CRNA PERCEPTION AND IMPLEMENTATION OF LUNG PROTECTIVE VENTILATION

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Abstract

Background General anesthesia causes the collapse of the alveoli, known as (atelectasis) in roughly 90% of anesthetized patients. Postoperative atelectasis may persist for several hours to days and significantly increases the risk for postoperative pulmonary complications (PPCs) and morbidity and mortality. Atelectasis and PPCs can be prevented by the use of lung protective ventilation (LPV). LPV is a ventilatory strategy that is designed to recover the aeration of the lung. LPV includes low tidal volumes (V_t), utilization of positive end-expiratory pressures (PEEP), application of low driving pressures, and use of alveolar recruitment maneuvers (ARMs). **Purpose** The goal of this DNP project is to provide practicing CRNAs with a concise recommendation for standardizing LPV implementation into practice. An investigation of the current attitudes and knowledge regarding the topic was performed. Additionally, this project discovered barriers preventing CRNAs from implementing LPV into clinical practice.

Methods A brief questionnaire investigating attitudes and knowledge regarding the topic was administered pre- and post-intervention. We anticipated that after an educational intervention, practicing CRNAs will have the appropriate comfort and knowledge to implement lung protective ventilation into their daily practice. Following the educational presentation, the same survey was distributed to the participants to see if or how their answers and practice had changed. **Results** Five of the participants indicated that he or she use the compliance and PV loops on the ventilator, two of which began following the educational intervention. Also, all participants reported on the pre-intervention surveys that they currently use some form of LPV. The surveys varied in responses on what prompts the provider to perform ARMs. None of the participants indicated why or if they are reluctant to implement all aspects of LPV into their current practice following the educational intervention. **Recommendations and Conclusions**

Currently, many anesthesia providers implement one or more aspects of LPV currently in practice. However, the method of determining the optimum level of PEEP, and the most effective method of performing recruitment maneuvers remains unclear.

Key Words “Lung Protective Ventilation OR LPV OR protective lung ventilation” OR “low-tidal volume” OR “positive-end-expiratory pressure OR PEEP” OR “alveolar recruitment maneuvers OR ARMS” OR “vital capacity breaths” OR “atelectasis” OR “postoperative pulmonary complications OR PPCs”

Background and Significance

The lungs and the respiratory system play a vital role in maintaining homeostasis. The respiratory system is responsible for pulmonary ventilation, gas exchange, acid-base balance, and removal of carbon dioxide. During spontaneous negative pressure ventilation, the mechanics of ventilation are controlled by the respiratory muscles. These muscles expand and contract the rib cage and diaphragm to allow air to flow down the pressure gradient into the alveoli where oxygen and carbon dioxide are exchanged; alveoli must remain open to maintain efficient gas exchange.

When a patient is mechanically ventilated, positive pressure ventilation pushes air into the lungs to ventilate the alveoli. The administration of neuromuscular blocking agents prevents the muscles of respiration from participating in ventilation. Positive pressure ventilation changes lung mechanics and can lead to altered distribution of ventilation (Hedenstierna & Edmark, 2015).

General anesthesia causes the collapse of the alveoli (atelectasis), in roughly 90% of anesthetized patients (Hedenstierna & Edmark, 2010). Postoperative atelectasis may persist for several days and significantly increases the risk for postoperative pulmonary complications (PPCs), morbidity, and mortality (Tusman & Böhm, 2010). Inducing general anesthesia causes a rapid collapse of the alveoli resulting in ventilation/perfusion mismatch (V/Q mismatch). Even in an uncomplicated general anesthetic, 15-20% of the lung will collapse (Hedenstierna & Edmark, 2010).

The use of lung protective ventilation (LPV) can prevent atelectasis and PPCs. LPV is a ventilatory strategy that is designed to recover the aeration of the lung (Tusman & Böhm, 2010). LPV includes low tidal volumes (V_t), utilization of positive end-expiratory pressures (PEEP), application of low driving pressures, and use of alveolar recruitment maneuvers (ARMs) (Young et al., 2019). Through the use of these tactics, a controlled amount of airway pressure opens the collapsed areas of the lungs and sufficient PEEP is applied to keep them open (Tusman & Böhm, 2010). Evidence suggests these strategies are beneficial for patients of all ages and many surgical procedures (Young et al., 2019). As an anesthetist, it is imperative to perform LPV, especially for those patients who are at higher risk of developing PPCs. High-risk patients include patients undergoing pulmonary restrictive procedures such as laparoscopy with pneumoperitoneum, and for the obese population. Ultimately, LPV can reduce the length of stay for postoperative patients and reduce the use of high FiO_2 in the post-anesthesia care unit (PACU).

Project Purpose

The goal of this DNP project was to provide practicing CRNAs with concise recommendations for standardizing LPV implementation into clinical practice. This was accomplished by providing LPV education to CRNAs at a full-service hospital in Cary, North Carolina. A brief questionnaire investigating attitudes and knowledge regarding the topic was administered pre- and post-intervention. Additionally, this project was intended to identify barriers preventing CRNAs from implementing LPV into clinical practice.

Review of Current Evidence

In this literature review, research discussing lung protective ventilation (LPV) is described, the importance and impact of LPV is analyzed, along with elements associated with its implementation into practice. A comprehensive review of the literature was completed by using the databases CINAHL, PubMed, and the catalog of Anesthesia Journals. Search terms used included: “Lung Protective Ventilation OR LPV OR protective lung ventilation” OR “low-tidal volume” OR “positive-end-expiratory pressure OR PEEP” OR “alveolar recruitment maneuvers OR ARMS" OR "vital capacity breaths" OR "atelectasis" OR "postoperative pulmonary complications OR PPCs". Inclusion criteria were reported data in adult patients over the age of 18 years old, intubated patients, and the intraoperative period. Exclusion criteria included the pediatric patient population and non-intubated patients.

Lung Protective Ventilation Strategies

Although LPV has been applied for many years at the bedside to manage patients with Acute Respiratory Disease (ARDs), LPV has more recently become adapted for mechanical ventilation during surgery (Kim et al., 2018; Rackley & MacIntyre, 2019). LPV includes the use of low tidal volumes, lower peak and plateau pressures, PEEP, and alveolar recruitment maneuvers. The application of these elements greatly enhances ventilation, gas exchange, and reduces atelectasis and the incidence of PPCs.

Tidal Volume

Tidal volumes of 6-8ml/kg of Ideal Body Weight (IBW) are recommended throughout the literature. The utilization of lower tidal volumes have been shown to decrease the incidence of PPCs when compared to using higher volumes (Ball et al., 2020; Deng et al., 2020; Güldner et al., 2015; Kim et al., 2018; Rackley & MacIntyre, 2019; Valenza et al., 2010; Young et al., 2019).

PEEP

There is widespread agreement that omitting PEEP is harmful to mechanically ventilated patients. However, determining the appropriate level of PEEP is controversial. Current literature suggests PEEP should be individualized for each patient, but selecting an optimal PEEP value can often be difficult. The determination of optimal PEEP considers surgical factors, positioning, the use of pneumoperitoneum, body habitus, and any underlying pulmonary conditions (Young et al., 2019).

Some studies have shown PEEP > 12 cmH_2O can injure the lung due to barotrauma in absence of recruitment (Deng et al., 2020; Güldner et al., 2015). PEEP maintains, but does not restore, functional residual capacity (FRC). Therefore, it is important to utilize PEEP to maintain alveoli open after ARMs (Deng et al., 2020; Young et al, 2019). Many studies recommend beginning with a PEEP of 5cmH_2O and increasing incrementally as needed (Deng et al., 2020; Hedenstierna & Edmark, 2015). Other studies recommend determining optimal PEEP through the use of a decremental PEEP trial. If the patient is hemodynamically stable after intubation, PEEP is increased to 20cmH_20 and the inspiratory pressure to 20 cm H_2O. After approximately 10 breaths, the PEEP is decreased in 2 cm H_2O increments to determine the lungs closing pressure, the pressure which causes the alveoli to collapse. The PEEP value right immediately prior to closure is the patient's optimal PEEP (Tusman & Böhm, 2010; Young et al., 2019). Ultimately, additional studies are needed to conclusively determine how to calculate a patient's individualized PEEP value (Ball et al., 2020; Deng et al., 2020; Güldner et al., 2015; Hedenstierna & Edmark, 2015; Kim et al., 2018; Ruszkai et al., 2021; Tusman & Böhm, 2010; Valenza et al., 2010; Young et al., 2019)

Alveolar Recruitment Maneuvers (ARMS)

Atelectasis may occur diffusely across the lung. Random pockets of collapse across the lungs are referred to as lung heterogeneity. ARMs are crucial in the reopening of collapsed alveoli and restoring lung homogeneity (Harris, 2020). ARMs can improve lung mechanics and reverse decreased Functional Residual Capacity (FRC). It is important that PEEP be applied after an ARM for alveolar recruitment to be preserved and to sustain lung homogeneity (Deng et al., 2020; Young et al., 2019).

When performing ARMs, a driving pressure of 30-40 cmH_2O is required for patients with a BMI < 35 kg/m^2 and 40-50 cmH_2O for patients with a BMI > 35 kg/m^2. Additionally, ARMs should be performed using the lowest possible FiO_2 in order to decrease the likelihood of reabsorption atelectasis (Deng et al., 2020; Güldner et al., 2015; Ruszkai et al., 2021; Tusman & Böhm, 2010; Valenza et al., 2010; Young et al., 2019).

There are several different ways to perform ARMs, including manual or ventilator driven. A manual recruitment maneuver is performed by turning the APL valve on the anesthesia machine to the appropriate pressure, according to the patient's BMI, and squeezing the bag to deliver the maneuver – holding this for at least 10 seconds. This technique is the least recommended due to the potential loss of PEEP when switching back to the ventilator and lack of control of pressure and volume (Young et al., 2019).

Ventilator-driven ARMs are more widely recommended in the research. There are three ways to perform ARMs using the ventilator. The first way is utilizing the vital capacity option on the machine. This resembles manual recruitment, but it is delivered through the ventilator circuit. The second way is using the pressure-controlled ventilation (PCV) setting. In PCV, airway pressure is based on BMI and is maintained for about 6-10 breaths before returning to baseline with an appropriate PEEP level. The third way is through the volume-controlled ventilation (VCV). With this setting, the machine is set for a V_t of 6-8ml/kg as a baseline and is incrementally increased by 4 ml/kg every 6 breaths until the desired plateau pressure is reached (Güldner et al., 2015; Young et al., 2019). Performing recruitment maneuvers appears to be most beneficial after intubation, after a disconnect from the breathing circuit, a significant position change, or with any periods of oxygen desaturation (Young et al., 2019). Additional research is needed to determine the optimal frequency of performing ARMs as well as protocols for “incrementally” increasing the volume or pressure.

Postoperative Pulmonary Complications

Postoperative pulmonary complications (PPCs) occur in 5-40% of surgical patients. PPCs are defined as the occurrence of acute hypoxemia appearing within the first few days post-operatively (Young et al., 2019). PPCs are a serious perioperative concern due to their high prevalence and potentially fatal consequences. Atelectasis is one of the most important and commonly occurring PPC and is often the precursor to the other, more severe, pulmonary complications. PPCs include atelectasis, respiratory failure, respiratory infection, and pneumothorax (Gallart & Canet, 2015).

Atelectasis

Atelectasis occurs in roughly 90% of all anesthetized patients. Atelectasis results in decreased FRC and compliance, increased intraoperative shunt, and impaired gas exchange (Whalen et al., 2006). As much as 20% of the entire lung can collapse during routine general anesthesia and can persist several days into the postoperative period. Mechanical ventilation contributes to atelectasis by allowing the collapse of small airways, reabsorption of alveolar gas, and mechanical compression of lung tissue (Güldner et al., 2015; Hedenstierna & Edmark, 2010, 2015).

High oxygen concentrations, commonly used on induction and maintenance of anesthesia, combined with loss of muscle tone, can result in airway closure and absorption atelectasis. According to Tusman and Böhm (2010), airway closure creates a ‘pocket’ of tissue without the access to future gas supply. The oxygen molecules trapped within these pockets can easily be absorbed by the pulmonary capillaries. Therefore, the higher the fraction of inspired oxygen, the more rapidly atelectasis will occur. The inspired oxygen will become absorbed behind the closed airways in the dependent portions of the lung causing a ventilation/perfusion mismatch (V/Q mismatch) and impairing oxygenation (Hedenstierna & Edmark, 2010, 2015; Tusman & Böhm, 2010).

Mechanical compression of lung tissue may occur in several ways during ventilation. External compression can result from obesity or cephalad displacement of the diaphragm with supine or Trendelenburg positioning. Mechanical compression will limit alveolar ventilation, causing airway collapse. Furthermore, injury to the lung during mechanical ventilation causes a physiologic inflammatory response. Inflammation promotes the release of inflammatory mediators and cytokines that can lead to respiratory infection, systemic inflammation, and multi-organ dysfunction (Güldner et al., 2015; Rackley & MacIntyre, 2019; Ruszkai et al., 2021).

Contributing Factors

Patient-related Factors. The most common patient-related risk factors for the development of atelectasis and PPCs are advanced age, increased BMI, congestive heart failure, cardiopulmonary bypass, smoking, abdominal distention, functional dependency, chronic obstructive pulmonary diseases, American Society of Anesthesiologists (ASA) class ≥ 3, and obstructive sleep apnea. Advanced age is considered 60 years and older and obesity is classified as a BMI greater than 40 kg/m^2 (Gallart & Canet, 2015; Güldner et al., 2015; Tusman & Böhm, 2010; Young et al., 2019).

Procedure-related Factors. The most prevalent procedure-related risk factors that increase the likelihood of the development of PPCs and atelectasis are cardiothoracic surgery, major vascular surgery, abdominal surgery, general anesthesia, prolonged surgical time (>2 hours), emergency surgery, body positioning, pneumoperitoneum from laparoscopic procedures, high fluid volume administration, residual neuromuscular blockade, and one-lung ventilation. Body positioning, as previously mentioned, could include supine, lateral, or Trendelenburg (Gallart & Canet, 2015; Güldner et al., 2015; Tusman & Böhm, 2010; Young et al., 2019). The presence of these factors requires a higher driving pressure to maintain alveoli in an open state.

Intraoperative monitoring of lung mechanics and oxygenation

Early recognition of atelectasis in the mechanically ventilated patient is the first step in restoring adequate ventilation and gas exchange. The use of standard monitors, such as SpO_2, FiO_2, and $EtCO_2$ can help anesthesia providers promptly detect hypoxemia and inadequate gas exchange. These monitors enable providers to immediately identify if the patient is hypoventilating, needs recruitment, or is hypoxic. The ventilator should be set at the lowest possible driving pressure to achieve the desired V_T and minimize the risk of barotrauma.

Lung mechanics can be monitored on the ventilator using the compliance and pressure-volume loops. The compliance value allows comparison of the patient's lung compliance to the baseline value before intubation, as well as quantifying the effect of alveolar recruitment. The pressure-volume loops enable providers to visually observe the patient inhale and exhale. The loops also display the amount of pressure needed for inhalation. One can also detect early collapse of alveoli on the expiratory limb of the flow time waveform on the ventilator. Thinning of the expiratory limb suggests collapse of alveoli during expiration, while widening of the expiratory limb indicates alveolar over-distention (Harris, 2020; Young et al., 2019).

Methods

Design

A brief questionnaire investigating attitudes and knowledge regarding the topic was administered pre- and post-intervention. We anticipated after an educational intervention, practicing CRNAs would have the appropriate confidence and knowledge of lung protective ventilation to implement it into their daily practice. Following the educational presentation, the same survey was distributed to the participants to determine if, or how, their responses or practice had changed.

Evidence-Based Practice Model

The Johns Hopkins Nursing Evidence-Based Practice Model is a practical, problem-solving approach to the implementation of nursing evidence-based practices within the clinical setting. The goal of this model is to, "ensure that the latest research findings and best practices are quickly and appropriately incorporated into patient care" (Dang & Dearholt, 2017; Tsistinas, n.d.). The model consists of a three-step process referred to as "PET" – meaning practice question, evidence, and translation. Step one, identifying the practice question, consists of defining the problem, developing an evidence-based practice question, and determining the research project team. Step two, identifying the best evidence, includes the research, appraisal, and summarization of the evidence, as well as developing recommendations for practice improvement. Step three, translation of evidence, is comprised of the creation and implementation of an action plan, evaluation of outcomes, and the dissemination of findings (Dang & Dearholt, 2017; Tsistinas, n.d.).

This practice model is directly applicable to this evidence-based project. The project involves the nursing field and coincides with the goal of this project, which is to inform CRNAs regarding the benefits of lung protective ventilation as well as identify barriers that prevent the implementation of LPV into their clinical practice.

Theoretical Framework

Andragogy, a cognitive theory created by Malcolm Knowles, is the theoretical framework for this project. Andragogy identifies the ways to facilitate the educational process for adult learners and is based on five areas. Initially, adults must be made aware of the benefits of learning certain material (McGrath, 2009). Secondly, andragogy states that if the learner is very self-confident, he or she must be given the opportunity to express views and opinions during the educational session (McGrath, 2009). The third premise is based on the learner utilizing his or her own previous experiences to augment their learning process (McGrath, 2009). Finally, motivation plays a key role in adult learning and heavily influences the learners' educational experience (McGrath, 2009). Lastly, it is imperative that the adult learner feels safe in the learning environment (McGrath, 2009).

Setting

We conducted this project at a full-service 208-bed acute care facility in Cary, NC that performs surgical procedures for gastrointestinal, critical care, emergency, obstetrics, gynecology, heart and vascular, neurologic and trauma services. Our project focused on acute care and surgical services. We received hospital IRB approval for this project following approval from the IRB at the University of North Carolina at Greensboro.

Sample

Our convenience sample population included the CRNAs and anesthesiology assistants (AAs) employed at the chosen facility. We recruited participants by posting flyers in the breakroom with information regarding our educational in-service. Participant inclusion criteria included CRNAs or AAs that work at the hospital. Exclusion criteria included CRNAs that do not work at this facility or anyone not in the anesthesia department.

Implementation Plan

We administered a questionnaire to the sample at the beginning of this project to determine their baseline understanding of lung protective ventilation (see Appendix A). After administering the questionnaire, we provided an educational in-service. The in-service provided participants with a concise overview of the benefits of lung protective ventilation, and a guide with which to implement LPV. After eight weeks, we administered an identical survey (Appendix B) to identify how many participants translated LPV into their daily practice. We determined whether the participants implemented LPV and if not, what barriers had prevented the adoption of LPV techniques. Limitations to the success of this project include having an insufficient number of participants, and/or participants not completing the pre- or post-survey.

A general overview of the literature regarding LPV was presented and an exploration of the strategies describing the implementation of LPV into practice. The CRNAs were provided with a concise, clear, standardized guideline describing how to provide LPV to all patients undergoing general anesthesia. A copy of the presentation was provided to the participants and a hard copy was placed in the breakroom for future reference.

Data Collection

Procedures. Approval from the Institutional Review Board (IRB) was obtained from both the University of North Carolina at Greensboro and the chosen facility prior to conducting this DNP project. According to the IRB, this project was not considered to be human subject research and, as a result, did not require a signed consent prior to implementation. However, an informative flyer was displayed at the hospital to inform potential subjects about the project, including that the completion of the pre- and post-intervention surveys implied consent to participate.

There were a few potential risks associated with this project. Breach of confidentiality was considered a small risk and appropriate steps were taken to minimize this risk. No identifiers, such as names, employee number, or gender, were collected at any point during the project. To protect participant identity while also being able to correlate pre- and post- surveys, we requested the first two numbers of the subjects' home addresses be provided on the surveys.

Data was collected by a pre- and post-intervention survey in order to evaluate participants' knowledge, perception, and attitudes towards the implementation of LPV. The pre-intervention survey was provided to the participants prior to the educational intervention. Each participant was instructed to fill out the survey and immediately place it face down in a marked manila envelope located on a table in the room. The envelope was then sealed and placed in a locked cabinet in the principal investigator's residence; upon project completion, the surveys were shredded. Eight weeks following the pre-intervention survey and the educational presentation, post-intervention surveys were distributed to the participants. The participants were instructed to fill out the survey and place it in the marked manila envelope located in the room. The surveys were then locked in the same cabinet as the pre-intervention surveys. Only the principal investigator, co-investigator, and DNP faculty had access to the raw data; the project site received a summary of findings upon project completion.

Instruments. Two seven question surveys were distributed to the participants – each containing identical questions. The participants were asked to identify themselves as an anesthesia assistant (AA), a CRNA, or an anesthesiologist. Participants were asked to list the components of LPV and indicate whether they currently implemented any form of LPV in their practice. If the answer was yes, they were asked to explain how they implement LPV. The subjects were then asked how they currently perform ARMs and what would prompt them to do so. Next, the subjects were asked how they determine an appropriate PEEP level for a patient. Finally, the survey asked if they currently utilize pressure-volume (PV) loops available on the ventilator (see Appendix A & B).

Data Analysis

Qualitative data was collected for this project. Once the surveys were collected, each pre-survey was paired with the coinciding post-survey that contained the matching identifier. After pairing the surveys, each was examined to discover any changes that occurred between the pre- and post-surveys. This information was recorded into an excel spreadsheet and compiled into tables.

Results

There were nine CRNAs and one AA who participated in this project. Each participant completed a pre- and post-survey and the results of each were compared. The surveys contained the same questions and were administered via a hard copy. The only descriptors of the participants recorded were the numbers of their own home address, which were provided by the participants.

A summary of the results from the surveys is in Table 1. There were several similar responses from the participants, such as correctly identifying the components of LPV, performance of ARMs, and determining appropriate PEEP levels. Some participants left questions blank, and some did not go into significant detail with their answers, which made interpretation of data difficult. Five of the participants indicated that they used the compliance and PV loops on the ventilator. Two participants said they began using these tools following the educational intervention. All participants reported on the pre-intervention surveys that they already currently use some form of LPV in their practice. The participants varied in their responses regarding factors leading them to perform ARMs. None of the participants identified rationales for failing to implement all aspects of LPV into their current practice following the educational intervention.

A McNemar test, presented in Table 2, was performed using IBM SPSS software to analyze the binary paired data of question number 7 in the pre- and post-surveys. This question was a “yes” or “no” response regarding the use of compliance and pressure-volume loops on the ventilator, as illustrated in Appendices A and B. The null hypothesis states there is no difference in use of compliance and/or pressure-volume loops on the ventilators between the pre- and post-surveys. Due to the limited sample size, the McNemar test concluded an acceptance of the null hypothesis.

Table 1

Survey Response Data

Participant Identifier	Survey Question	Pre-Survey	Post-Survey
1	2	low Tidal Volume	low FiO2
CRNA		low inspiratory pressures	BMI tailored PEEP
		preventing atelectasis	Tidal Volume 6-8ml/kg
	3	YES	YES
		increased PEEP	low FiO2
		Vital Capacity breaths	PCV mode on ventilator
	4	increased PEEP	Vital Capacity breaths
		Vital Capacity breaths	
		tidal volume 6-8ml/kg	
	5	increased BMI	atelectasis
		insufflation	position changes
		position changes	
	6	BMI x 0.3	BMI x 0.3
	7	YES	YES
Participant Identifier	**Survey Question**	**Pre-Survey**	**Post-Survey**
12	2	Tidal Volume	decreased FiO2

CRNA		PEEP	PEEP
			Tidal Volume 6-8ml/kg
	3	Sometimes	YES
	4	Manual	Vital Capacity breaths
			Manual
	5	Type of Surgery	decreased oxygen saturation
			position changes
	6	PEEP 6-10 on everyone	BMI tailored PEEP
	7	NO	NO
Participant Identifier	**Survey Question**	**Pre-Survey**	**Post-Survey**
57	2	increased PEEP	PEEP
CRNA		low FiO2	minute ventilation
		recruitment	Functional residual capacity
			compliance
	3	YES	CPAP
			PEEP based on BMI x 0.3
			recruitment before extubation
			use of PV loop
	4	Manual	manual
		Vital Capacity breaths	Vital Capacity breaths
	5	open alveoli	open alveoli
		increase rate of diffusion	leave PEEP to prevent atelectasis
	6	BMI x 0.3	BMI x 0.3
	7	YES	YES
Participant Identifier	**Survey Question**	**Pre-Survey**	**Post-Survey**
3309	2	low FiO2	PEEP
CRNA		BMI tailored PEEP	Tidal Volume 6-8ml/kg
		tidal volume 6-8ml/kg	
	3	YES	YES
		ARM	increased PEEP
		low FiO2	decreased tidal volume
	4	Vital Capacity breaths	Vital Capacity breaths
			manual
	5	after induction	length of case

		as needed throughout case	BMI
			position changes
			oxygen saturation
	6	BMI x 0.3	peak pressures
			oxygen saturation
	7	YES	NO
Participant Identifier	**Survey Question**	**Pre-Survey**	**Post-Survey**
14	2	tidal volume 6-8ml/kg	Tidal Volume 6-8ml/kg
CRNA		PEEP based on BMI x 0.3	FiO2 < 50%
			PEEP based on BMI x 0.3
	3	YES	YES
		tidal volume 6-8ml/kg	
		PEEP based on BMI x 0.3	
		position changes	
		Type of Surgery	
	4	stepwise	stepwise
		comparing PEEP with PIP	
	5	increased CO2 with decreased tidal volume	decreased compliance
		decreased oxygen saturation	decreased oxygen saturation
		decreased compliance	
	6	BMI x 0.3	BMI x 0.3
	7	YES	YES
Participant Identifier	**Survey Question**	**Pre-Survey**	**Post-Survey**
7	2	Vital Capacity breaths	low FiO2
AA		PEEP	PEEP based on BMI x 0.3
		Tidal Volume	Tidal Volume 6-8ml/kg
	3	YES	YES
		Vital Capacity breaths	low FiO2
			Vital Capacity breaths
	4	Vital Capacity breaths	Vital Capacity breaths
	5	after induction	atelectasis
		circuit disconnection	
	6	5 on everyone	BMI tailored PEEP
		(Except on lung patients and hypotension)	

	7	NO	NO
Participant Identifier	**Survey Question**	**Pre-Survey**	**Post-Survey**
8	2	low driving pressures	low FiO2
CRNA		PEEP based on BMI x 0.3	PEEP based on BMI x 0.3
		ARM	Tidal Volume 6-8ml/kg
	3	YES	YES
		PCV lowest pressures	ARM
		tidal volume 6-8ml/kg	low FiO2
	4	Vital Capacity breaths	Vital Capacity breaths
	5	after induction	after induction
		decreased oxygen saturation	as needed throughout case
	6	BMI x 0.3	BMI x 0.3
	7	NO	YES
Participant Identifier	**Survey Question**	**Pre-Survey**	**Post-Survey**
11	2	Tidal Volume	low FiO2
CRNA		PEEP	PEEP
			Tidal Volume 6-8ml/kg
	3	YES	YES
		low Tidal Volume	low FiO2
		PEEP based on BMI x 0.3	PCV low
	4	Vital Capacity breaths	Vital Capacity breaths
	5	patient history	atelectasis
		decreased oxygen saturation	
		arterial blood gas	
	6		BMI
	7	NO	NO
Participant Identifier	**Survey Question**	**Pre-Survey Response**	**Post-Survey Response**
22	2	low Tidal Volume	PEEP based on BMI x 0.3
AA		individualized PEEP	PCV
			low FiO2
	3	YES	YES
		individualized PEEP	FiO2 < 60%
			PEEP
	4	manual	Manual
			Vital Capacity breaths

	5	BMI	type of surgery
		Type of Surgery	position changes
		decreased oxygen saturation	
	6	BMI	BMI x 0.3
		position changes	
	7	NO	NO
Participant Identifier	**Survey Question**	**Pre-Survey Response**	**Post-Survey Response**
23	2	low FiO2	PEEP
CRNA		PEEP based on BMI x 0.3	low tidal volume
		PCV	increased respiratory rate
		tidal volume 6-8ml/kg	compliance
	3	YES	YES
		PCV	increased PEEP
		FiO2 < 40%	increased respiratory rate
	4	Vital Capacity breaths	Vital Capacity breaths
	5	decreased oxygen saturation	position changes
		position changes	one lung ventilation
		Type of Surgery	decreased oxygen saturation
		insufflation	
	6	BMI x 0.3	watch PIP
			PEEP 5-10
			compliance
			oxygen saturation
	7	NO	YES

Table 2

McNemar Test

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.

Discussion

Interpreting the results of this project was challenging. Responses suggested the participants gained knowledge regarding LPV following the educational intervention. Barriers preventing the implementation of LPV were unclear and it is uncertain if the educational intervention actually improved implementation. Conversations with the CRNAs during the educational intervention made it apparent that many were hesitant about implementing such large PEEP values recommended in the current literature; the larger PEEP levels simply made them uncomfortable. Several stated they preferred to manually perform recruitment maneuvers with the ventilator bag because they felt they could feel through the bag how tight the patient's lungs were and what the patient required.

The theoretical framework for this project, Andragogy, coincided with the results. During the educational intervention, the participants were given the opportunity to express their opinions and views on the topic (McGrath, 2009). It was obvious during the educational intervention that many of the participants were uncomfortable with using the recommended higher PEEP level of BMI x 0.3. Also, a few expressed concerns regarding limiting FiO_2 levels recommended in current literature, a contradiction to traditional evidence-based practice guidelines. These factors could be the principal barriers preventing the complete implementation of LPV by these anesthesia providers. To overcome these barriers, the CRNAs need to have significant amounts of time with the newer evidence-based practice guidelines regarding LPV to fully understand and rationalize a change in practice. Fully understanding the physiology of LPV could provide CRNAs with the knowledge and confidence needed to justify changing their practices.

Limitations

There were several limitations of the project. The first was a small sample size. We were challenged to recruit enough participants due to the relatively small size of the anesthesia department. Furthermore, we were unable to be present every day to serve as a reminder to complete the project. Emails and reminders were sent throughout the course of the data collection and several weeks were allowed for the surveys to be completed. We also posted a reminder flyer in the anesthesia breakroom. However, it is our understanding that many participants forgot to complete the post-intervention survey. To avoid this in the future, we would recommend conducting a project at a larger facility with a larger anesthesia department. This could compensate for a few people not participating, while still obtaining an adequate sample size.

The second limitation we encountered was that many participants did not provide an identifier on both surveys. We recommend that the identifier be prominent on the surveys, so it is not overlooked by the participants. Despite the identifier being positioned at the top of the survey, many participants might have neglected to see it as a requirement.

The third limitation of this project was the design of the surveys. The surveys were created as more of an explanation and discussion questionnaire. Because of this, it was difficult to compare answers between surveys because each answer differed slightly. It would have been easier to analyze the data had we designed and written the surveys with a Likert-scale, which would have made the data collected more concise. Explicit questions could have also strengthened this survey, for example, we should have asked the participants to identify their reservations regarding the implementation of LPV into their clinical practice.

Recommendations for Future Studies and Clinical Practice

For future projects such as ours, we recommend that project managers collaborate with a statistician to create and organize surveys and other research materials; ensuring that any data collected will be concise and easier to analyze. Also, more research is needed to develop a protocol for calculating a patient's individualized PEEP. There is little published research or guidance to specify how this should be done currently. In addition, the process of calculating PEEP for specific patients remains ambiguous.

This project helped to gain insight regarding the current use and implementation of LPV by the participants. The project enabled us, as researchers, to obtain information and a better understanding of the changes that are occurring in the anesthesia community, specifically concerning lung protective ventilation. This project also provided additional insight into the attitudes, beliefs, and hesitations of CRNAs in this local practice to implement lung protective ventilation.

Conclusion

Lung protective ventilation is a rapidly growing trend in contemporary anesthesia practice. It has proven to be extremely effective in general anesthesia and provides great benefits to patients experiencing endotracheal intubation and mechanical ventilation. Some providers still have doubts or misconceptions regarding the aspects of LPV, which has prevented LPV from becoming widely used today. This project was completed to gain insight into the current use of LPV by CRNAs, the attitudes of anesthesia providers towards LPV, and the barriers that exist preventing LPV from being implemented into everyday practice. Our results suggest more CRNAs currently implement LPV than do not, but that there is still some uncertainty regarding the use of PEEP and recruitment maneuvers. Specific guidance for calculating individualized PEEP and clearer direction for providing recruitment maneuvers should increase the clinical application of lung protective maneuvers.

References

Ball, L., Almondo, C., & Pelosi, P. (2020). Perioperative Lung Protection: General Mechanisms and Protective Approaches. *Anesthesia and Analgesia*, *131*(6), 1789–1798. https://doi.org/10.1213/ANE.0000000000005246

Deng, Qi-Wen., Tan, Wen-Cheng., Zhao, Bing-Cheng., Wen, Shi-Hong., Shen, Jian-Tong., & Xiu, Mao. (2020). Intraoperative ventilation strategies to prevent postoperative pulmonary complications: a network meta-analysis of randomised controlled trials. *British Journal of Anaesthesia*, 124(3), 324-335. https://doi.org/10.1016/j.bja.2019.10.024

Gallart, L., & Canet, J. (2015). Post-operative pulmonary complications: Understanding definitions and risk assessment. *Best Practice & Research Clinical Anaesthesiology*, *29*(3), 315–330. https://doi.org/10.1016/j.bpa.2015.10.004

Güldner, A., Kiss, T., Serpa Neto, A., Hemmes, S. N. T., Canet, J., Spieth, P. M., Rocco, P. R. M., Schultz, M. J., Pelosi, P., & Gama de Abreu, M. (2015). Intraoperative Protective Mechanical Ventilation for Prevention of Postoperative Pulmonary ComplicationsA Comprehensive Review of the Role of Tidal Volume, Positive End-expiratory Pressure, and Lung Recruitment Maneuvers. *Anesthesiology*, *123*(3), 692–713. https://doi.org/10.1097/ALN.0000000000000754

Harris, E.M. (2020, October 14). *Lung protective ventilation and the mechanical breath profile.* Zoom. https://wcu.zoom.us/rec/play/TYpqra64vC81UunbE1GBEedl8Y9uUfMrtJ4UdhWduD-qlh0jD22ZmMfZEbH0HywC2HyAh1Q1efuyo1bE.sg_9C_oNFlXJF8kt?continueMode=t rue&_x_zm_rtaid=DNi5EZvnRSCKTKbx_9L3aQ.1628368256266.fb5e7cdd2f63e8fb93f90dd35440415d&_x_zm_rhtaid=322

Hedenstierna, G., & Edmark, L. (2010). Mechanisms of atelectasis in the perioperative period. *Best Practice & Research Clinical Anaesthesiology*, *24*(2), 157–169. https://doi.org/10.1016/j.bpa.2009.12.002

Hedenstierna, G., & Edmark, L. (2015). Effects of anesthesia on the respiratory system. *Best Practice & Research Clinical Anaesthesiology*, *29*(3), 273–284. https://doi.org/10.1016/j.bpa.2015.08.008

Kim, H. S., Na, S., Lee, K. W., Choi, H., Kim, J. (2018). Application of intraoperative lung-protective ventilation varies in accordance with the knowledge of anaesthesiologists: a single-centre questionnaire study and a retrospective observational study. *BMC Anesthesiology, 18*(33). https://doi.org/10.1186/s12871-018-0495-7

McGrath, V. (2009). Reviewing the Evidence on How Adult Students Learn: An Examination of Knowles' Model of Andragogy. *Adult Learner: The Irish Journal of Adult and Community Education*. https://eric.ed.gov/?id=EJ860562

Rackley, C. R., & MacIntyre, N. R. (2019). Low Tidal Volumes for Everyone? *Chest*, *156*(4), 783–791. https://doi.org/10.1016/j.chest.2019.06.007

Ruszkai, Z., Kiss, E., László, I., Bokrétás, G. P., Vizserálek, D., Vámossy, I., Surány, E., Buzogány, I., Bajory, Z., & Molnár, Z. (2021). Effects of intraoperative positive end-expiratory pressure optimization on respiratory mechanics and the inflammatory response: A randomized controlled trial. *Journal of Clinical Monitoring and Computing*, *35*(3), 469–482. https://doi.org/10.1007/s10877-020-00519-6

Tsistinas, O. (n.d.). *Subject Guides: Johns Hopkins Nursing Evidence-Based Practice: Johns Hopkins EBP Model*. Retrieved March 1, 2021, from https://guides.upstate.edu/c.php?g=1023176&p=7411252

Tusman, G., & Böhm, S. H. (2010). Prevention and reversal of lung collapse during the intra-operative period. *Best Practice & Research Clinical Anaesthesiology*, *24*(2), 183–197. https://doi.org/10.1016/j.bpa.2010.02.006

Valenza, F., Chevallard, G., Fossali, T., Salice, V., Pizzocri, M., & Gattinoni, L. (2010). Management of mechanical ventilation during laparoscopic surgery. *Best Practice & Research Clinical Anaesthesiology*, *24*(2), 227–241. https://doi.org/10.1016/j.bpa.2010.02.002

Whalen, F. X., Gajic, O., Thompson, G. B., Kendrick, M. L., Que, F. L., Williams, B. A., Joyner, M. J., Hubmayr, R. D., Warner, D. O., & Sprung, J. (2006). The effects of the alveolar recruitment maneuver and positive end-expiratory pressure on arterial oxygenation during laparoscopic bariatric surgery. *Anesthesia and Analgesia*, *102*(1), 298–305. https://doi.org/10.1213/01.ane.0000183655.57275.7a

Young, C. C., Harris, E. M., Vacchiano, C., Bodnar, S., Bukowy, B., Elliott, R. R. D., Migliarese, J., Ragains, C., Trethewey, B., Woodward, A., Gama de Abreu, M., Girard, M., Futier, E., Mulier, J. P., Pelosi, P., & Sprung, J. (2019). Lung-protective ventilation for the surgical patient: International expert panel-based consensus recommendations. *British Journal of Anaesthesia*, *123*(6), 898–913. https://doi.org/10.1016/j.bja.2019.08.017

Appendix A

First two numbers of your home address (this will only be used as an identifier):

LUNG PROTECTIVE VENTILATION STRATEGIES

Pre-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. 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?

Appendix B

First two numbers of your home address (this will only be used as an identifier):

LUNG PROTECTIVE VENTILATION STRATEGIES

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. What prompts you to perform recruitment maneuvers?

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

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