriptive survey conducted in a 24-bed, adult, medical-surgical critical care unit in Australia, using 80 nurse practitioners, it was found that MOV increases the risk of aspiration and VAP in the critically ill patient (Rose and Redl, 2008(b):364). In a survey conducted by Ganner (2001:1127-1134) assessing accurate measurements of cuff pressures post cardiac

surgery amongst theatre and critical care unit nursing staff, it was concluded that cuff pressures were too high using the minimal occlusion technique and that the cuffs are prone to leaking when using this technique.

A study to compare endotracheal cuff pressure obtained by estimation techniques with direct cuff pressure measurements by means of a manometer was conducted using 40 anaesthesia providers. Pressures obtained by estimation techniques ranged from 6 to 60 cmH₂O. The authors conclude that estimation techniques for cuff inflation are inadequate and suggest direct measurements by means of using a manometer (Stewart *et al*, 2004:443-447). The findings of the study were supported by Fernandez, Blanch, Mancebo, Bonsoms and Artigas (1995:1328) who compare the accuracy of finger estimation with direct cuff pressure measurements in 20 participants in a critical care unit. Accuracy for the estimated method by finger palpation was 69% for high pressures, 58% for normal pressures and 73% for low pressures. It was concluded that the palpation technique is inadequate for cuff pressure measurement and that direct measurements by means of manometry be used.

The best practice evidence summary supports this in stating that direct measurements using a manometer could prevent over-inflation and under-inflation (Porritt, 2009) In an observational study done by Galinski, Treoux, Garrigue, Lapostolle, Barron and Adnet (2006:545-547), using 107 patients to assess the incidence of excessive cuff pressures, it was found that the majority of cuff pressures exceeded the normal recommended values and that frequent measurements with a manometer should be performed to correct the problem.

In a quasi-experimental study comprising of three groups of anaesthesiologists, it was found that there is a tendency to over-inflate endotracheal tube cuffs amongst all the participants. The study findings suggest that cuff pressures should be done with a manometer routinely in order to avoid excessive or under-inflation of cuffs (Wujtewics, Sawicka, Owczuk, Sommer and Wujtewics, 2009:166). Recommendations from a quasi-experimental study conducted amongst 93 patients in three private hospitals in Kentucky suggest that endotracheal tube pressures be monitored with a manometer (Sengupta, Sessler, Maglinger, Wells, Vogt, Durrani and Wadhwa, 2004:6). In an observational study done in 113 patients in two different critical care units, it was found that the incidence of tracheal tube over-inflation remains high. It was recommended that the use of manometry alone was not sufficient in reducing the incidence of over-inflation, but that a management protocol should be in place guiding practice (Morris, Zoumalan, Roccaforte and Amin, 2007:639).

Sole *et al* (2009: 133-143) conducted a single-group repeated measure design where they used ten critically ill patients who were intubated and mechanically ventilated. The study results show a total of 30% of the pressure measurements were less than 20 cmH₂O, which can expose the patients to a higher risk of aspiration. Another finding is that 16% of the cuff pressures were higher than 30 cmH₂O. It is recommended from this study that continuous monitoring of endotracheal tube cuff pressures should be used rather than intermittent monitoring with a manometer. However, this was a small sample size and findings should thus not be generalised. Only one other observational study was found providing information on continuous recording of cuff pressures. In this study, the cuff pressures were continuously recorded in nine intubated patients. Patients who spent 25% of continuous recording had cuff pressures more than 30 cmH₂O, thus suggesting that continuous cuff pressure monitoring reduces the risk over- and under-inflation (Duguet, D'Amico, Biondi, Prodanovnic, Gonzalez-Bermejo and Similowski, 2007:128).

Another, more recent correlation study by Efrati, Deutsch, Gurman, Noff and Conti (2010:984-990) suggests a new method for estimation of the percentage of endotracheal tube lumen obstruction during controlled mechanical ventilation. The estimation is based on the changes in the cuff pressure during peak inspiratory pressure. The axioms of the method are that the trachea is completely sealed by the endotracheal tube cuff and that the ventilator pressure is higher than the cuff pressure. This method is proved to detect excessive cuff pressures early, but further studies are needed in order to evaluate the method as part of daily clinical practice in intubated patients.

In a quasi-experimental study by Brimacombe, Keller, Giampalmo, Sparr and Berry (1999:708) using ten adult patients, it was found tracheal mucosal pressures were highest and that the rotated position caused a greater increase in tracheal mucosal pressure than the extended or flexed position. This study highlighted the fact that the patient's position does have an influence on cuff pressures.

An observational study that was performed in a ten-bed critical care unit using 101 patients confirmed the findings that patients with cuff pressures less than 20 cmH₂O develop a risk of aspiration, while the incidence for tracheal stenosis was common in patients with cuff pressures more than 30 cmH₂O. In the study, 73% of the patients developed over-inflation, while 45% developed under-inflation when recording of cuff pressures was performed for eight hours. Absence of sedation and duration of intubation were associated with cuff under-inflation (Nseir, Brisson, Marquette, Chaud, Pompeo, Diarra and Durocher, 2009:229).

1.5.3 Normal range for endotracheal tube cuff pressure monitoring

“What are the normal ranges at which endotracheal tube cuff pressures should be maintained?”

After establishing what is the best recommended method for measuring endotracheal tube cuff pressures, one should consider the best recommended normal ranges to maintain cuff pressures. Cuff pressures are monitored on the theory that high cuff pressures result in significant tracheal injury and reducing this pressure could prevent tracheal damage. A cuff pressure greater than 30 cmH₂O for ten to 15 minutes is sufficient to induce histological evidence of mucosal lesions, which is the first step in development of mucosal damage or immediate complications, such as tracheal rupture (Galinski *et al*, 2006:545)

A major advance in the design of endotracheal tube cuffs has been the high-volume, low-pressure cuff, which attempts to reduce the pressure that the cuff exerts on the tracheal wall. Modern cuffs are made of softer material but over-inflation might still result in tracheal injury (Keller, Brimacombe and Boehler, 2002:1074). In order to prevent the complications related to over- and under-inflation, it is of the utmost importance that the cuff pressure be maintained at the best recommended ranges. The acceptable recommended range of cuff pressures reported in literature varies from 25 to 30 cmH₂O or 18 to 22 mmHg.

Rationale

A retrospective study of 756 patients at a long-term critical care facility, who had been ventilated for three weeks by endotracheal tubes was conducted by Rumbak, Walsh, Anderson, Rolfe and Solomon (1999:1092-1095). In this study it was found that 37 (5%) of the patients developed failure to wean secondary to tracheal stenosis or obstruction to granulation tissue, often manifested as higher peak airway pressure or difficulty in passing a suction catheter down the airway. Tracheal stenosis was found to be a common complication related to over inflation of cuff pressures.

A case report presented by Robert *et al* (2007:237-240) illustrated that the incidence of trachea-esophageal fistula (TEF) increases if endotracheal tube cuff pressures are not correctly measured and maintained. In the case reported, a 53-year-old man developed TEF, which were located approximately 2 cm inferior to the vocal cords and 2 cm superior to the tracheostomy site. Over the course of his hospital stay in the critical care unit, multiple occurrences of a cuff leak around the endotracheal tube were noted, subsequently remedied by increasing the endotracheal tube cuff volume. The patient presented with two episodes of

aspiration and a worsening in the respiratory status. On examination, the endotracheal tube cuff pressure was measured at 48 cmH₂O and a CT scan of the chest found that the cuff was inflated to 44 mm in diameter. In this case, it was found that patient presented with severe agitation, excessive head movement and was exposed to a prolonged duration of an over-dilated and over-inflated endotracheal tube cuff. Collectively, the situations led to mucosal ischemia, necrosis and eventually, erosion into the esophagus. Recognising that poorly managed endotracheal tube cuff pressure was likely the cause of trachea-esophageal fistula (TEF), the case report emphasises the importance of maintaining endotracheal tube cuff pressure of not greater than 22 mmHg.

Hameed *et al* (2008: 23) report on another case where a 35-year-old male in a critical care unit on day 15 was diagnosed as having a trachea-esophageal fistula. The cuff pressure was measured and was found to be 40 cmH₂O. Based on the findings of the case report, it was suggested that measures to prevent tracheal stenosis and fistulas should include maintenance of cuff pressures at 25 to 30 cmH₂O.

Hung, Hsu, Huang and Yang (2007:676) report a case of an 86-year-old male who developed a TEF and a trachea-subclavian artery fistula after 12 days of critical admission. On examination, it was found that the endotracheal tube cuff was over-inflated. It was speculated that mucosal necrosis from long-standing high cuff pressures, mucosal trauma from the tip of the tube and excessive tube movements during prolonged ventilation were all the probable causes of the TEF. In addition, excessive cuff pressure, prolonged intubation and the presence of a nasogastric tube increased the risk of TEF. The study findings recommend that endotracheal cuffs should not be inflated more than 22 mmHg in order to reduce the risk of mucosal necrosis.

Another case report referred to a 56-year-old male who developed tracheal stenosis within four days of mechanical ventilated in the critical care unit. The patient presented one month later with increasing difficulty in breathing and an audible wheeze. The tracheal cuff pressures were found to be 40 cmH₂O (De, 2008, 195). Spittle and McCluskey (2000:1000) state that patients with tracheal stenosis remain asymptomatic for a variable period and then develop difficulty in breathing, which can progress to airway obstruction with the development of stridor. Post-intubation tracheal stenosis was misdiagnosed at initial presentation in as many as 44% of the patients in their study. Patients usually remain asymptomatic until the tracheal has stenosed to 30% of its original diameter and may take as long as three months before diagnosis. A conference paper by Make, Hill, Goldberg,

Bach, Criner and Dunne (1998:289S), suggests that cuff pressures greater than 30 cmH₂O compress mucosal capillaries and impair blood flow, with total occlusion occurring at 50 cmH₂O. It is, therefore, recommended that cuff pressures do not exceed 30 cmH₂O.

In a quasi-experimental study by Braz, Navarro, Takata and Nascimento (1999:243-247), it was proven that endotracheal tube cuff pressures in the intubated critically ill patient were routinely high. The study comprised of 86 patients who were intubated with cuffed endotracheal tubes ranging from 7.0 to 9.0 mm in internal diameter. The cuff pressures were measured by means of a manometer. The study results show high cuff pressures (>40 cmH₂O) in 90.6 % of the patients. Recommendations from the study suggest that endotracheal tube cuff pressures be measured and monitored routinely by manometry to minimise trauma to the tracheal mucosa and surrounding structures. Recommendations based on survey done in 32 critical care units by Spittle and Beavis (2001:344-354) suggest that endotracheal tube cuff pressures should be measured at least daily and be maintained 25 to 30 cmH₂O.

In a literature paper by Diaz, Rodriguez and Rello (2005:902), it is recommended that cuff pressures be maintained to balance the risk of mucosal damage and the risk of VAP. In patients on mechanical ventilation, the use of low-pressure cuffs may increase the risk of VAP whereas high-pressure cuffs may increase the risk of tracheal damage. Cuff pressures should be maintained below 30 cmH₂O. In a study by Rello, Sonara, Jubert, Artigas, Rue and Valles (1996:111-115), 83 intubated patients were evaluated. The study results found that there was a higher risk for pneumonia amongst patients with a persistent cuff pressures lower than 25 cmH₂O. They confirm the recommendation that cuff pressures should be maintained at 25 to 30 cmH₂O. A literature review paper confirms this by stating that the pressure of the endotracheal tube cuff should be sufficiently high to avoid the loss of gas from the lower respiratory tract and the leakage of pathogens around the cuff into the lower respiratory tract. To achieve this goal, cuff pressures should not exceed 30 cmH₂O (Lorento, Blot and Rello, 2007:1194).

In a survey by Raynham, Lubbe and Fagan (2009: 645) in the critical care units in the Western Cape in South Africa, it was found that in 135 critically ill patients, 30% of the patients surveyed had excessive and potentially high cuff pressures. In the group with high cuff pressures, 9% had cuff pressure monitors that were not in use. Only 15% had cuff pressures monitored twice daily. A survey done in the Bloemfontein area revealed that 50% of the 112 nurses working in 11 different critical care units did not routinely practice

endotracheal tube cuff pressures while only 50% of the staff felt that they had sufficient knowledge regarding cuff care management. Tracheal stenosis was a common complication related to over-inflated endotracheal tube cuffs (Mol, De Villiers, Claassen and Joubert, 2004:14).

A literature paper by Rello *et al* (1996:111-115) stated that cuff pressures less than 20 cmH₂O (15 mmHg) are associated with an increased risk of aspiration and a 2.5-fold increase in ventilator associated pneumonia. A pilot study using a pneumatic device confirmed that cuff pressures greater than 30 cmH₂O (22 mmHg) may impede capillary blood flow to the area of the tracheal wall in contact with the cuff, resulting in damage of the tracheal wall mucosa. Total obstruction of the tracheal blood flow occurs at pressures greater than 50 cmH₂O. In patients with hypotension, cuff pressures of 34 cmH₂O may exceed the perfusion pressures of the trachea resulting in significant tracheal damage (Duguet *et al*, 2007: 128-132).

Derived from the above studies and evidence found, it can be concluded that tracheal stenosis, TEF, aspiration and increased risk for VAP-related conditions is due to under-inflation and over-inflation of endotracheal tube cuff pressures. Therefore, it is recommended that endotracheal tube cuff pressures should be maintained at 25 to 30 cmH₂O or 18 to 22 mmHg.

1.5.4 Management of cuff leaks

It is recommended that when a cuff leak occurs that the endotracheal tube be inflated until cessation of the audible leak. However, if more than 10 ml of air is injected, the practitioner should investigate and try to correct the cause.

Rationale

Loss of cuff volume and/or pressure is a common occurrence that increases the risk of aspiration of pharyngeal content and VAP. Management of patients presenting with a leaking endotracheal tube should include a thorough physical examination. Cuff leaks are usually detected by sounds generated during lung inflation. When a cuff leak becomes audible, the volume of the leak can be determined by noting the difference between the desired inflation volume and the exhaled volume recorded by the ventilator. The endotracheal cuff should be inflated until cessation of an audible leak. However, the resultant cuff pressure should then be checked. If the cuff pressure is greater than 25 mmHg, the patient may be allowed to continue ventilating with an air leak as long as adequate tidal volumes and appropriate

ventilation are maintained or the endotracheal tube can be changed (Robert *et al*, 2007:239). According to Sengupta *et al* (2004:6) injected volumes of 2 and 4 ml of air usually produce cuff pressures between 20 and 30 cmH₂O independent of tube size. However, when air is injected, it is recommended to measure cuff pressures rather than estimating the volume of air injected. Furthermore, it is recommended that if there is a need to inflate the cuff to more than 10 ml, the practitioner should raise a concern about tracheal injury and investigate the cause of the leak (Hameed *et al*, 2008:23).

The findings of a observational study done by Sridermma, Limtangturakool, Wongsurakait and Thamlikitkul (2007:74-78) concur when their study findings revealed that in 34 intubated adult patients in Siriraj Hospital, the volume of air required to inflate the cuff adequately was 7,1 ml. If more air is required for inflation, the cause should be investigated.

1.6 SUMMARY OF RECOMMENDATIONS

The recommendations formulated can be used to guide professional nurses to provide safe and consistent care, while reducing the complications related to over- and under-inflation of endotracheal tube cuff pressures. Table 1.2 provides a summary of the recommendations.

Table 1.2: BEST PRACTICE RECOMMENDATIONS FOR ENDOTRACHEAL TUBE CUFF PRESSURE MONITORING

- Endotracheal tube cuff pressures should be monitored at eight-hour intervals or at least once per shift (Grade B).
- The patient's position does influence cuff pressure measurements. It is recommended that cuff pressures be re-checked after changes in the patient's position (Grade D).
- Endotracheal tube cuff pressures should be monitored by means of the cuff pressure measurement method performed with a manometer (Grade B).
- In order to prevent the complications related to over- and under-inflation, it is of utmost importance that the cuff pressure be maintained at the best recommended ranges of 25 to 30 cmH₂O or 18 to 22 mmHg (Grade B).
- It is recommended that when a cuff leak occurs that the endotracheal tube be inflated until cessation of the audible leak (Grade D).
- However, if more than 10 ml of air is injected, the practitioner should investigate and try to correct the cause (Grade D).

1.7 EDITORIAL INDEPENDENCE

The responses from the professional nurses completing the structured questionnaires formed the basis for the development of this evidence-informed guideline. The promoter of the study assisted in the conception and the design of the guideline. Although funding was received from the institution where the study was conducted, this guideline is editorially independent of the funding body. No funding was obtained from product manufacturers. No conflict of interest is applicable to the development of this guideline.

1.8 CONCLUSION

A wide variety of evidence was found to assist in the formulation of the recommendations. However, the lack of randomised control trials and systematic reviews was considered when recommendations were made. While there is a paucity of good quality Level I and II evidence regarding endotracheal tube cuff pressure monitoring, the synthesis of the research provided the best available evidence to address the gaps and variances in practices that were found amongst professional nurses in the Nelson Mandela Metropole. None of the studies included cost information; therefore no information regarding cost is included in this guideline.

ANNEXURE Y

ALGORITHM FOR “THE WHEN, HOW AND WHAT” OF ENDOTRACHEAL TUBE CUFF PRESSURE MONITORING

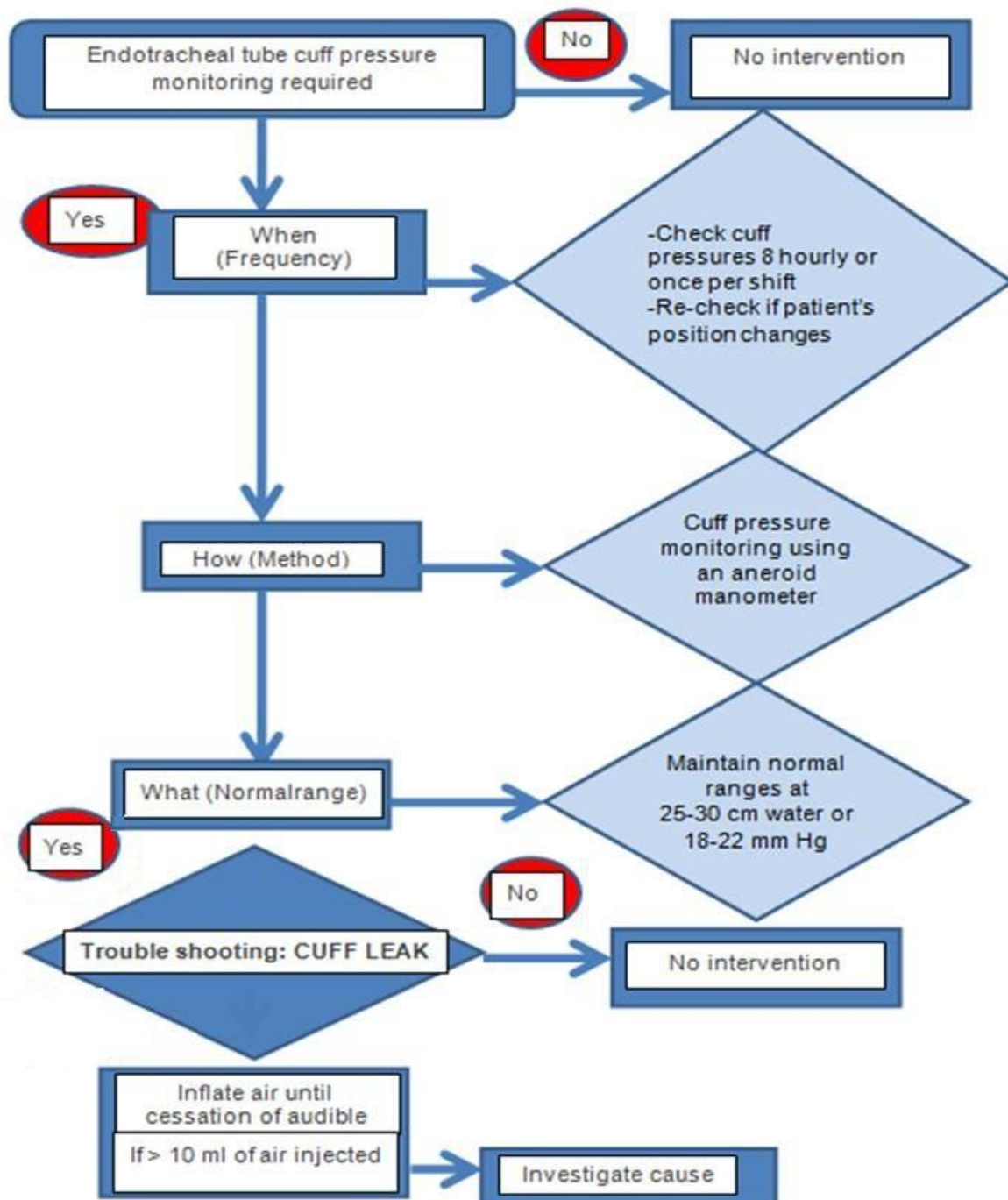


Figure 6.2 Algorithm for endotracheal tube cuff pressure monitoring