CRNA PERCEPTION OF LUNG PROTECTIVE VENTILATION FOR THE INTUBATED PATIENT

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Abstract

Background: Alveolar collapse [atelectasis] occurs in over 90% of intubated patients and leads to altered lung mechanics. Atelectasis can lead to postoperative pulmonary complications (PPCs), which increase morbidity and mortality. Lung Protective Ventilation has the potential to reduce PPCs intraoperatively. **Purpose**: This QI project seeks to evaluate the current evidence supporting LPV and to provide consensus recommendations to practicing anesthesia providers with the goal of standardizing lung-protective ventilation strategies for intubated patients receiving general anesthesia. **Methods**: Practicing anesthesia providers received an education in-service detailing current research in support of LPV and practice recommendations. Prior to the presentation, a pre-intervention survey was administered and approximately 8 weeks later an identical survey was administered to determine if practice changed. **Results**: McNemar test was used to assess binary paired data and revealed acceptance of the null hypothesis. Qualitative analysis reveals varied growth in knowledge and utilization of LPV following the educational intervention. **Recommendations and Conclusion**: Research studies are needed to determine patient-specific optimal PEEP levels. Facilities should prioritize continuing education and LPV protocols to encourage uniformity in practice.

Keywords: Lung protective ventilation; protective lung ventilation; post-operative pulmonary complications; atelectasis; alveolar collapse, alveolar recruitment maneuver, alveolar recruitment

Background and Significance

The human body relies on the lungs to remove CO_2 as well as extract enough oxygen from the air to maintain aerobic metabolism. In a spontaneously breathing individual, the diaphragm descends and the rib cage expands causing air to flow down its pressure gradient, filling the lungs. However, during mechanical ventilation lung expansion is driven by positive pressure. The chest is now being pushed open rather than pulled, resulting in the central alveoli expanding first and compressing the outer alveoli. Additionally, the induction of anesthesia causes a reduction in resting lung volume and functional residual capacity (FRC) further promoting the development of atelectasis. Güldner et al. (2015) found that 90% of patients receiving general anesthesia develop atelectasis. Alveolar collapse and reinflation increase the amount of stress and strain placed on lung parenchyma resulting in impaired oxygenation and increased cardiopulmonary pressures, and inflammation (Hedenstierna & Edmark, 2010). As a result, PPCs can develop, including hypoxemia, pneumonia, and acute respiratory failure. PPCs increase perioperative morbidity and mortality and ultimately lead to higher healthcare costs (Deng et al., 2020; Magnusson & Spahn 2003; Young et al., 2019).

Purpose

The goal of this DNP project is to assess how clinicians are currently implementing LPV and provide consensus recommendations based on current published evidence to standardize practice.

Review of Current Evidence

A thorough search of the literature was conducted using databases PubMed and CINAHL, and the catalog of Anesthesia Journals. Eligible articles were found by using the following search terms: (Lung protective ventilation OR LPV or Protective lung ventilation) OR (low-tidal volume) or (Positive-end expiratory pressure OR PEEP) OR (Atelectasis) OR (post-operative pulmonary complications OR PPCs) OR (Alveolar recruitment maneuvers OR ARMs OR Recruitment maneuvers OR Vital capacity breaths). Articles included reported data for adults aged 18 years or older and discussed findings and techniques from the intraoperative period. Articles not published in English, those without abstracts, and/or those addressing ventilator management in the ICU were excluded.

Consequences of Altered Lung Mechanics

"Post-operative pulmonary complications (PPCs)" is a term broadly used to describe various alterations in lung mechanics. As previously explained, hypoxemia, atelectasis, and pneumonia are examples of complications from altered lung function (Güldner et al., 2015). PPCs can lead to higher healthcare costs due to prolonged PACU stays or costly ICU admissions to manage pulmonary complications (Deng et al., 2020; Güldner et al., 2015; Young et al., 2019). Anesthesia providers are in a unique position to prevent PPCs. Experts agree protective lung ventilation decreases the development of PPCs. While PPCs is an umbrella term encompassing multiple ailments, atelectasis remains the primary source in the development of postoperative lung complications.

Atelectasis

Induction of anesthesia leads to a reduction in resting lung volume, also known as Functional Residual Capacity (FRC). Atelectasis, or alveolar collapse, is one of the principal causes of PPCs. Atelectasis impedes the lungs' ability to effectively remove CO_2 and exchange it for oxygen. It is reported that greater than 90% of intubated patients receiving general anesthesia develop atelectasis and it can persist for days to weeks following major surgery (Güldner et al., 2015, Hedenstierna & Edmark, 2010; Magnusson & Spahn, 2003; Young et al. 2019). Alveolar homogeneity allows for pressure and volume to be evenly distributed among the alveoli. Regional alveolar collapse results in a disproportionate distribution of inspired volume to aerated, open units, causing overdistension (Güldner et al., 2015; Magnusson & Spahn, 2003). Since tidal breathing is cyclical, the repetitive over-expansion of some areas and collapse of others leads to the release of inflammatory cytokines causing lung injury. Many events during the intraoperative period contribute to the formation of atelectasis, by identifying these causes, providers can manage them appropriately.

Intraoperative Challenges

Atelectasis is a common occurrence amongst intubated patients receiving general anesthesia. The intraoperative events that make patients more susceptible to this pulmonary manifestation begin with endotracheal intubation. By exchanging a patient's normal, negative inspiratory flow pattern with positive pressure ventilation, the interdependent alveolar units are no longer pulled open expanding the surface area, but rather pushed open. This alteration negatively affects gas exchange by decreasing pleural surface area which increases alveolar surface tension (Levitzky, 2018). Additionally, provider-dependent actions like suctioning, and circuit disconnects, can contribute to the development of atelectasis. These actions result in a loss of the positive pressure required to maintain lung volume, leading to alveolar collapse. Patient positioning can also affect alveolar expansion. Steep Trendelenburg and supine position cause cephalad displacement of the abdominal contents leading to decreased diaphragmatic excursion. Similarly, cases requiring pneumoperitoneum impair diaphragmatic descent, impeding lung filling (Tharp et al., 2020). These actions require an increased driving pressure to adequately ventilate the lungs and overcome the lack of expansion. Neto et al. (2016) reported an association between driving pressures and the development of PPCs. Increased driving pressure correlates with lung injury due to continual strain placed on lung parenchyma. While many intraoperative events contribute to atelectasis, a thorough understanding of pressure and volume relationships can improve intraoperative management.

Intraoperative Assessment

Recognizing atelectasis is the first step for anesthesia providers to determine the appropriate intervention. In addition to common assessment tools such as a stethoscope and SpO_2 monitoring, modern anesthesia gas machines are equipped with tools to help assess respiratory system compliance. Two important variables in evaluating ventilation are plateau pressure and PEEP. Plateau pressure is calculated and displayed on the anesthesia machine during a brief inspiratory hold. It represents the pressure applied to alveoli and small airways and reflects pulmonary compliance (Williams et al., 2019). Driving pressure is the difference between plateau pressure and PEEP. Experts believe it is the key determinant of pulmonary compliance. Multiple studies link high driving pressures directly to the development of PPCs, highlighting the necessity for anesthesia providers to have a thorough understanding of this value (Amato et al., 2015; Neto et al., 2016). Modern anesthesia ventilators display these pressure and volume measurements that can be used to guide ventilation intraoperatively.

Lung Protective Ventilation Strategies

Lung protective ventilation has garnered the attention of anesthesia providers after its successful use in managing ventilator-dependent ARDS patients. While experts promote its use in the surgical setting, there remains variability in how it is practiced. LPV consists of small tidal volumes, low peak and plateau pressures, PEEP, and alveolar recruitment maneuvers.

Tidal Volume

Lower tidal volumes consisting of 6-8 ml/kg of ideal body weight (IBW) maintain patients resting lung volume without increasing stress and strain on lung parenchyma (Deng et al., 2020; Futier et al., 2014; Güldner et al., 2015; Young et al., 2019). Lohser & Ishikawa (2019) further recommend 4-6 ml/kg of IBW for protective ventilation and only to increase to 6-8 ml/kg of IBW in the presence of hypoxemia or severe hypercapnia. While many studies agree low TV is a key component in protective lung ventilation, there is much debate surrounding PEEP levels and recruitment strategies.

PEEP

Physiologic PEEP is between 3-5 cmH_2O. PEEP <5 cmH_2O may be detrimental to the intubated patient under general anesthesia. Conversely, PEEP >12 cmH_2O contributes to ventilation-induced lung injury (VILI) due to inflammatory cytokine release from alveolar overdistension (Deng et al., 2020; Güldner et al., 2015). Therefore, it is recommended to initiate ventilation with PEEP at 5 cmH_2O and titrate up as needed. Many articles mention the need for individualized PEEP, considering it varies based on surgical factors such as position and gastric insufflation, as well as patient factors such as body habitus and underlying lung conditions (citations needed). Currently, the quantitative method for determining a patient-specific PEEP value requires the use of esophageal manometry, which is not easily measured in the operating room (Shaefi & Eikerman, 2018). A simple technique to determine optimal individualized PEEP values is needed to encourage the use of this intervention.

Alveolar Recruitment

Alveolar recruitment is maintained by PEEP but not restored by it. According to Deng et al. (2020), recruitment of alveolar units is more successful when a recruitment maneuver is followed by the application of PEEP than with PEEP alone. General anesthesia leads to decreased FRC, altering the pressure-volume relationship within the lungs due to alveolar heterogeneity. A vital capacity breath reverses alveolar collapse and restores an equal distribution of volume. Adequate PEEP following an alveolar recruitment maneuver maintains the open lung acquired from the initial recruitment maneuver. Magnusson and Spahn (2003) found that when PEEP was discontinued atelectasis reoccurred. A recruitment maneuver requires a pressure of up to 30-40 cmH_2O for non-obese patients and 40-50 cmH_2O for obese patients (Magnusson & Spahn, 2003; Young et al., 2019). All reviewed studies agreed recruitment maneuvers should be performed with low FiO_2. High FiO_2 contributes to reabsorption atelectasis, an increased O_2 uptake by the pulmonary capillaries leading to alveolar collapse (Güldner et al., 2015; Magnusson & Spahn, 2003; Young et al., 2019). ARMs can be delivered in several ways; manually, vital capacity breath by the ventilator or provider-controlled pressure/volume increases. Manual delivery is least recommended in the literature due to the loss of PEEP upon switching between delivery modes, as well as lack of control of pressure and volume (Young et al., 2019). Similarly, a vital capacity breath administered by the ventilator provides a single "sigh" breath. The two most effective methods describe a gradual increase in tidal volume when using volume control ventilation or a gradual increase in pressure when using pressure control ventilation (Güldner et al., 2015; Young et al., 2019). Both strategies begin by determining the patient's opening pressure based on their BMI. In VCV, PEEP is set, and TV is gradually increased over multiple breaths until the desired opening pressure is achieved. In PCV, an inspiratory pressure is set, and PEEP is gradually increased over multiple breaths until the desired opening pressure is achieved. Following recruitment, TV and PEEP are decreased to the patient's optimal level. Currently, ARMs appear to be most useful following a patient disconnect from the circuit and following position changes, such as prone or Trendelenburg.

Conceptual Framework

Malcolm Knowles is an American educator accredited with developing the adult learning theory Andragogy in the 1970s. Originally, Pedagogy was the only term used to philosophize the utilization of knowledge, but the term specifically referred to educating children. In 1967, Eduardo C. Lindeman pioneered theories on understanding adult learning. Lindeman (1926) stated, "…the resource of highest value in adult education is the learner's experience…experience is the adult learner's living textbook" (p. 9-10). As Knowles further shaped early pioneering theories, he identified the five doctrines of Andragogy. First, motivation for learning begins with the need to learn (Knowles, 1978). In other words, adult learners must first feel the intrinsic burden to learn. Thereby, for this project, it is imperative to convince CRNAs at inception how understanding and implementing LPV puts them in control of patient outcomes and reduces cost. Knowles' (1978) second and third tenets rely on the belief that incorporating learning with experience is a core methodology. Through the use of clinical scenarios, the educational in-service allowed participants to connect to the new information through their work experience. Fourth, adult learners prefer self-direction (Knowles, 1978). Adult learners require time to engage with the material and evaluate the best way to incorporate it, rather than simply complying with given direction. Finally, many different learning styles exist, and educators must employ various techniques to engage all participants (Knowles, 1978). This DNP project utilized multiple learning styles, through the use of PowerPoint guided lecture, demonstration, and group discussion.

Methods

Design

This quality improvement project evaluated change in practice by comparing CRNA practice before and after an educational in-service. Considering current literature already asserts that LPV helps to prevent PPCs, this project focused on provider implementation to encourage uniformity amongst anesthesia providers. Through the use of a translational framework, this project followed well-established structures created to guide quality improvement projects and implement change in practice.

Translational Framework

The Iowa Model is a popular model which will serve as the framework for this DNP project. Originally published in 1993 and revised in 2001, this model focuses on improving quality care. The first step of the model is to define what "triggered" the need for change (citation needed somewhere in this paragraph for the Iowa Model). Lung protective ventilation is a current standard of care that has recently garnered attention, prompting new clinical recommendations to be published. Although current recommendations exist, there remains inconsistency in implementation amongst providers. This trigger would be classified as a "knowledge-focused trigger". After defining the trigger and confirming it is significant to the organization, the researcher assembles a team to compile and critique all the relevant research. This is a critical step within the framework because if the team determines there is insufficient research, then the recommendation shifts to generating new research and clinical studies. LPV is a popular subject that has garnered attention within the clinical community, therefore, multiple studies already exist on the topic. The Iowa Model then advocates beginning piloting the change in practice. As a DNP student, the best way to pursue this step is by conducting an educational in-service to present CRNAs with current practice recommendations to facilitate their acceptance into practice.

Setting and Population

This project was conducted at a 208-bed urban medical center in the southeastern U.S. As the only full-service hospital in its area, the not-for-profit facility offers a wide variety of medical services to the community. The 13 operating rooms and endoscopy suites are staffed by one of the largest anesthesia management companies in the U.S. The anesthesia department employs an anesthesia care team model which includes Anesthesiologists, CRNAs, and Anesthesiologist

Assistants. The CRNAs at this facility will serve as the population for this DNP project. All CRNAs employed at this facility were invited to participate.

Project Implementation

Lung protective ventilation has generated interest in the anesthesia community for its use in managing intubated surgical patients. There remains a lack of consensus on how to implement LPV intraoperatively. After a thorough review of current literature, anesthesia staff at the 208-bed urban medical center received an educational intervention on LPV. The presentation consisted of a discussion of the prevalence and identification of impaired lung mechanics in surgical patients. Additionally, current research supporting LPV for management of these disturbances, and practice recommendations for LPV implementation were presented. A pre-intervention survey was completed by attendees before the presentation to gather baseline information about current LPV implementation and knowledge at the facility. LPV flyers and educational material from the presentation were made available to staff following the presentation. Eight weeks following the presentation, a post-intervention survey was completed by the original attendees. The post-intervention survey and pre-intervention survey were identical to enable comparison of their respective results.

Data Collection

Data for this project was collected by administering a 6-question survey to assess LPV practice and knowledge. Before the educational in-service a pre-survey was distributed to attendants. Following the in-service, educational material was emailed directly to staff and made available in the breakroom. The two PIs were available to assist staff with LPV implementation during this time. After 8 weeks, staff received an email requesting they complete the post-intervention survey. The post-intervention survey was posted in the breakroom as well as sent electronically.

Data Analysis

Two of the six questions in the surveys were used for statistical analysis to conduct the McNemars test using IBM SPSS software. The remaining questions were evaluated using qualitative analysis.

Results

The target population for this project was CRNAs practicing at the 208-bed urban medical center. The sample size consisted of 10 CRNAs, no demographic data was collected on the participants. 100% of respondents affirmed they implement some form of LPV. Table 1 presents the results of the McNemar test, which was used to assess the binary paired data in question #7 regarding the use of compliance and pressure-volume (PV) loops on the ventilator. The null hypothesis states there is no difference between the pre- and post-intervention survey responses. Given the limited sample size, the McNemar test revealed acceptance of the null hypothesis. The 4 remaining survey questions were open-ended. Question #2 asked participants to list the components of LPV, to which 80% of participants answered TV and PEEP. The remaining participants mentioned a variety of lung-protective strategies such as low driving pressure, alveolar recruitment, and low FiO_2. The post-survey yielded 90% of participants responding TV and PEEP and the remaining 10% answered with previously discussed strategies. Comparatively, 20% of respondents listed low FiO_2 in their pre-survey, after an educational intervention, 70% of participants defined low FiO_2 as a component of LPV. Question #4 asked, “How do you perform recruitment maneuvers,” 7 out of 10 participants report using VC breaths, whereas the remaining listed increasing PEEP and/or TVs. Post-survey results had minimal change. Question #5 asked participants what prompts them to perform recruitment maneuvers. Half of the respondents listed low O_2 saturation and TV or high $ETCO_2$. The remaining participants varied in answers listing patient factors like atelectasis, increased BMI, and surgical factors like position changes, insufflation, and type of surgery. In the post-survey, zero participants prioritized increased BMI as a recruitment prompt while 3 additional participants listed position changes and atelectasis. Question #6 asked respondents to describe how they determine appropriate PEEP for their patient, 70% reported using one-third of patients' BMI, and the remaining 30% listed either 5 cmH_2O or 6-10 cmH_2O. Post-survey results showed that 80% of participants utilizing one-third BMI calculation to obtain PEEP value.

Table 1

McNemar Test SPSS

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
PostTest * PreTest	10	100.0%	0	0.0%	10	100.0%

PostTest * PreTest Crosstabulation

Count

		PreTest		
		yes	no	Total
PostTest	yes	2	2	4
	no	1	5	6
Total		3	7	10

Chi-Square Tests

	Value	Exact Sig. (2-sided)
McNemar Test		1.000[a]
N of Valid Cases	10	

a. Binomial distribution used.

Barriers and Limitations

The most significant barrier to project completion was the lack of participation. Modifications were made to increase the number of participants: the educational in-service material was provided to staff to view independently, and surveys were posted in the breakroom and emailed to staff. Despite persistent advertisement, it was challenging to recruit participants to complete the surveys. The project progressed according to the expected timeline but there is a lack of generalizability due to the small sample size. During the educational in-service many clinicians voiced hesitancy in elevating PEEP values based on BMI. Due to high BMI, PEEP values are often set above 10 mmHg, which is a deviation from the norm for many providers. Providers were concerned that elevated PEEP would increase the risk of barotrauma. Similarly, clinicians expressed hesitancy to use higher pressures during recruitment maneuvers out of concern for barotrauma.

Discussion

This project assessed provider knowledge and implementation of LPV before and after an educational in-service. Survey results showed anesthesia providers are cognizant of the importance of implementing LPV strategies but consensus on how to implement them varied. Protective lung ventilation is a dynamic strategy consisting of low TVs, PEEP, and ARMs with the goal of maintaining low pressures (Deng et al., 2020; Futier et al., 2014; Güldner et al., 2015; Young et al., 2019). When participants were asked if they implement any form of LPV, 100% answered affirmatively, however variation emerged in the details of how much PEEP is applied or how ARMs are performed. The education material presented providers with current practice recommendations, and while post-surveys indicated increased knowledge in some areas, the sample size was too small to generalize. Based on the adult learning framework Andragogy, "…experience is the adult learner's living textbook," it would have been ideal to pair participants with the primary investigators for more hands-on instruction in the OR (Knowles, 1978, 9-10). Survey question #7 asked participants if they utilize compliance and/or pressure-volume loops on the ventilator, this question highlighted an area of improvement for providers. Seventy percent of providers reported they do not use these tools on the ventilator, following the in-service, 50% reported use. While there was minor improvement in the pre and post-survey, it is imperative for anesthesia providers to use the measurements to guide LPV. Modern anesthesia ventilators display pressure and flow measurements which provide insight into overall respiratory system compliance. A thorough understanding allows providers to customize LPV strategies to optimize the benefits of LPV and minimize the risk of ventilation-associated injury (Williams et al., 2019).

Conclusion

Lung protective ventilation is a strategy first introduced to care for ventilator-dependent ICU patients with acute respiratory distress syndrome (ARDS). Since the development of LPV, providers have adapted aspects of this strategy for use in the operating room. LPV improves lung mechanics, combats atelectasis, and prevents postoperative pulmonary complications (Güldner et al., 2015, Hedenstierna & Edmark, 2010; Magnusson & Spahn, 2003; Young et al. 2019). While this project focused on the impact of education on LPV utilization, it would be helpful if additional studies were available to more precisely determine individualized PEEP. Current evidence identifies goals for other components of LPV, such as TV, ARMs, and driving pressure, but guidelines for determining optimal PEEP are lacking. Results from this project in particular highlight the need for each institution to have an LPV protocol. Survey results showed large variability in LPV implementation among providers at the same facility. It is clear anesthesia staff recognizes the importance of LPV but additional education on current practice recommendations is needed. Project results will be disseminated to the participating staff and facility stakeholders via email.

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Appendix A: Information Sheet

Project Title: CRNA perception and barriers of lung protective ventilation for the intubated patient

Principal Investigator: Paige Newman and Briana Glaspy

Faculty Advisor: Terry Wicks

What is this all about?
I am asking you to participate in this quality improvement project because lung protective ventilation is well studied, yet inconsistently implemented into practice. This quality improvement project will only take about 30 minutes and will involve you completing a pre and post intervention survey and attending an education in-service. Your participation in this quality improvement project is voluntary.

Will this negatively affect me?
No, other than the time you spend on this project there are no known or foreseeable risks involved with this study.

What do I get out of this research project?
You and your colleagues will get a concise overview of current evidenced based literature regarding lung protective ventilation strategies. It will also enhance your anesthesia practice and in turn potentially improve patient outcomes.

Will I get paid for participating?
There will be no compensation for this study.

What about my confidentiality?
We will do everything possible to make sure that your information is kept confidential. All information obtained in this study is strictly confidential unless disclosure is required by law. We will not ask for any identifying information, like name or employee ID number. We will use unique ID numbers, pseudonyms and/or maintain computer firewalled data storage on personal laptops. In addition, the data will be loaded into box.uncg for faculty review. No one else will have access to raw data

What if I do not want to be in this research study?
You do not have to be part of this project. This project is voluntary and it is up to you to decide to participate in this research project. If you agree to participate at any time in this project you may stop participating without penalty.

What if I have questions?
You can ask Paige Newman pkmorri2@uncg.edu, Briana Glaspy baglaspy@uncg.edu, and/or Terry Wicks tcwicks@uncg.edu anything about the study. If you have concerns about how you have been treated in this study call the Office of Research Integrity Director at 1-855-251-2351.

Appendix B: Pre- and Post-intervention survey

1. Circle one: AA CRNA Anesthesiologist

2. List the components of lung protective ventilation.

3. Do you currently implement any form of LPV? If yes, how/what?

4. How do you perform recruitment maneuvers?

5. If so, what prompts you to perform recruitment maneuvers?

6. How do you determine appropriate PEEP for your patient?

7. Do you currently utilize compliance or PV loops on the ventilator?