REVIEW

Nursing care of the mechanically ventilated patient: What does the evidence say?
Part one

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Summary The care of the mechanically ventilated patient is at the core of a nurse’s clinical practice in the Intensive Care Unit (ICU). Published work relating to the numerous nursing issues of the care of the mechanically ventilated patient in the ICU is growing significantly. Literature focuses on patient assessment and management strategies for patient stressors, pain and sedation. Yet this literature is fragmentary by nature. The purpose of this paper is to provide a single comprehensive examination of the evidence related to the care of the mechanically ventilated patient.

In part one of this two-part paper, the evidence on nursing care of the mechanically ventilated patient is explored with specific focus on patient safety: particularly patient and equipment assessment. Part two of the paper examines the evidence related to the mechanically ventilated patient’s comfort, the patient/family unit, patient position, hygiene, management of stressors, pain management and sedation.

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Introduction

Mechanical ventilation is indicated for numerous clinical and physiological reasons. The nursing management of the mechanically ventilated patient is challenging on many levels: from the acquisition of highly technical skills; expert knowledge on invasive monitoring; and implementation of interventions to care for the patient. Each critically ill patient brings the clinical rationale for mechanical ventilation and additional complexities associated with their illness. It is recognised that the reason for mechanical ventilation and patient admission impacts on patient assessment and management. However, there are core evidence-based collaborative principles which underpin the nursing management of such patients in the intensive care unit (ICU), those being patient safety: patient and equipment assessment; and patient comfort: patient position; hygiene; management of stressors and; pain and sedation management.

To identify the evidence supporting practice a thorough review of current literature was undertaken using the following steps: electronic search conducted of MEDLINE, CINAHL, EMBASE and Psych-Review databases for articles published between 1995 and 2006 and; key words used were mechanical ventilation, patient assessment, airway management, sedation and comfort.

Many confounding variables exist in the care of the critically ill mechanically ventilated patient in the ICU. Consequently not all practice may be supported by evidence. As evidence-based literature addressing the overarching care of the mechanically ventilated patient is scant, for the purpose of this paper common practice is supported by expert or anecdotal comment. This paper presents a summary of the important principles in the management of the mechanically ventilated patient. The focus of this article, the first in a two-part series, is the examination of literature addressing patient assessment and safety.

Patient safety

A useful strategy for promoting the safety of the mechanically ventilated patient is to utilise a health assessment framework. The Emergency Care Cycle is one health assessment framework that facilitates a systematic and comprehensive approach to patient assessment. This framework has two components: the Primary survey (see Table 1) which identifies immediate life-threatening events, and the Secondary survey (see Table 2) which often utilises a head-to-toe systems approach to assess the functional status of each body system (Nettina, 2006). The safety considerations in the care of the mechanically ventilated patient will be discussed utilising this framework (Fig. 1).

Some overall patient safety considerations are worth noting first. Patients receiving mechanical ventilation in ICU require continuous observation and monitoring. For this reason a nurse/patient ratio of 1:1 is recommended (ACCCN, 2005). This ensures that the patient can be closely monitored and that response to any alarms can be rapid (Winters and Munro, 2004). Promoting safety for the ventilated patient also involves ensuring emergency equipment (see Table 3) is available in the event of accidental extubation or ventilator failure (Yeh et al., 2004). Routine safety measures utilised

<table>
<thead>
<tr>
<th>Table 1 Primary survey</th>
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<tr>
<td><strong>Assessment parameters</strong></td>
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| A: Airway | Is the airway patent and secure?  
- Listen to air movement  
- Observe rise and fall of chest  
- Check tube is secure and length is correct |  
| B: Breathing | Is the patient breathing?  
- Observe chest rise and fall  
- Observe patient colour |  
| C: Circulation | Does the patient have adequate circulation?  
- Check for a pulse  
- Assess strength of pulse  
- Observe patient colour |  
| D: Disability | What is the patient’s level of consciousness? |
| E: Exposure | What is the patient’s surrounding environment?  
Is the patient’s dignity preserved? |  
| SpO₂, tidal volume, respiratory rate |  
| Heart rate and rhythm, arterial blood pressure |
Table 2 Secondary survey: systems approach for the ventilated patient

<table>
<thead>
<tr>
<th>System</th>
<th>Assessment parameters</th>
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| Neurological | • Glasgow Coma Score  
                  • Ability to communicate  
                  • Sedation score  
                  • Degree of neuromuscular blockade  
                  • BIS monitoring |
| Respiratory  | **Artificial airway:**  
                  • Tube placement  
                  • Tube security  
                  • Cuff status  
                  **Airway patency:**  
                  • Assessment of lung secretions (suctioning)  
                  • Adequacy of humidification  
                  **Breathing:**  
                  • Respiratory rate, volume and pressure  
                  • ABG analysis  
                  • Pulse oximetry  
                  • Capnometry |
| Cardiovascular | • Heart rate and rhythm  
                  • Blood pressure  
                  • Central venous pressure  
                  • Peripheral perfusion  
                  • Chest X-ray interpretation  
                  • Measurement of cardiac output  
                  • Observe for signs of DVT |
| Gastrointestinal | • Abdominal discomfort/distension  
                  • Presence of bowel sounds  
                  • Amount and characteristics of gastric aspirates  
                  • Frequency of bowel movement  
                  • Physical strength and body weight  
                  • Serum phosphate level  
                  • Liver function tests |
| Metabolic    | • Temperature  
                  • Blood glucose level |
| Renal        | • Urine output  
                  • Serum electrolytes, urea and creatinine levels |
| Skin integrity | • Pressure ulcer risk  
                  • Observe for presence of pressure ulcers |

when caring for any critically ill patient should also be applied. These include checking intravenous infusions; checking patient equipment and alarm settings; ensuring the correct attachment of monitoring devices and appropriateness of alarm settings.

Primary survey

The Primary survey (see Table 1) is concerned with identifying life-threatening circumstances that require immediate attention (Nettina, 2006). The pneumonic A: Airway, B: Breathing, C: Circulation, D: Disability and E: Exposure is utilised. The assessment is essentially unchanged regard-

Table 3 Emergency equipment and safety checks

<table>
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<tr>
<th>Essential equipment required at the bedside</th>
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| • Self-inflating manual resuscitation bag with appropriately sized face mask  
| • High-flow suction unit with Yankeur sucker and endotracheal suction catheters |
| Additional equipment readily accessible to the bedside |
| • Intubation equipment  
| • Oxygen—wall and portable supplies  
| • Battery operated suction unit |
| Safety checks |
| • All equipment is present, readily accessible and in full working order  
| • The ventilator is connected where possible to an uninterrupted power supply  
| • Intravenous infusions are being delivered according to a current order with the correct rate, composition, time of expiry, point of administration, etc.  
| • Patient equipment is functioning properly and safe alarm limits are set  
| • Monitoring devices are connected appropriately and safe alarm limits are set |
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less of whether or not the patient is mechanically ventilated. Particular attention should be given to ensuring the artificial airway is secure to prevent dislodgement, and to checking the insertion length of the airway for correct placement. As a caution, the availability of additional numerical data from the mechanical ventilator and monitoring devices should not substitute for physical assessment of the patient. Used in conjunction with physical assessment, the numerics provide rapid and valuable information, however their validity should be verified by direct patient observation to avoid inaccurate assessment.

Secondary survey

The Secondary survey assesses the function of each body system individually and usually is completed in a head-to-toe format (Hillman and Bishop, 2004). Acute dysfunction in one or more body systems is the precursor to initiation of mechanical ventilation. The addition of artificial respiratory support further impairs physiological function by altering physiological homeostasis (Hillman and Bishop, 2004). Assessing all body systems thoroughly enables early identification of issues and appropriate intervention to minimise or prevent complications. The discussion focuses on the considerations specific to the mechanically ventilated patient.

Neurological system

Neurological assessment of the patient on mechanical ventilation involves a range of methods. The Glasgow Coma Score (GCS) remains a widely used tool for assessing conscious level in terms of arousal and verbal/physical response in many patient populations (Fischer and Mathieson, 2001). Administration of sedative and/or muscle relaxant agents, as well as the inability of the ventilated patient to make a verbal response will impact on the application and accuracy of the GCS. The limitations of using the GCS for intubated patients have been overcome through use of communication scoring systems. These subjective tools assess the patient’s ability to communicate via non-verbal means, including mouthing words, using letter boards, writing notes, etc. (Lindgren and Ames, 2005). It is also important to assess pupil size and reaction as part of a focused neurological assessment (Fischer and Mathieson, 2001). In the sedated patient, early signs of neurological deterioration such as a decrease in level of consciousness are masked leaving late signs, such as pupillary changes, as one of the few indications of a change in the patient’s neurological condition.

Many ventilated patients require some form of sedation to enable them to tolerate this therapy. To reduce the significant risks associated with oversedation (e.g. increased ventilation time and increased length of stay, both ICU and hospital), a number of tools have been developed to determine the patient’s level of sedation (Hogarth and Hall, in press; Heffner, 2000). Some of these tools assess degree of sedation as well as degree of agitation. When sedation orders include a target score on the sedation—agitation scale, this allows the ICU nurse to titrate sedation doses accordingly (Ely et al., 2003). This will be expanded further in part two of this paper.

Neuromuscular blockade is occasionally required for ventilated patients in order to allow greater ease of ventilation. When this therapy is used, it is important to ensure that the blockade remains partial rather than complete as this is associated with an increased risk of critical illness neuropathy (De Jonghe et al., 2004). The level of paralysis can be easily assessed using a peripheral nerve stimulator, with administration of paralytic agents titrated to achieve the required level. Bispectral Index Score (BIS) monitoring, which analyses electroencephalography (EEG) waveforms and statistically estimates level of sedation, is becoming more popular for monitoring sedation in the paralysed patient (Riker and Fraser, 2001). While used commonly during administration of anaesthetics, a systematic review (LeBlanc et al., 2006) showed that its application in the ICU setting requires further investigation.

Assessment of the patient’s conscious state and communication assists in determining the best approach to use in this area, as will be discussed further in part two of this paper.

Respiratory system

Effective respiratory assessment is pivotal to ensuring the safety of the mechanically ventilated patient. A helpful way to gather the data is to divide the assessment into three main areas — the artificial airway, airway patency and breathing.

Artificial airway

All mechanically ventilated patients have an artificial airway in situ to enable delivery of the respiratory support. Regardless of whether this is an endotracheal tube or a tracheostomy tube, the aspects of tube placement, tube security and cuff status must be addressed.
Incorrect tube placement places the patient at significant risk. Absent or ineffective ventilation, aspiration and injury to the airway can result from oesophageal intubation or from placement that is too high or low in the trachea (Winters and Munro, 2004). Tube placement at the time of insertion may be assessed in various ways depending on the available equipment. Subsequent displacement of the tube however may result from head flexion, tension during transport (DeBoer et al., 2003) and swelling of surrounding tissues, thus ongoing assessment promotes patient safety.

Frequently used strategies to verify placement include auscultation, end-tidal carbon dioxide monitoring and radiological examination (DeBoer et al., 2003). Auscultation of breath sounds across the lung fields is a commonly used technique. Stethoscopes are readily accessible however referred sounds may be transmitted even with incorrect tube placement (DeBoer et al., 2003; Grmec, 2002). End-tidal carbon dioxide monitoring using capnometry and capnography was determined to be a reliable method for assessing tube placement in two small studies, although influenced by the clinical setting, availability of equipment and experience of the user (Knapp et al., 1999; Grmec, 2002). The numerical and waveform displays provide continuous data on expired carbon dioxide levels, changes to which may indicate tube dislodgement or obstruction. A concern however is that subtle changes to tube position such as movement into the larynx may not be readily detected (Knapp et al., 1999). Chest radiograph is often considered as the standard for assessing tube placement however this technique also has limitations. Of note is that the assessment is at a single point in time and thus does not provide regular or continuous data, delays between the time of imaging to viewing the film can be lengthy, and anatomy or image quality can make assessment of placement difficult (DeBoer et al., 2003). All endotracheal tubes and some tracheostomy tubes have distance markings along the length of the tube. These assist in assessing placement if measured consistently in relation to a fixed structure (for example, the teeth or gums). Given the lack of evidence supporting one method as superior and the limitations of any of the methods outlined above, it would seem prudent to utilise two or more techniques, one of which is able to be measured regularly or continuously, to assess tube placement in the mechanically ventilated patient.

Tube security supports maintenance of correct tube placement and minimises injury to the airway caused by excessive movement. Techniques to secure artificial airways ideally will hold the tube firmly in position independent of head and neck movement, be easily applied and removed to enable adjustment to tube position and attention to hygiene and will minimise trauma to adjacent tissues. Available options include cotton tape, specifically designed tube holders and non-stretch adhesive tapes. Although a number of studies comparing methods of securing endotracheal tubes exist, a systematic review by Gardner et al. (2005) indicates that no conclusions regarding the benefits of one method over another have been determined. Assessment includes ensuring the method used is properly applied and that the tube is secured in the desired position.

The presence of an artificial airway places the patient at risk of developing complications associated with the tube itself. Regular assessment of the cuff enables effective management to minimise the risk of aspiration from underinflation and tracheal mucosal injury from overinflation (Vyas et al., 2002). Evidence to support a single management technique as superior is limited. Crimlisk et al. (1996) performed a descriptive study which indicated two primary techniques which were utilised in the clinical setting: measuring cuff pressures to ensure they remain at 25 mmHg or below; inflating the cuff with the minimum volume of air required to ensure air leak on inspiration (minimal occlusive volume); and inflating the cuff with the minimum volume of air to allow a small leak on inspiration (minimal leak technique). Consideration of inflation pressures, patient head movement and tube diameter to airway diameter ratios should also be considered if the desired seal is not achieved (Vyas et al., 2002).

**Airway patency**

Assessment of airway patency encompasses the assessment of lung secretions and strategies to manage these. The normal respiratory function of the mechanically ventilated patient is compromised placing them at risk of complications. Artificial airways bypass the humidification and filtering mechanisms of the upper airways (St John and Malen, 2004), medical gas is cold and dry and disease processes and therapies can impair the cough reflex (Jaber et al., 2004). Lung secretions should be assessed for colour, consistency and volume (Winters and Munro, 2004). Endotracheal suctioning provides opportunity to assess the secretions but also to support the patient by removing secretions. Endotracheal suctioning in itself however is potentially hazardous to the patient and should be performed with care.

A review by Day et al. (2002) indicates that the frequency of suctioning should be determined by the patient’s need, rather than performed
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In the care of the mechanically ventilated patient, observation of airway pressures and trends in pulse oximetry and end-tidal carbon dioxide readings are also important (Winters and Munro, 2004). Suctioning only when needed limits exposure to potential complications.

Hypoxaemia is the most common complication noted with suctioning (Demir and Dramali, 2005). Techniques for supplementing oxygenation during the suctioning procedure include hyperoxygenation alone or in combination with hyperinflation. A review by Day et al. (2002) and a meta-analysis by Oh and Seo (2003) indicate that both techniques are effective in preventing hypoxaemia, however both are capable of causing respiratory damage or haemodynamic instability. Perhaps due to variability in application of the interventions, the literature is inconclusive regarding the ideal method of preventing hypoxaemia (Wynne et al., 2004; Day et al., 2002; Oh and Seo, 2003). A randomised controlled trial conducted in 2002 by Demir and Dramali (2005) found that patients suctioned using a closed technique without hyperoxygenation did not demonstrate a significant difference in partial pressure of oxygen or oxygen saturation. The majority of subjects however had an FiO2 of less 50% or less, a positive end expiratory pressure (PEEP) of 8 cm H2O or less and a mean pre-suction PaO2 of 95.49 mmHg, suggesting they may not have been at high risk of developing hypoxaemia. Consideration of the patient’s status prior to suctioning including: PEEP; FiO2; PaO2; heart rate (HR); mean arterial pressure (MAP); and observation of the patient’s response to suctioning, provide useful data to guide suctioning practices which promote patient safety by minimising the adverse effects caused by hypoxaemia.

Instillation of normal saline via the endotracheal tube prior to suctioning is a common practice in some intensive care units. The theory behind this practice is that the saline loosens and thins secretions and stimulates the cough reflex thus facilitating removal of secretions (Blackwood, 1999). While the theory may seem plausible, two reviews of the literature do not support the technique and suggests that it may actually be harmful to the patient (Blackwood, 1999; Day et al., 2002).

Complications are also associated with the suctioning procedure itself for which general recommendations based on limited studies and accepted practice have been made. The size of catheter used should be less than one-half the diameter of the artificial airway to minimise the risk of atelectasis (Day et al., 2002). The suction catheter should be inserted to the depth of the carina and then withdrawn by 1 cm prior to commencing suctioning (Day et al., 2002). Care should be taken however as persistent contact with the carina can result in ulceration and induce haemodynamic changes associated with coughing and vagal stimulation. Limiting the duration of the suctioning procedure to less than 10–15 s reduces the risk of hypoxaemia and atelectasis (Day et al., 2002; Subirana et al., 2003). Restricting the number of passes in a suction episode to three or less also assists in minimising complications. A further consideration is the degree of negative pressure applied during the procedure. Evidence is lacking to suggest an exact maximum pressure to be applied, however pressures of 200 mmHg or greater have been associated with tracheal damage (Day et al., 2002; Donald et al., 2000). Recommendations for acceptable suction pressures given in the literature range from 80 to 170 mmHg (Day et al., 2002; Donald et al., 2000).

Of importance also is the use of open versus closed suction systems. The latter are reported to have the advantages of minimising hypoxaemia, maintaining PEEP and reducing contamination (Subirana et al., 2003). Two prospective randomised controlled trials found that a closed system presented no additional complications for the patient although it may not decrease complications associated with suctioning (Zeitoun et al., 2003; Lorente et al., 2005). In particular, a literature review by Grap and Munro (2004) indicates that closed suction systems offer no advantage in the prevention of ventilator associated pneumonia (VAP). However, the closed nature of the systems and ability to leave the system in situ greater than 24 h, reduces breaks to the ventilation circuit and thus the possibility of contamination from the environment (Kollef, 1999).

A further consideration when assessing the physical airway is evaluating the adequacy and function of humidification devices. Inadequate humidification can lead to partial or complete airway obstruction and damage to respiratory tissue (Jaber et al., 2004). Two humidification systems are available: heated humidifiers (HH); and heat and moisture exchangers (HME). In a discussion of the literature by Kelly et al. (2004), it is suggested that both systems are effective; however both also have potential adverse effects including bacterial contamination and over-hydration (HH), or thick sputum and increased work of breathing (HME). The humidification system used should take into consideration factors such as the anticipated duration of mechanical ventilation, the degree of spontaneous effort by the patient and the amount and...
consistency of sputum. Whichever system is in use, assessment of the patient is essential (Kelly et al., 2004). Excessively thick or thin secretions, crusting in the artificial airway, water in the circuit or changes in airway pressures may suggest inappropriate humidification. A holistic approach involving adequate systemic hydration is also important.

**Breathing**

A comprehensive understanding of the adequacy of ventilation and oxygenation in the mechanically ventilated patient is essential as some if not all of the respiratory effort is coordinated by the ventilator. Necessary information is gathered from performing a physical assessment and from analysis of laboratory and patient monitoring data.

Physical assessment provides invaluable information concerning the patient’s interaction with the ventilator. The presence of dyspnoea, dysynchronous chest and abdominal movement, the use of accessory muscles and agitation may suggest the ventilation settings are inappropriate for the patient’s requirements (Hillman and Bishop, 2004). Physical assessment of the patient may also alert the clinician to subtle changes in the patient’s respiratory status which otherwise may have gone unnoticed. Altered breath sounds and asymmetrical chest movement, for example, may indicate the development of a pneumothorax when other signs such as dyspnoea and rapid, shallow breathing are masked by sedation and full mandatory ventilation.

Monitoring data from the ventilator also aids in understanding the patient’s respiratory status and the appropriateness of the ventilator settings. Respiratory rate, tidal volume, minute volume and airway pressures as absolute values reflect the current delivery of ventilatory support. When analysed as trends over time, such data can provide information about the status of lung function and the patient’s respiratory effort (Jubran and Tobin, 1996).

Monitoring of gas exchange is a routine aspect of caring for a mechanically ventilated patient. Arterial blood gas (ABG) analysis is the gold standard for determining arterial carbon dioxide and oxygen levels. The complications and costs associated with repeated ABG analysis however support the use of non-invasive monitoring techniques. Pulse oximetry and capnometry are relatively simple and effective tools for monitoring gas exchange. A meta-analysis indicated that pulse oximeters are accurate to ±2% for oxygen saturations greater than 70% (Jensen et al., 1998). Capnometers provide a numerical reading of end-tidal carbon dioxide levels. Reviews by Capovilla et al. (2000) and Frakes (2001) suggest that in the context of stable ventilation/perfusion dynamics and cardiac output, capnometry trends provide an excellent indication of arterial carbon dioxide levels. Even in less stable states, the variation between the end-tidal and arterial carbon dioxide levels provides information on dead space and perfusion changes (Soubani, 2001; Frakes, 2001). As with any technology however, a sound understanding of how the data are obtained and the factors that influence the measurements is essential to avoid inappropriate interpretation (Martin and Wilson, 2002). Regardless, if used appropriately, non-invasive monitoring devices provide a continuous and safe method for assessing gas exchange.

**Cardiovascular system**

The patient receiving mechanical ventilation may experience a marked alteration in cardiovascular function. The increase in intrathoracic pressure that occurs results in a reduction in preload as venous return decreases. This is exacerbated in patients who have high PEEP settings or who are on inverse ratio ventilation. The extent of impairment depends on the baseline cardiovascular state of the patient (Pinsky, 2005). It is important that the ICU nurse undertakes comprehensive cardiovascular assessment of the patient to determine adequacy of cardiac output and to observe for complications associated with poor cardiac output. This involves assessment of heart rate and rhythm, blood pressure, central venous pressure, peripheral perfusion, urine output and chest X-ray, as well as serum electrolytes (McGrath and Cox, 1998). Regular assessment of haemoglobin is also important in this group due to the significant impact that anaemia can have on the patient’s oxygen-carrying capacity. Measures to conserve blood should be considered to prevent and/or treat anaemia (Fowler and Berensen, 2003). Patients receiving mechanical ventilation should have continuous multi-lead electrocardiography monitoring to enable timely assessment and treatment of cardiac arrhythmias or myocardial ischaemia (Robb, 1997).

A relatively new technique called **Pulse Pressure Variation** assesses the variation in pulse pressure (via an arterial catheter or plethysmograph) with respiration, which provides an estimate of fluid status — the higher the variation, the ‘drier’ the patient is. This method is yet to be substantially validated, but a prospective clinical investigation (Cannesson et al., 2005) shows that it could provide a simple, accurate measurement of fluid status using existing monitoring equipment.

It is well recognised that accurate determination of cardiac output in the most critically ill patients using these basic assessment parameters
is difficult. Techniques that endeavour to provide an accurate measurement of cardiac output are numerous (Adams, 2004). The so-called ‘gold-standard’ is the bolus thermodilution method using a pulmonary artery catheter (Zink et al., 2004). Other techniques have sought to provide the same accuracy in measurement while providing continuous data and/or reducing invasiveness and cost. These include continuous thermodilution method, transthoracic/transoesophageal echocardiography, pulse contour analysis, and oesophageal Doppler (Adams, 2004).

The reduction in preload experienced by ventilated patients can be best managed by maintaining an adequate fluid volume status. It is reported that maintaining adequate filling pressures (e.g. CVP of 10–12 mmHg) optimises preload and therefore reduces the risk of a reduction in cardiac output (Pinsky, 2005).

The risk of developing deep vein thrombosis (DVT) is greatly increased in the ventilated patient as a result of venous stasis related chiefly to immobility, but also to the decrease in venous return described above (Pinsky, 2005). It is important to assess the patient for signs of DVT and to initiate preventative measures early (Yang, 2005). Current practice in DVT prophylaxis involves use of thrombo-embolic deterrent (TED) stockings, sequential compression devices, passive movement exercises and administration of either unfractionated heparin or low-molecular weight heparin. A review paper (Yang, 2005) indicates that of these therapies the mechanical options are not associated with a decreased risk when used alone, so the combination of mechanical and pharmacological is recommended.

### Gastrointestinal system

Nutritional status is a vital part of assessment and care for the mechanically ventilated patient. The capacity for oral intake is limited in this situation due to the presence of the ETT and the patient’s level of sedation, though it is possible for patients ventilated via tracheostomy. In most critically ill patients requiring ventilation, early enteral feeding via an oro/nasogastric tube is a well-established practice (Lindgren and Ames, 2005). Use of an established feeding protocol, where feed absorption is closely monitored, feeding rate increased gradually and prokinetic agents given as required has been shown to provide the best outcomes, when implemented in a pilot study (Bowman et al., 2005). Accurate assessment of caloric requirements in the critically ill patient remains a topic of some debate. According to a multi-centre study (Krishnan et al., 2003), best outcomes were found in patients receiving moderate rather than high caloric intake, around 9–18 kcal/kg/day.

It is important to note that effective functioning of the gastrointestinal tract (GIT) can be impaired during mechanical ventilation as a result of a reduction in splanchnic blood flow secondary to decreased cardiac output (Aneman et al., 1999). The reduction in GIT motility caused by use of sedative and narcotic agents further impairs functioning. Mechanically ventilated patients need to be regularly assessed for abdominal discomfort and/or distension, presence of bowel sounds, amount and characteristics of gastric aspirates and frequency of bowel movement (Bowman et al., 2005).

Adequacy of nutrition is particularly important in the weaning phase of mechanical ventilation, where patients are required to breathe with less support from the ventilator (Lindgren and Ames, 2005). Assessment of the patient’s muscle mass or degree of muscle wasting, physical strength and body weight will provide an indication of the need for increased nutritional support (Sabol, 2004; Flancbaum et al., 1999). Assessment of serum electrolytes, particularly phosphate which is important in energy production, and supplementation if required is also important to promote muscle functioning (McClave et al., 2002).

Hepatic blood flow via the portal vein may also be compromised as a result of decreased cardiac output associated with mechanical ventilation (Aneman et al., 1999). It is important to regularly measure liver function tests as well as clotting times to observe for any hepatic impairment (Winters and Munro, 2004).

### Metabolic system

Assessment of temperature is a basic yet important parameter to monitor as an elevated temperature can signal the patient’s response to infection (Winters and Munro, 2004). Ventilated patients have a significant risk of developing nosocomial infections as a result of suppressed immune function and the presence of artificial tubes (e.g. ETT, urinary catheter, central venous catheters) (Lindgren and Ames, 2005). Other methods that are commonly used to detect response to infection are measurement of white blood cell count, C-reactive protein (CRP), IL-6 and procalcitonin (PCT) levels. A prospective study (Gaini et al., 2006) has recently shown that CRP and IL-6 are more sensitive markers of infection than PCT, while PCT is a better indicator of severity. Some ICUs also utilise routine surveillance of high risk patients (e.g. patients ventilated for 48 h or more) to assist in the early detection of
infection and identification of potential infection control problems (Tablan et al., 2003).

Coupled with the assessment and early detection of infective processes are measures to minimize the risk of ventilated patients developing nosocomial infections. The Centre for Disease Control and Prevention and a group representing the Canadian Critical Care Trials Group and the Canadian Critical Care Society have published guidelines outlining best practice for the prevention of ventilator-associated pneumonia. The guidelines suggest a multi-faceted approach to prevention which includes oral versus nasal intubation, limited interruptions to ventilator circuitry, elevation of the head of the bed, strategies for the management of respiratory equipment, minimising the duration of mechanical ventilation, and effective hand hygiene (Tablan et al., 2003; Dodek et al., 2004). Such strategies along with strict application of Standard Precautions should constitute standard practice for the nursing management of the mechanically ventilated patient to prevent the development of nosocomial infections.

Blood glucose monitoring and control is not a new concept, but one which has certainly been the focus of much research in the critically ill patient population recently. Evidence from a randomised-controlled trial (van den Berghe et al., 2006) suggests that maintenance of blood glucose within tight limits (4.4—6.1 mmol/L) is associated with a reduction in mortality. This is of particular significance in patients who are ventilated as they frequently have an elevated blood glucose level as a result of initiation of the body’s stress response that occurs in critical illness (Winters and Munro, 2004). The ‘Surviving Sepsis Guidelines’ recommend that patients with severe sepsis have a blood glucose level maintained less than 8.3 mmol/L (Dellinger et al., 2004).

Renal system

The reduction in cardiac output associated with positive pressure ventilation may result in reduced urine output through neural and hormonal mechanisms (i.e. antidiuretic hormone secretion and activation of the rennin—angiotensin—aldosterone system) (Pinsky, 2005). It is important to closely monitor the urine output of a ventilated patient as well as serum levels of urea and creatinine to detect any renal impairment. Ensuring urine output is greater than or equal to 0.5 mL/kg/h is one way of assessing adequate renal function, according to a recent evidence-based review (Rhodes and Bennet, 2004). It is also important to maintain adequate cardiac output, mean arterial pressure and renal perfusion pressure to prevent acute renal failure (Leblanc et al., 2005).

Skin integrity and mobility

Ventilated patients are at increased risk of impairment in skin integrity chiefly through immobility associated with sedation and ventilation (Lindgren and Ames, 2005). Effective pressure ulcer prevention is essential in reducing the patient’s length of ventilation and hospital stay (Wolverton et al., 2005). Although the Braden and Norton scales have been tested for validity and reliability in a prospective multi-centre study (Schoonhoven et al., 2002), assessment of pressure ulcer risk using the Waterlow scoring system best describes the risk for critically ill patients. It includes administration of inotropic agents, cytotoxics and high-dose steroids in its risk assessment, and also has strategies for pressure relief/reduction depending on the level of risk (Boyle and Green, 2001).

Semi-recumbent positioning rather than supine positioning has been recommended as a measure to reduce the risk of ventilator associated pneumonia, according to a randomised trial (Drakulovic et al., 1999). Mobility can be enhanced in the longer-term ventilated patient through sitting him/her in a chair for periods of time through the day. This improves lung expansion and can reduce the risk of ventilator associated pneumonia (Safdar et al., 2005).

Summary

The mechanically ventilated patient presents many challenges for the intensive care nurse. Nursing care and management of the critically ill mechanically ventilated patient is demanding and necessitates an expert understanding of technological issues underpinned with a patient focused approach. From the discussion above it is clear that while mechanical ventilation is a necessary therapeutic intervention for many patients, it brings with it an array of potential or actual complications which present further challenges for the critically ill patient. Nursing care based on evidence is pivotal to ensuring quality health outcomes for the mechanically ventilated patient.

To support the use of evidence in the practice, the concept of a ‘Ventilator Care Bundle’ had been utilised in the United States and the United Kingdom. The bundle includes four interventions which have sound evidence to support their effectiveness in improving outcomes for the mechanically ventilated patient: elevation of the head of the bed; management of sedation including daily ‘sedation
Nursing care of the mechanically ventilated patient


INSTITUTE FOR HEALTHCARE IMPROVEMENT. Implement the ventilator bundle. http://www.ihi.org/IHI/Topics/CriticalCare/
IntensiveCare/Changes/ImplementtheVentilatorCareBundle.htm; [retrieved 3rd July 2006].


