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Apneic Oxygenation: An Adjunctive Therapy for Laryngoscopy during Anesthesia Induction

Yaro Hoffman

APNEIC OXYGENATION: AN ADJUNCTIVE THERAPY FOR LARYNGOSCOPY DURING ANESTHESIA INDUCTION

by

Yaro N. Hoffman, Sr.

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Approved by:

Dr. Michong Rayborn, Committee Chair
Dr. Stephanie Parks, Committee Member

Dr. Michong Rayborn Committee Chair	Dr. Lachel Story Director of School	Dr. Karen S. Coats Dean of the Graduate School

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ABSTRACT

Endotracheal intubation is an essential component within the skill set of anesthesia providers. Rapid arterial desaturation remains a primary risk factor during laryngoscopy and intubation. The risk for hypoxemia exists because during endotracheal intubation, patients are apneic or hypo-ventilating (Wong et al., 2017). Apneic oxygenation (AO) has been advocated to attenuate hypoxemia during endotracheal intubation (Pavlov et al., 2017).

The aim of this project was to assess for any knowledge deficits regarding AO among anesthesia providers and assess the willingness of these providers to include AO into their current practice. The project investigator conducted an education session involving the evidence-based literature findings of AO and its implementation during endotracheal intubation. A pre and post-teaching tool survey was administered to each participant to assess for any knowledge expansion regarding AO. Both the pre and post-teaching tool surveys were scored and given a quantitative value. These values were then computed into a mean, standard deviation, and variance. An "expansion of knowledge" regarding AO in this project was defined as a statistically significant improvement in the mean scores between both the pre and post-teaching tool surveys. A paired t-test was performed to determine the presence of any statistical significance. Statistical significance was considered using a p-value of 0.05.

A total of 12 anesthesia providers participated and were evaluated in this project. The mean, standard deviation, and variance for the pre-teaching tool surveys were: 81.6, 19.1, and 363.9, respectively. The mean, standard deviation, and variance for the post-teaching tool surveys were: 93.3, 16.9, and 288.9, respectively. The post-teaching tool

survey mean score reflected expansion of AO knowledge when compared to the pre-teaching tool mean survey score (standard error of the mean [SEM]: 5.751; test statistic: 2.028; critical value: 1.795; p-value: 0.05). Fifty-eight percent of participants expressed a willingness to incorporate AO into their current practice.

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I would like to express sincere thanks to my committee chair, Dr. Michong Rayborn, for her support, assistance, and motivation throughout this project. I would also like to extend my appreciation to my committee member, Dr. Stephanie Parks, for her belief and support in this idea. Finally, my sincere thanks are extended to every anesthesia provider who elected to participated in this project, without whom, I could not have conducted this project.

DEDICATION

I would like to dedicate this project to my wife, Charmaine Hoffman, the best partner in life I could ever have been blessed with. To my sons, Yaro Nykee Hoffman, II, Chairo Alexander Hoffman, and Pharo Maxim Hoffman. There simply is no me without them. To my mother, Paulette for her love and ever encouraging spirit. To my siblings for their support and validation. To my father and brother, Cyril and Ashanti, may they continue to resonate and live through me. Finally, to all of my extended family and friends, for their support and encouragement, I dedicate this project to you all and say thank you from the depths of my heart.

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LIST OF ABBREVIATIONS

AACN	American Association of Colleges of Nursing
AANA	American Association of Nurse Anesthetists
AO	Apneic Oxygenation
ASA	American Society of Anesthesiologists
AVMF	Aventilatory Mass Flow
CO_2	Carbon Dioxide
DNP	Doctor of Nursing Practice
FAO_2	Alveolar Fraction of Oxygen
FiO_2	Fraction of Inspired Oxygen
FRC	Functional Residual Capacity
ICU	Intensive Care Unit
L/min	Liters Per Minute
mL	Milliliters
mL/min	Milliliters Per Minute
SpO_2	Peripheral Oxygen Saturation
V/Q	Ventilation-Perfusion
PaO_2	Partial Pressures of Arterial Oxygen
USM	The University of Southern Mississippi

CHAPTER I – INTRODUCTION AND BACKGROUND

Problem Statement

Arterial desaturation continues to be a risk for airway failure and adverse events during laryngoscopy and intubation. Failed, difficult, or delayed intubation is directly associated with hypoxia (Smischney et al., 2017). During laryngoscopy, hypoxemia can reach a critical point and lead to life-threatening complications such as dysrhythmias, hypoxic brain injury, seizures, surgical airway, or cardiac arrest (Weingart & Levitan, 2012). Critical hypoxemia, as defined by an arterial oxygen saturation less than 70% during airway instrumentation, is highly associated with cardiac arrest (Mort, 2004). Injuries resulting from these complications can often be irreversible. Such deleterious events pose a risk during every intubation because there is no single and consistent predictor for a difficult airway (Pratt & Miller, 2016). These adverse events can increase morbidity and mortality for patients while at the same time increasing hospital costs, intensive care unit (ICU) services, and hospital length of stay.

To attenuate rapid arterial desaturation during laryngoscopy, the technique of AO has been proposed and implemented by various anesthesia and critical care providers. Apnea can be defined as the cessation of diaphragmatic breathing during anesthesia induction (Gleason et al., 2018). The physiology of AO is centered around the alveoli and its capacity to continuously capture oxygen passively without pulmonary ventilation (Oliveira et al., 2017). Apnea can be described in terms of a “safe apneic” period. This safe apneic period is the limited time clinicians are afforded to establish a secure airway during laryngoscopy (Gleason et al., 2018). This period of time varies depending on the patient. Providing evidence of how AO can minimize arterial desaturation during laryngoscopy is the intent of this project.

Available Knowledge

An online comprehensive search was conducted to identify articles from the following databases: PubMed, The Cochrane Library, MEDLINE, CINAHL, The National Center for Biotechnology Information, Google Scholar, and Web of Sciences. The search was limited to articles published from 2010-2019, with the exception of classical articles containing foundational information. The following keywords were searched: *apneic oxygenation, hypoxemia, pre-oxygenation, apnea, laryngoscopy, nasopharyngeal insufflation, aventilatory mass flow,* and *high flow nasal cannula.* Study designs such as randomized controlled trials, case-control studies, observational studies, systematic reviews and meta-analyses that were published in English were evaluated to collect the current state of knowledge on AO and its efficacy in the peri-operative environment. Evidence sources were also thoroughly examined for scientific consistency. Abstracts were reviewed to identify articles that evaluated the use of AO. The websites of professional organizations such as the American Association of Nurse Anesthetists (AANA), American Society of Anesthesiologists (ASA), and Difficult Airway Society were also examined.

Apneic Oxygenation

The phenomenon of AO is not a contemporary subject but rather has been described as early as 1908 by Volhard (Patel & Nouraei, 2015). Throughout the years and after various investigations, this phenomenon has taken on many descriptors such as ‘diffusion respiration’ by Draper and Whitehead (Draper et al., 1947). AO was described by Bartlett, Brubach, and Specht (1959) as ‘aventilatory mass flow’ (AVMF) and finally as ‘apneic oxygenation’ by Nahas (Frumin et al., 1959). Each of these terms describes the continuous administration of oxygen during the apneic period after the cessation of diaphragmatic movement. The alveoli can continuously capture oxygen in the absence of ventilatory efforts as long as cardiac output remains sufficient, oropharyngeal patency is maintained, hemoglobin is in the normal reduced state, alveolar nitrogen is replaced with oxygen, and a continuous insufflation of oxygen is provided (Draper et al., 1947). However, the physiologic basis that drives this mechanism was not always agreed upon. Draper et al. (1947) described the functioning of the ‘hemoglobin-oxygen’ pump and proposed it was the driving force and mechanism through which oxygen was able to passively diffuse through the pharynx and into the alveoli. Alveolar oxygen, according to Draper et al. (1947), attached to reduced hemoglobin and this subsequently lowered the tension of oxygen and barometric pressure within alveolar spaces (Draper et al., 1947). This mechanism consequently provided an inward suction on the atmosphere at the glottis and is maintained by circulation during respiratory arrest (Draper et al., 1947).

Frumin et al. (1959) adopted the term ‘apneic oxygenation’ to eliminate any misconception that the process of molecular diffusion in the conducting air passages brought oxygen to the alveoli from the environment. The research of Frumin et al. (1959) revealed that carbon dioxide (CO_2) production may equal the oxygen consumption during AO; however, CO_2 was not readily returning to the alveoli nearly as fast as oxygen was leaving. Oxygen extraction from the alveoli is approximately 250 milliliters per minute (ml/min) while CO_2 return is 8-20 ml/min under apneic conditions (Wong et al., 2017). Under normal breathing conditions, the CO_2 return to the alveoli is approximately 250 ml/min (Wong et al., 2017). The distribution between these two gases during apnea leads to sub-atmospheric conditions within the alveoli that ultimately allow for the production of a pressure gradient which insufflates and entrains oxygen from the pharynx to the alveoli (Gleason et al., 2018). Holmdahl estimated that under apneic conditions, 90% of the metabolically produced CO_2 remains in the blood while only 10% enters the alveoli (Frumin et al., 1959). This early indication of serum CO_2 accumulation during AO provided a fundamental physiological distinction between tissue oxygenation and respiratory ventilation.

Pre-Oxygenation History

Pre-oxygenation is performed to oxygenate the functional residual capacity (FRC) within the lungs before laryngoscopy in an attempt to prolong the safe apneic period (Butterworth et al., 2013). This allows the maximum amount of time for instrumentation of the airway without the incidence of hypoxemia. During apnea, tissue oxygenation is maintained at the expense of the body's oxygen reserves, which are very low in quantity and are mainly situated in lungs, plasma, and hemoglobin (Bouroche & Bourgain, 2015).

In 1948, research demonstrated that inhalation of a fraction of inspired oxygen (FiO_2) of 100% resulted in the rapid increase of arterial oxyhemoglobin saturation to between 98% and 99% (Colldahl, 1961). In 1955, Hamilton and Eastwood (1955) showed that "denitrogenation" of the FRC was 95% complete within 2 to 3 minutes in subjects breathing normally from a circle anesthesia system with 5 liters per minute (L/min) of oxygen (Hamilton & Eastwood, 1955). Dillon and Darsi (1955) observed desaturation during apnea after anesthetic induction and recommended that the induction of anesthesia and endoscopy be preceded by oxygen administration for 5 minutes

(Benumof & Hagberg, 2007). Heller and Watson (1964) found that 3 to 4 minutes of oxygen breathing was necessary for patients before anesthetic induction (Benumof & Hagberg, 2007). In 1959 Weitzner et al. (1959) demonstrated the effects of face-mask ventilation with a FiO_2 of 100% on arterial desaturation before endotracheal intubation. Now, the standard of care is to pre-oxygenate before laryngoscopy in an attempt to provide an apneic oxygen reservoir within the lungs. In the peri-operative environment, patients are often pre-oxygenated with a FiO_2 of 100% and paralyzed to extend the safe apneic period and improve intubating conditions.

Literature evidence demonstrates important distinctions between various pre-oxygenation techniques. While each technique delivers similar partial pressures of arterial oxygen (PaO2) levels, the rate of arterial desaturation varied with certain techniques producing slower desaturation results than others (Bouroche & Bourgain, 2015). The difference in desaturation rates from one pre-oxygenation technique to another is a significant finding that demonstrates the importance of choosing the correct pre-oxygenation technique for certain patient populations. For example, parturient patients with a reduced FRC and increased basal oxygen requirement will likely demonstrate a rapid decline in arterial oxyhemoglobin saturation levels. This patient population may certainly benefit from the creation of a longer safe apneic period during laryngoscopy.

Pre-Oxygenation and The Apneic Oxygenation Technique

A pre-oxygenation strategy of normal tidal breathing for 3 minutes of pure oxygen has become a common technique in current anesthesia practice (Kang et al., 2010). Achieving an end-tidal expiratory oxygen concentration greater than 90% is considered adequate for pre-oxygenation and replacement of the nitrogen volume within the lung (Bhatia et al., 1997). Pre-oxygenation serves the primary purpose of extending the “safe apnea” period of time it takes until a patient reaches an arterial oxygen saturation level of 90% (Semler et al., 2016). Current literature suggests that at a saturation level of 90%, patients enter onto the steep portion of the oxyhemoglobin curve and a precipitous drop in the arterial oxygen saturation levels can occur (Bellelli, 2010). When critical hypoxemic levels are reached, achieving favorable outcomes become more of a challenge. However, pre-oxygenation alone cannot always prevent rapid arterial desaturation during laryngoscopy. Physiologic conditions and pathological states such as pregnancy, sepsis, and morbid obesity all reduce the ‘safe apneic’ period before desaturation by either decreasing the FRC, increasing oxygen demand, or both (Butterworth et al., 2013).

The addition of AO to standard pre-oxygenation therapy has been advocated to directly address this issue of rapid arterial desaturation during laryngoscopy. To implement the AO technique, before pre-oxygenation, a nasal cannula insufflating oxygen at 5 L/min is placed within the nares. Subsequently, a face mask is applied, and standard pre-oxygenation can be initiated. After pre-oxygenation is complete and deemed sufficient, the face mask can be removed and then laryngoscopy can be initiated while the nasal cannula remains in place insufflating oxygen at 5 L/min.

Hypoxemia and Intubation

Hypoxemia is clinically described as a relatively low oxygen concentration within the circulating blood volume (Graham et al., 2019). Hypoxia describes the regional lack of oxygen distribution to cells, tissues, and/or organ systems (Weingart, 2011). The most frequent cause of hypoxemia within the human body is a shunt effect (Weingart, 2011). Other contributory causes are inadequate alveolar oxygenation, diffusion abnormalities, dead space, abnormal ventilation-perfusion (V/Q) ratios, and low venous blood saturation (Weingart, 2011). During anesthesia induction and before complete airway control, oxygen reserves can become insufficient to support the oxygen demands and this eventually leads to arterial desaturation during apnea (Bouroche & Bourgain, 2015). While there remain other contributory factors to the development of hypoxemia during anesthesia induction, difficult airway management accounted for 27% of all adverse respiratory events in the ASA closed claims database with 67% occurring during intubation (Pratt & Miller, 2016).

The Utility of Pulse Oximetry Monitoring

The oxyhemoglobin curve is of clinical significance because it represents cooperative oxygen binding to hemoglobin under physiologic conditions (Bellelli, 2010). Current experiments confirm the existence of hemoglobin under two independent quaternary conformations, both R ("relaxed") and T-states ("tense") respectively (Bellelli, 2010). The T-state demonstrates a lower affinity for oxygen molecules whereas the R-state has an increased affinity (Despopoulos & Silbernagl, 2006). Each conformation demonstrates a different ligand affinity, such as for CO_2 vs oxygen. Of clinical significance in anesthesia is the application of the pulse oximetry monitor and the peripheral oxygen saturation (SpO_2) as a surrogate for which conformational state of hemoglobin may be largely present (Bellelli, 2010). The steep portion of the oxyhemoglobin curve favors the dissociation of oxygen molecules from hemoglobin secondary to positive cooperativity (Despopoulos & Silbernagl, 2006). This portion of the oxyhemoglobin curve highly suggests that hemoglobin largely exists in the T-state, which readily dissociates from oxygen, indicating a right shift (Bellelli, 2010). The shifting of large concentrations of hemoglobin to the T-state contributes to the rapid arterial desaturation observed when attempting to intubate patients whose SpO_2 values are < 90% before intubation. The plateau portion of the oxyhemoglobin curve is representative of hemoglobin that is left-shifted, or in the R-state respectively (Despopoulos & Silbernagl, 2006). Anesthesia providers are strongly encouraged to utilize the SpO_2 value, understand the relationship of this value to the state of hemoglobin (R vs. T) largely present, and what interventions may be applied to prevent desaturation during induction.

Practical Impact of Apneic Oxygenation

Stakeholders

Stakeholders include practicing anesthesia providers who routinely engage in airway management, current University of Southern Mississippi (USM) faculty, and medical staff who provide surgical services to patients at a nearby Mississippi hospital. These stakeholders routinely engage in difficult airway scenarios where AO implementation could prove useful. The ASA closed claims database identified a strong association between difficult airway management and deleterious respiratory events, with 67% of the events occurring during intubation and 12% on extubation (Pratt & Miller, 2016). A risk stratification approach was introduced by Weingart and Levitan (2012) to recommend specific techniques that included AO to optimize intubating conditions for patients who exhibit certain risk factors. The Difficult Airway Society in the United Kingdom released guidelines for the management of the unanticipated difficult airway that included AO as an intervention for patients who are at high risk for arterial desaturation (Pratt & Miller, 2016). AO is provided as an adjunct to pre-oxygenation for anesthetists and clinicians who routinely perform airway instrumentation and may encounter difficult airway scenarios.

Within hospitals, the ICU often provides extended service to patients who have suffered hypoxic injury secondary to delayed, difficult, or failed airway intervention. Hospital costs and length of stay, increased mortality and disability are all the potential factors associated with arterial desaturation during laryngoscopy. Hospitals and the anesthesia providers they employ can benefit from implementing an AO strategy that can potentially avoid patient injury and save on costs.

Impact on Healthcare and Anesthesia Practice

An objective of this project was to provide literature evidence that AO can extend the safe apnea period and reduce the incidence of patient injury during laryngoscopy and intubation. The period of "safe apnea" begins with the cessation of diaphragmatic movement, discontinuation of standard pre-oxygenation, and initiation of laryngoscopy. This period of safe apnea ends with the onset of rapid arterial desaturation usually indicated by a SpO2 level of 90% (Gleason et al., 2018). Oxygen levels below 90% can indicate that the hemoglobin offloading of oxygen has approached the steeper portion of the oxyhemoglobin dissociation curve where critical levels of oxygen saturation (SpO2 $<$ 70%) can be reached within seconds (Weingart & Levitan, 2012). Evidence outlined in systematic reviews and meta-analyses demonstrates that the implementation of AO can extend the period of time during safe apnea, decrease rates of hypoxemia, and increase first-pass intubation success (Oliveira et al., 2017).

Anesthesia practice can be improved by the implementation of an AO strategy after a standard pre-oxygenation technique on certain patient populations. Obese and parturient patients present with decreased functional residual capacities (FRC), while pediatric and septic patients often present with increased oxygen utilization for different physiologic reasons (Bouroche & Bourgain, 2015). In turn, these physiologic changes compromise respiratory reserves and reduce the safe apneic period during laryngoscopy (Wong et al., 2017). Heard et al. (2017) achieved clinically important prolongation of safe apnea times with the implementation of AO on obese patients during the induction of anesthesia. Median apnea times with SpO2 > 95% were 750 seconds in the AO group vs. 296 seconds in the control group respectively (Heard et al., 2017). These results were consistent with the AO studies conducted on obese patients by White et al. (2017). Arcaris et al. (2016) demonstrated a reduced incidence of hypoxemia with AO implementation among pediatric patients in an observational study.

Patient Safety

Pre-oxygenation is performed to denitrogenate the FRC within the lungs in an attempt to prolong the safe apneic period by creating an oxygen reservoir (Nagelhout & Plaus, 2018). This pre-intubation technique provides a safe buffer of time before desaturation. Upon breathing ambient air, the lung oxygen reserve for an FRC of 3000 milliliters (mL) can be calculated as 0.21 x 3000 = 630 mL. After complete pre-oxygenation, the alveolar fraction of oxygen (FAO_2) is close to 0.95 and the reserve increases as follows: 0.95 x 3000 = 2850 mL (Bouroche & Bourgain, 2015). Pre-oxygenation allows the maximum amount of time for instrumentation of the airway without the incidence of critical hypoxemia. During apnea, tissue oxygenation is maintained by oxygen reserves in the lungs, plasma, and hemoglobin (Bouroche & Bourgain, 2015). The administration of oxygen through the pharynx during the apneic period could increase the uptake of oxygen into the bloodstream, thus reducing the occurrence of potentially harmful hypoxemic events. More importantly, AO prolongs the safe apnea period already established through adequate pre-oxygenation. At the end of pre-oxygenation, the size of the oxygen reservoir remains fixed and AO only serves to provide a continuous insufflation of oxygen into the lungs, thereby reducing the removal of oxygen from the residual reserve capacity (Patel & Nouraei, 2015). This technique broadens the safety window for laryngoscopy and this reason, AO is recommended as an adjunct to pre-oxygenation rather than a stand-alone therapy.

Specific Aims

The purpose of this project was to provide an evidence-based foundation for anesthesia providers regarding the clinical application and benefits of AO implementation during laryngoscopy and induction. This foundation was provided through the development and deployment of a teaching tool document which was presented in an education session. A corollary objective in this project was to assess whether providers would be willing to implement AO after having gained new information. This doctoral project aimed to improve anesthetic quality through the expansion of knowledge regarding an evidence-based technique that would improve the safe administration of anesthesia.

DNP Essentials

The Doctor of Nursing Practice (DNP) Essentials as outlined by The American Association of Colleges of Nursing (AACN) are eight educational competencies required for advanced nursing practice (DNP Essentials Task Force, 2006). The DNP essentials serve as quality indicators and provide standards for advanced nursing practice. Each of the eight essentials was met in the completion of this DNP project and outlined in Appendix A.

Summary

Evidence from the literature suggests that a strategy of AO extends the safe apnea period but to varying degrees among certain patient populations. However, implementing AO on patients who present with intrapulmonary shunting provides little clinical improvement (Gleason et al., 2018). This physiologic derangement often does not respond or correct to oxygenation, even at a FiO_2 value of 1.0 (Weingart et al., 2016). In selected patient scenarios, an AO strategy can extend the safe apnea period and attenuate hypoxemia during laryngoscopy and intubation (Pratt & Miller, 2016).

CHAPTER II – METHODOLOGY

Context

This project received approval from the USM Institutional Review Board (Protocol # IRB-20-27). A detailed exploration into AO, the physiology that makes it possible, and its benefit in contemporary anesthesia practice were all essential elements of this project. This project also provides an in-depth analysis of pre-oxygenation, laryngoscopy, hypoxemia, pulse oximetry monitoring and how AO can directly impact each of these events.

A comprehensive review of the literature was conducted regarding the established evidence and methods for implementing AO during laryngoscopy. The evidence gathered in the literature review establishes a clinical role for AO in attenuating arterial desaturation during laryngoscopy. AO was associated with increased peri-intubation SpO_2 levels, decreased hypoxemia, and increased first-pass intubation success rate (Oliveira et al., 2017). Taha et al (2006) demonstrated that AO is a simple technique that can follow pre-oxygenation and significantly increase the period of subsequent apnea without desaturation. A meta-analysis established that the implementation of AO was simple, effective at extending the safe apnea time, and has the potential to turn intubation into a "safer" procedure (Oliveira et al., 2017).

The information from this extensive literature search was comprised of a single page document and then allocated to anesthesia providers as a teaching tool (see Appendix B). This teaching tool document was administered to anesthesia providers after assessing their knowledge of AO through a pre-teaching survey (see Appendix C). Subsequent reading the teaching tool document, anesthesia providers were then given a post-teaching survey (see Appendix D) to assess for any expansion in knowledge regarding AO and its implementation. This particular project design ensures the dissemination of literature findings to anesthesia providers and an evidenced-based approach to the implementation of AO.

Design

This project deployed a survey assessment to capture the baseline knowledge of anesthesia providers regarding AO and its clinical use. After baseline knowledge assessment, a teaching tool document was administered to each participant. Following the review of the teaching tool document, participants were then administered a second and final survey to assess for any expansion in knowledge regarding AO and any willingness to incorporate this technique into their current practice.

An education session was performed at an area hospital with practicing anesthesia providers. Participants were not randomized and each voluntarily participated. A panel of four anesthesia experts, including certified registered nurse anesthetists (CRNAs), were also participants in this project. Each participant signed an informed consent stating their willingness to be involved in this project. All surveys were submitted anonymously with no identifiers. Since the primary interest of this project was to assess the baseline knowledge of AO among current anesthesia providers, a five-question pre-teaching survey was developed. The pre-teaching survey included the following questions:

1. What is Apneic Oxygenation (AO)?
2. What device can be used to implement AO?
3. When do you apply the AO device for implementation?
4. What is the desired goal while the device is applied?

5. When do you remove the device?

The education session included an initial assessment of knowledge regarding AO (pre-teaching survey), followed by an educational discussion highlighting the clinical and physiologic benefits of AO as outlined in the teaching tool document. Finally, the post-teaching survey was given to assess for any knowledge gained within the education session. The teaching tool document elaborated on the process of pre-oxygenation, laryngoscopy, and intubation while implementing AO. The application and timing of AO were outlined in detail and its discontinuation after the establishment of a definitive and secure airway. This teaching tool document provided contemporary information regarding AO and more importantly, its current use in the clinical theaters of modern anesthesia. A post-teaching survey was administered to participants only after review of the teaching tool document. The post-teaching survey asked precisely the same questions as the pre-teaching survey except for one additional question. Questions in the pre and post-teaching surveys addressed specific learning objectives within the teaching tool document.

Statistical Analysis

Upon completion of both surveys, participants were administered a point score with 100 points being designated for answering all 5 survey questions correctly, 80 points for four correct answers, 60 points for three correct answers, 40 points for two correct answers, 20 points for one correct answer, and 0 points for no correct answers. Each survey was scored accordingly, and the scores were treated as continuous data. The continuous data from each of the pre-teaching survey results were computed into a mean, standard deviation, and variance. The same was done for the continuous data from each of the post-teaching survey results. This data was then analyzed for statistical significance using a paired t-test for a comparison of means. An "expansion of knowledge" regarding AO in this project was defined as a statistically significant difference in the mean scores between both the pre and post-teaching surveys. All continuous data computations were made using the Python programming language (Van Rossum & Drake Jr., 1995). The graphical representation of all continuous data was performed with Microsoft Excel (Bruns, 2017).

Assessment and evaluation of knowledge expansion is a crucial component of this project. How this knowledge expansion is measured is of equal value and, therefore, remains the reason this project deploys a statistical approach in determining any knowledge gains. The appropriate assessment of knowledge provides the opportunity to critically appraise the effectiveness of the teaching tool document and surveys surrounding it.

Data Analysis

The data in this project was analyzed using a paired t-test. Inferential testing methods allow for inferences to be made about the population (anesthesia providers) from conclusions drawn from the sample size (local anesthesia providers and expert panel members). The sample data (survey scores) was computed into the mathematical likelihood or probability, that conclusions drawn from this data are representative of the general population, as a whole. A test statistic and critical value were calculated and compared for analysis. The test statistic was greater than the critical value (test statistic > critical value), concluding that there was a statistically significant difference between the pre and post-teaching mean survey scores.

Summary

An education session was conducted by deploying two surveys and a teaching tool document. The goal of this project was to assess for any knowledge gaps and provide the evidence-based literature findings regarding AO. Surveys were conducted and implemented for data collection. A teaching tool document with the literature findings was utilized in an education session and thoroughly discussed among participating anesthesia providers. Feedback was also collected from all participants and all scores were analyzed for statistical significance and interpretation. This project aimed to assess, whether or not, after having gained expansion of knowledge regarding AO, if individual anesthesia providers would be willing to incorporate AO into their practice. Long term, this project aims to increase patient safety by expanding the knowledge of an evidenced-based technique such as AO that can ameliorate rapid arterial desaturation events during laryngoscopy and anesthesia induction.

CHAPTER III - RESULTS

Analysis of Results

The total number of anesthesia providers who participated in this study was 12. The participants included four expert panelists and eight anesthesia providers from an area hospital in Mississippi. The scores for each of the pre-teaching surveys are Participant 1: 80, participant 2: 100, participant 3: 100, participant 4: 100, participant 5: 100, participant 6: 60, participant 7: 80, participant 8: 100, participant 9: 100, participant 10: 80, participant 11: 100, and participant 12: 80. The scores are as follows for each of the post-teaching tool surveys: Participant 1: 80, participant 2: 100, participant 3: 100, participant 4: 100, participant 5: 100, participant 6: 100, participant 7: 80, participant 8: 100, participant 9: 100, participant 10: 100, participant 11: 100, and participant 12: 100. The mean, standard deviation, and variance for the pre-teaching tool survey scores are 81.6, 19.07, and 363.8. The mean, standard deviation, and variance for the post-teaching survey scores are 93.3, 16.99, 288.8, respectively.

Table 1 outlines the results for each participant along with the computed mean scores. The mean survey scores provide the basis for analysis through a ‘comparison of means’ test, also known as a paired t-test. Graphically, the mean score results are represented below (Figure 1) and demonstrate an overall improvement in the post-teaching mean survey score as compared to the pre-teaching mean survey score. The graphical representation of the mean score results allows for visual inspection and detection of any potential meaningful difference in the survey results. While this crude inspection requires further extrapolation, it does provide valuable insight into the potential trajectory of the data.

Table 1

Individual Pre/Post Teaching Survey Score Results with Score Differences

Participant	Pre-Teaching Survey Score	Post-Teaching Survey Score	Difference in Scores
1	100	100	0
2	80	100	20
3	80	100	20
4	100	100	0
5	40	100	60
6	80	100	20
7	100	100	0
8	100	100	0
9	60	40	-20
10	100	100	0
11	60	80	20
12	80	100	20
Mean Survey Scores	81.6	93.3	
Difference in Mean Survey Scores		11.7	
Cumulative Difference in Scores			140

Note. Mean scores for both the Pre/Post Teaching Surveys with the difference

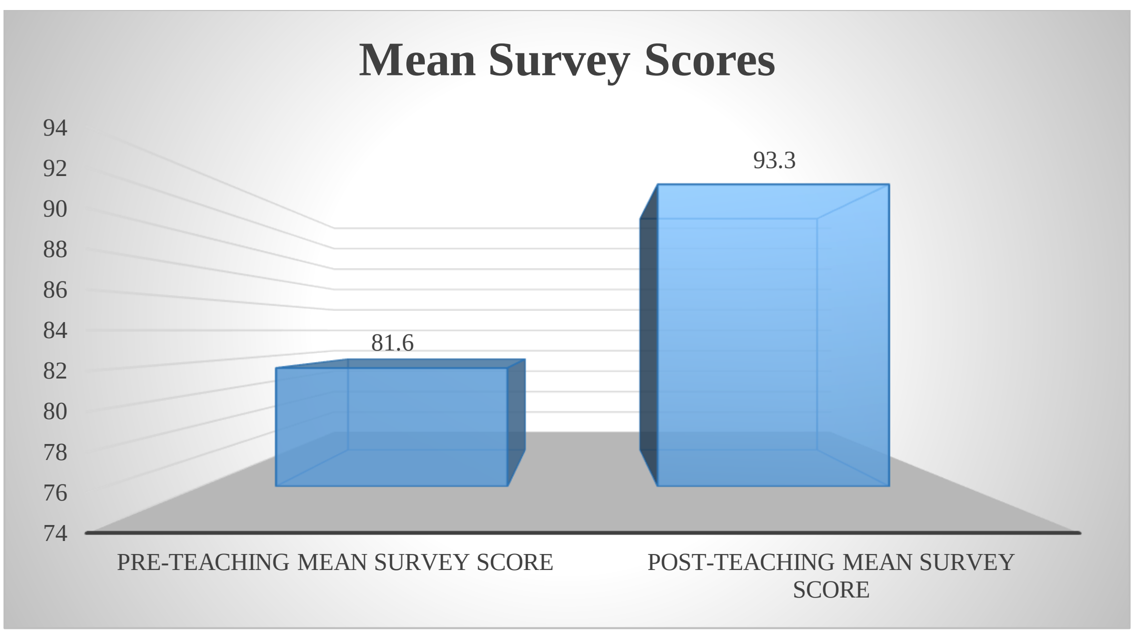

Figure 1. *Comparison of Pre/Post Teaching Mean Survey Scores*

Paired T-test

The paired t-test resulted in a computed critical value of 1.795 with 11 (n-1) degrees of freedom and a p-value of 0.05. The computed test statistic was 2.028 (Figure 2). This value was greater than the critical value (test statistic: 2.028 > critical value: 1.795) and was thus interpreted as being statistically significant. This statistical significance suggests that the mean scores between the pre-teaching surveys and post-teaching surveys are from different populations and are, therefore, statistically different, with the post-teaching mean survey score being greater than the pre-teaching mean survey score. The statistically significant difference between mean survey scores suggests that there was an expansion in knowledge regarding AO and the implication and meaning of this expansion will be discussed in the following section.

Each participant was inquired of their willingness to incorporate AO into their current practice and 58% (7/12) of the respondents suggested they would be willing to do so (Figure 3). A sub-group of participants who did not demonstrate an improvement in their post-teaching survey scores as compared to their pre-teaching survey scores are identified in Figure 4. Analysis of this sub-group reveals potential confounding variables and is discussed in the following section.

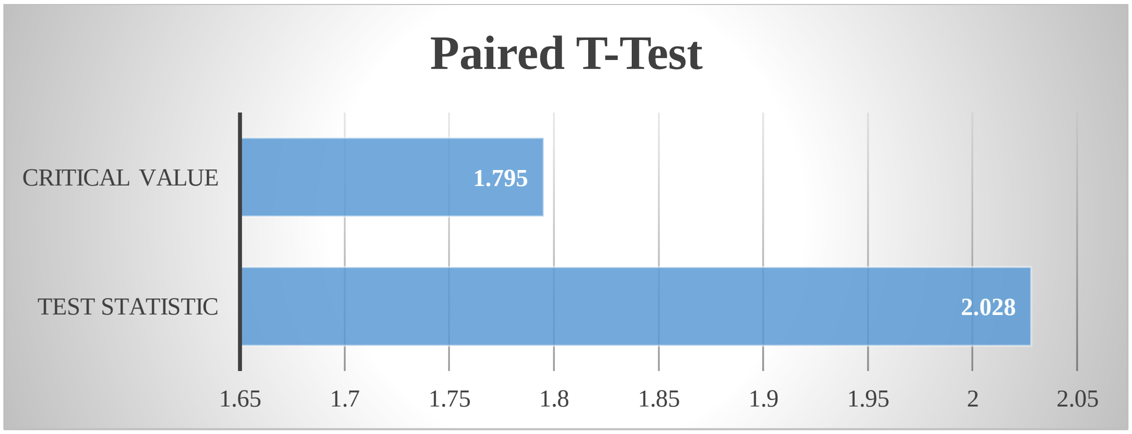

Figure 2. *Critical Value and Test Statistic.*

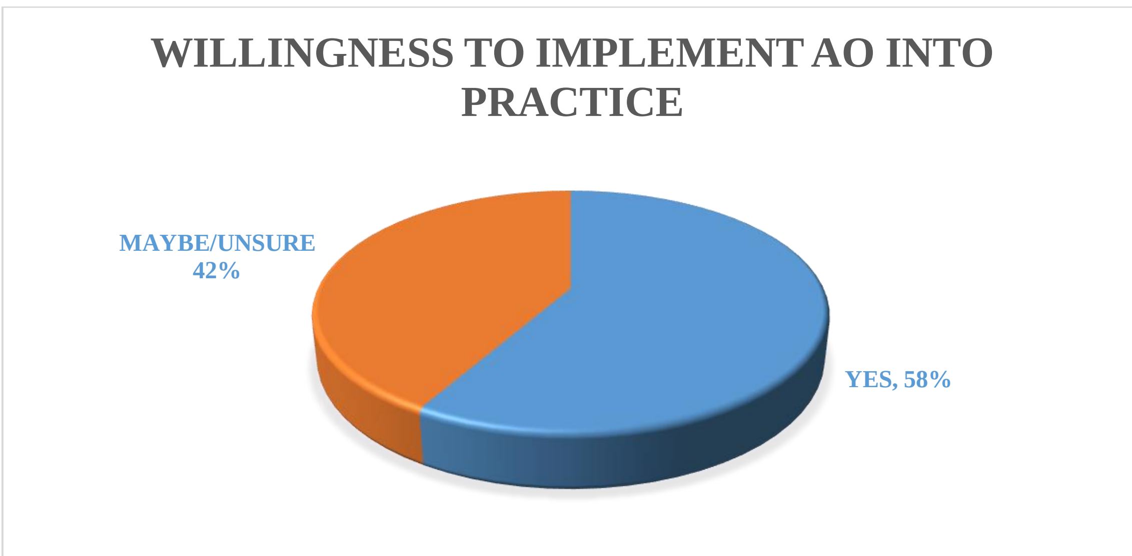

Figure 3. *Participants Willing to Implement the AO Technique.*

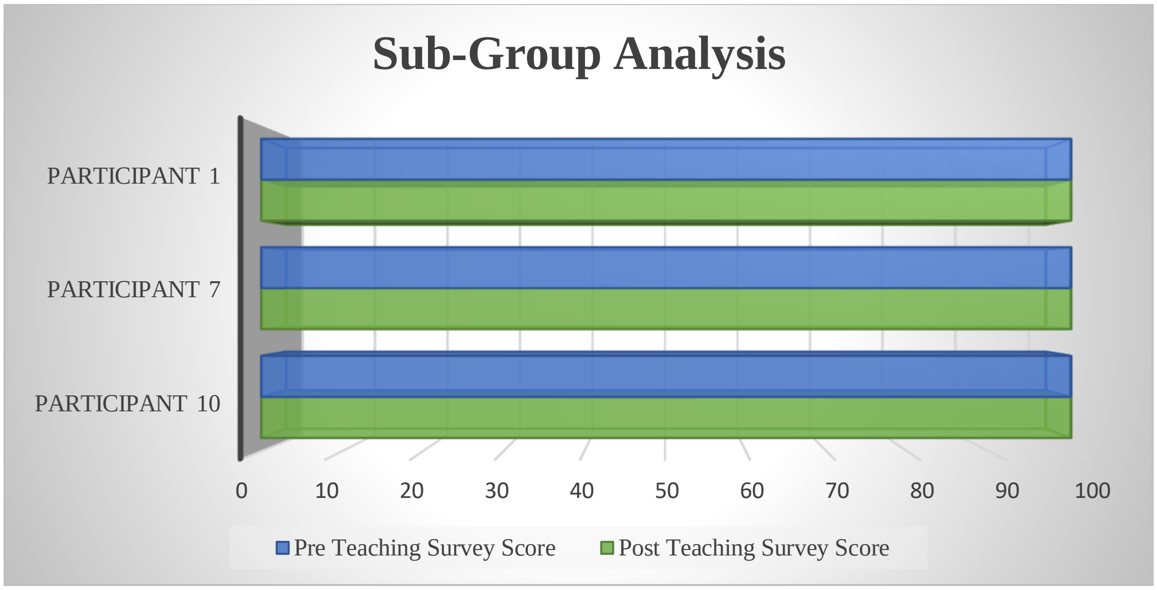

Figure 4. *Sub-Group Analysis of Participants Unsure of Implementing AO.*

Summary

The mean scores for the pre and post-teaching surveys are 81.6 and 93.3, respectively. A paired t-test was utilized to analyze this data for statistical significance. A statistically significant difference in mean scores was determined and reflects an expansion in knowledge regarding AO. With this expansion in knowledge regarding AO, the majority of anesthesia participants did reflect a willingness to incorporate the AO technique into their practice.

CHAPTER IV – CONCLUSION

Discussion

The paired t-test yielded a statistically significant difference between the pre-teaching and post-teaching mean survey scores. This statistical difference infers that there was an expansion in knowledge regarding AO as defined by the criteria outlined in this project. Each participant was inquired of their willingness to incorporate AO into their current practice and 58% (7/12) of the respondents suggested they would be willing to do so (Figure 3). Regarding this 58% of total participants, the project designer does infer a direct correlation with the teaching tool document and the expansion in AO knowledge measured with these specific respondents.

Each participant within the sub-group (Figure 4) selected correct answer choices for both the pre and post-teaching surveys and, therefore, could not demonstrate any improvement in their survey performances. These specific participants also declined to state a willingness to implement AO into their current practice. This sub-group was of particular interest because some confounding variables may have influenced the respondents in deciding whether or not to implement AO. Such variables would include: the specific device used to deploy AO and the time it takes to do so. The project designer assumes that the individuals within this sub-group were already familiar with AO (due to their survey score results) but did not find potential concerns they may have had regarding AO addressed in the teaching tool document. The device used to implement AO may be a confounding variable that was not addressed with great detail in this project. The project designer assumes that the lack of attention to this variable may have had an impact on the decision by some participants to be unwilling to implement AO into their practice. These participants represented 25% (3/12) of the total respondents, and again, may have been impacted by such confounding variables. Feedback was collected from each participant and presented to a panel of experts for analysis and direction for future and potential projects.

Limitations

One significant limitation of this study was the sample size. Larger sample sizes are more representative of the general population, whereas results extrapolated from smaller sample sizes can be inconclusive. Another limitation of this study was that the participants were not randomized, so the potential for selection bias did exist and could have skewed the results observed. Information related to the time it takes to implement AO was not disseminated among anesthesia providers and unfortunately, does not provide the participants of this study a contextual framework to stand on. Without this time framework, participants may assume that applying the AO technique is time-consuming and, therefore, opt-out of any willingness to alter their anesthetic practice. The lack of information regarding the time it takes to apply the AO device is another confounding variable that may have been the basis for any unwillingness to deploy this technique among some participants. Another limitation of this study design was that it did not elaborate on the literature evidence regarding the variation of devices used to implement the AO technique.

Summary

Assessment of current anesthesia providers by the methods detailed in this study revealed a lack of knowledge regarding AO and its implementation. This knowledge gap was supplemented with evidence from the literature and any expansion of knowledge was assessed statistically using a paired t-test to compare the mean survey scores of both the pre and post-teaching surveys. This project demonstrated that some participants did experience expansion in knowledge regarding AO while others did not. This lack of expansion in knowledge could be secondary to the knowledge proficiency some participants may have already had with the concept of AO. All participants were inquired of their willingness to implement AO into their current practice. Twenty-seven percent of adverse respiratory events are airway related and of these, 67% occur during intubation (Pratt & Miller, 2016). The literature evidence outlines the safety impact AO has during laryngoscopy by extending the safe apnea period and, therefore, attenuating deleterious hypoxic events. This project has demonstrated a willingness on the part of some participants, to incorporate AO into their practice.

An area of future study would be in assessing the willingness among anesthesia providers to make AO the standard of care during laryngoscopy and intubation. While requiring an anesthesia provider to implement AO may lack support, the evidence remains clear that this technique can prevent harm and increase safety for patients under anesthesia care. Future projects could also focus and elaborate on the various devices used when implementing the AO technique.

APPENDIX A – DNP Essentials

Essential One: Scientific Underpinnings for Practice	This project combines the highest scientific evidence demonstrated in systematic reviews and randomized controlled trials to establish an evidence-based technique to improve patient safety. The teaching tool document was formulated with scientific evidence regarding AO.
Essential Two: Organizational and Systems Leadership for Quality Improvement and Systems Thinking	This doctoral project aimed to improve quality through the expansion of knowledge and an evidence-based technique that would improve the quality and safe administration of anesthesia. A literature search was performed to investigate a technique that would improve patient outcomes during intubation.
Essential Three: Clinical Scholarship and Analytical Methods for Evidence-Based Practice	This doctoral project deployed statistical analysis to appraise the collected data for significance and the determination of expansion in knowledge regarding AO.
Essential Four: Information Systems/Technology and Patient Care Technology for the Improvement and Transformation of Health Care	This essential was met through the development and implementation of pre/post teaching tool survey given to evaluate the anesthesia providers knowledge of AO.
Essential Five: Healthcare Policy for Advocacy in Health Care	This essential is met through the advocacy of patient safety and expanding the knowledge of anesthesia providers regarding an evidence-based technique proven to ensure improved outcomes. This project could provide the foundational support for making AO the standard of care by enhancing the quality of anesthesia care.
Essential Six: Inter-professional Collaboration for Improving Patient and Population Health Outcomes	This doctoral project utilized professional communication and collaboration with an expert panel of CRNAs, physicians, and anesthesia providers.

Essential Seven: Clinical Prevention and Population Health for Improving the Nation's Health	This essential was met by the demonstration of expansion in knowledge among select anesthesia providers. These same providers also expressed a willingness to implement an evidence-based technique such as AO into their practice as a result of the efforts of this project.
Essential Eight: Advanced Nursing Practice	This essential is met through a thorough appraisal of scientific literature, conduction of an education session based on that literature, and the culminating expansion in the knowledge that resulted from each of these independent efforts.

APPENDIX B – Teaching Tool Document

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Apneic Oxygenation Findings

Objectives:

- Define Apneic Oxygenation (AO)
- Discuss the role of preoxygenation and the clinical evidence of its sufficiency.
- What patients can benefit from this intervention?

A. AO is simply, the continuous insufflation of oxygen into the alveoli after diaphragmatic paralysis. **To attenuate rapid arterial desaturation during laryngoscopy, the technique of apneic oxygenation (AO) has been proposed and implemented by various anesthesia and critical care providers.**

B. The addition of apneic oxygenation to standard preoxygenation therapy has been advocated to directly address this issue of rapid arterial desaturation during laryngoscopy. **Prior to preoxygenation, a nasal cannula insufflating at least 5 liters of oxygen per minute is placed within the nares.** Subsequently, a face mask can be applied and standard pre-oxygenation initiated. After preoxygenation is complete and deemed sufficient, the face mask can be removed. Laryngoscopy can then be initiated with the nasal cannula in place infusing 5 liters of oxygen per minute. **The AO device can be removed upon establishing a definitive airway**.

C. There is clear evidence from research that a strategy of AO extends the safe apnea period but to varying degrees among certain patient populations, such as obese and pregnant clients (Bouroche & Bourgain, 2015). However, there is little clinically significant improvement with a single modality strategy of AO alone on clients who present with intrapulmonary shunting (Gleason et al., 2018).

APPENDIX C – Pre-Teaching Survey

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Apneic Oxygenation

Pre-Teaching Survey

Confidentiality Statement

Your responses are confidential and will be analyzed collectively with other participant responses.

The conductor of this survey does not disclose individually identifiable responses.

Participation in this study is completely voluntary. There are no repercussions for non-participation.

Directions:

Please mark only one answer for each question unless otherwise requested.

1. **What is Apneic Oxygenation (AO)?**
   A.) A mixture of volatile anesthetic and oxygen, that is potent enough to render apnea in patients undergoing general anesthesia.
   B.) The administration of oxygen after the cessation of ventilation in patients.

2. **What device can be used to implement AO?**
   A.) A standard nasal cannula or high flow nasal cannula.
   B.) A 50/50 concentration of oxygen and nitrous oxide via an ETT to reduce the MAC of volatile anesthetics

3. **When do you apply the AO device for implementation?**
   A.) Prior to stage 2 of anesthesia to attenuate potential injury.
   B.) Prior to pre-oxygenation and laryngoscopy.

4. **What is the desired goal while the device is applied?**
   A.) Prolong the safe apnea time.
   B.) Prevent atelectasis and alveolar collapse.

5. **When do you remove the device?**
   A.) Upon establishing a definitive airway.
   B.) Upon return of spontaneous ventilations

Thank you for completing this survey.

APPENDIX D –Post-Teaching Survey

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Apneic Oxygenation

Post-Teaching Survey

Confidentiality Statement

Your responses are confidential and will be analyzed collectively with other participant responses.

The conductor of this survey does not disclose individually identifiable responses. There are no repercussions for non-participation.

Directions:

Please mark only one answer for each question unless otherwise requested.

1. **What is Apneic Oxygenation (AO)?**
   A.) A mixture of volatile anesthetic and oxygen, that is potent enough to render apnea in patients undergoing general anesthesia.
   B.) The administration of oxygen after the cessation of ventilation in patients.

2. **What device can be used to implement AO?**
   A.) A standard nasal cannula or high flow nasal cannula.
   B.) A 50/50 concentration of oxygen and nitrous oxide via an ETT to reduce the MAC of volatile anesthetics

3. **When do you apply the AO device for implementation?**
   A.) Prior to stage 2 of anesthesia to attenuate potential injury.
   B.) Prior to pre-oxygenation and laryngoscopy.

4. **What is the desired goal while the device is applied?**
   A.) Prolong the safe apnea time.
   B.) Prevent atelectasis and alveolar collapse.

5. **When do you remove the device?**
   A.) Upon establishing a definitive airway.
   B.) Upon return of spontaneous ventilations

6. **Will you implement AO into your current practice?**

Thank you for completing this survey.

Feedback:

APPENDIX E – Evidence Matrix

Author	Design	Sample/Data Collections	Findings	Recommendations
Oliveira et al. (2017). Effectiveness of Apneic Oxygenation During Intubation: A Systematic Review and Meta-Analysis.	Systematic Review and Meta-Analysis. Qualitative and Quantitative analysis.	A total of 14 studies were included for qualitative analysis, and 8 studies (1,837 patients) underwent quantitative analysis.	In this meta-analysis, apneic oxygenation was associated with increased peri-intubation oxygen saturation decreased rates of hypoxemia and increased first-pass intubation success.	In summary, apneic oxygenation was associated with increased peri-intubation SpO_2, decreased hypoxemia, and increased first-pass intubation success.
Heard et al. (2017). Apneic Oxygenation During Prolonged Laryngoscopy in Obese Patients: A Randomized, Controlled Trial of Buccal RAE Tube Oxygen Administration.	Randomized-controlled efficacy trial.	Forty obese patients with body mass index (BMI) 30–40 were randomly assigned to standard care (n = 20) or buccal oxygenation (n = 20) during induction of total IV anesthesia.	Clinically important prolongation of safe apnea times can be achieved delivering buccal oxygen to obese patients on the induction of anesthesia.	The novel use of apneic oxygenation via the oral route may improve the management of the difficult airway and overcome some of the limitations of alternative techniques.
Semler et al. (2016). Randomized Trial of Apneic	Randomized-controlled efficacy trial.	This was a randomized, open-label, pragmatic	Apneic oxygenation does not seem to increase the lowest	For patients with abnormal pulmonary

Oxygenation during Endotracheal Intubation of the Critically Ill.		trial in which 150 adults undergoing endotracheal intubation in a medical intensive care unit was randomized to receive 15 L/min of 100% oxygen via high-flow nasal cannula during laryngoscopy (apneic oxygenation) or no supplemental oxygen during laryngoscopy.	arterial oxygen saturation during endotracheal intubation of critically ill patients compared with usual care.	function, provision of oxygen by mask or noninvasive ventilation was insufficient to avert intubation, providing 15 L/min by nasal cannula during intubation might be expected to be ineffective.
Taha et al. (2006). Nasopharyngeal oxygen insufflation following pre-oxygenation using the four-deep breaths technique.	Randomized-controlled trial.	The study was performed on 30 patients with an age range of 20–52 years scheduled for elective surgery under general anesthesia.	This study concluded that nasopharyngeal oxygen insufflation following pre-oxygenation using the four deep breath technique can delay the onset of hemoglobin desaturation for a significant period of the time during the subsequent apnea.	This study suggests that nasopharyngeal oxygen insufflation, which provides apneic diffusion oxygenation is a simple technique that can follow pre-oxygenation by the four-deep breaths technique within 30 sec and significantly

				increase the period of subsequent apnea without desaturation.
White et al. (2017). Apneic oxygenation during intubation: A Systematic Review and Meta-analysis.	Systematic Review and Meta-Analysis.	Of the 15 articles, 11 met the inclusion criteria, i.e. intubations were performed with both a control group (no apneic oxygenation) and an intervention group (apneic oxygenation during intubation). These 11 studies included 2,078 patients (Table 1). Each study was then screened for risk of bias and methodological quality using the Cochrane Collaboration's tool for assessing the risk of bias (Table 2). Of these 11	Successful apneic oxygenation was assessed qualitatively. Overall, there was conflicting evidence in support of apneic oxygenation. Of the eleven studies, eight showed significant improvement. The remaining three studies by Dyett et al. (2015) and Semler et al. (2016) showed no significant benefit in hypoxic respiratory failure patients. Meta-analysis: Strong evidence was found for the use of apneic oxygenation to prevent desaturation. Apneic oxygenation during intubation is associated with a reduced risk of desaturation (RR 0.65, p =0.005).	Where feasible, future studies could add to our knowledge by including firm outcome measures such as cardiac arrest, duration of ventilation, the incidence of hypoxic brain injury and mortality.

		studies, six were high-quality level one RCTs, four were low-quality level two studies and one was a low-quality level three study.		
Ramachandran et al. (2010). Apneic oxygenation during prolonged laryngoscopy in obese patients: a randomized, controlled trial of nasal oxygen administration.	Prospective Randomized-controlled trial.	Thirty obese patients undergoing surgery with general anesthesia.	Intervention group fell below 95% SpO_2 level at 5.29 min vs 3.49 min in the control.	Nasal oxygen administration is associated with significant increases in frequency and duration of SpO_2 > or = 95%, and higher minimum SpO_2 during prolonged laryngoscopy in obese patients.
Baraka et al. (2007). Supplementation of pre-oxygenation in morbidly obese patients using nasopharyngeal oxygen insufflation.	Randomized-controlled trial.	Thirty-four morbidly obese patients undergoing gastric band or bypass surgery.	94% of the intervention group maintained a SpO_2 level of 100% before and after intubation.	When nasopharyngeal oxygen insufflation followed pre-oxygenation, the onset of oxyhemoglobin desaturation during the subsequent

				apnea was significantly delayed.
Pavlov et al. (2017). Apneic oxygenation reduce the incidence of hypoxemia during emergency intubation: A systematic review and meta-analysis.	Systematic Review and Meta-Analysis.	Eight studies with 1,953 patients requiring intubation.	Apneic oxygenation reduced the relative risk of hypoxemia by 30% (95% CI [0.59 to 0.82]). There was a trend toward lower mortality in the apneic oxygenation group (RR of death 0.77; 95% CI [0.59 to 1.02])	Apneic oxy genation sig nificantly reduces the incidence of hypoxemia during emergency endotrachea l intubation. These findings support the inclusion of apneic ox ygenation in everyday clinical practice.

APPENDIX F – USM IRB Approval Letter

Office *of*
Research Integrity

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

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NOTICE OF INSTITUTIONAL REVIEW BOARD ACTION

The project below has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services regulations (45 CFR Part 46), and University Policy to ensure:

- The risks to subjects are minimized and reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered involving risks to subjects must be reported immediately. Problems should be reported to ORI via the Incident template on Cayuse IRB.
- The period of approval is twelve months. An application for renewal must be submitted for projects exceeding twelve months.

PROTOCOL NUMBER: IRB-20-27
PROJECT TITLE: Apneic Oxygenation: An Adjunctive Therapy For Laryngoscopy During Anesthesia Induction
SCHOOL/PROGRAM: School of LANP, Leadership & Advanced Nursing
RESEARCHER(S): Yaro Hoffman, Michong Rayborn

IRB COMMITTEE ACTION: Approved
CATEGORY: Expedited

7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

PERIOD OF APPROVAL: February 7, 2020

Donald Sacco Jr.

Donald Sacco, Ph.D.
Institutional Review Board Chairperson

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