EDUCATION ON LUNG PROTECTIVE VENTILATION AND ANESTHESIA PROVIDER PERCEPTION IN THE INTRAOPERATIVE PERIOD

Anna Ruse, BSN, RN, SRNA

A Project Report Submitted to
the Faculty of The School of Nursing at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the
Doctorate in Nursing Practice

Greensboro
2024

Approved by:

Terry C. Wicks	Project Team Leader
Wanda Williams	DNP Program Director

Table of Contents

Abstract

Background: Post-operative pulmonary complications (PPCs) are one of the leading causes of morbidity and mortality during the postoperative period. These complications add over $3.5 billion annually to the healthcare system. With induction of general anesthesia and alveoli collapse, causing atelectasis in about 90% of patients. When atelectasis occurs, it increases the risk of PPCs. Atelectasis and PPCs can be reduced using the lung-protective ventilation (LPV) strategy. The LPV strategy incorporates low tidal volumes, positive end-expiratory pressure (PEEP), alveolar recruitment maneuvers, and lower driving pressures. **Purpose:** This DNP project aims to educate anesthesia providers on the benefits of lung protective ventilation and increase its utilization in the intra-operative period. There is a wide variation in how anesthesia providers ventilate their patients. This project aims to promote the adoption of lung protective ventilation techniques by providing education emphasizing current evidence-based best practices. **Methods:** A pre and post-intervention survey will be administered to the providers. After the pre-intervention survey, an educational in-service will be provided, detailing current research supporting LPV and practice recommendations. A "badge buddy" will be handed out to the anesthesia staff at the hospital which will focus on the crucial elements of Lung Protective Ventilation. Four weeks later a post-intervention survey will be administered to determine if practice change occurred. **Results:** The McNemar test assessed two questions of binary paired data. The first question assessing LPV use in the intra-operative period accepted the null hypothesis. The second question examined whether providers assessed driving pressures in the intra-operative period. The data on this question rejected the null hypothesis. Qualitative analysis was used to analyze the remaining data collected through the survives. **Recommendations and Conclusions:** Many providers already implemented elements of LPV in current practice.

However, more research needs to be conducted to determine the optimal level of PEEP. Anesthesia providers and facilities should continue to prioritize the use of LPV to help minimize PPCs.

Keywords: Lung protective ventilation OR LPV; driving pressures; post-operative pulmonary complications; alveolar recruitment maneuvers OR recruitment maneuvers OR vital capacity breath; atelectasis; positive end-expiratory pressure OR PEEP

Background and Significance

With more than 300 million surgical procedures performed worldwide every year, postoperative pulmonary complications (PPCs) are one of the leading causes of morbidity in the postoperative period (Tsumura et al., 2021). When pulmonary complications occur, they increase the patient's length of stay (LOS) in the hospital and the risk of morbidity and mortality. PPCs include pneumonia, acute respiratory failure, and hypoxemia (Li et al., 2021). The cost of these complications adds over $3.5 billion annually to the healthcare system (Trethewey et al., 2021). Many factors contributing to PPCs are non-modifiable, such as body habitus, patient comorbidities, and surgical factors. However, ventilation strategies can be modified to decrease PPCs (Tsumura et al., 2021). In current anesthesia practice, there needs to be more consistency in how providers choose to ventilate their patients under general anesthesia.

Traditionally, providers have used high tidal volume without positive end-expiratory pressure (PEEP) (Trethewey et al., 2021). This ventilation strategy can lead to alveolar overdistension and barotrauma, which causes the release of pro-inflammatory mediators, increasing the patient's risk for PPCs (Tsumura et al., 2021). Lung protective ventilation (LPV) has been beneficial in ventilating patients with acute respiratory distress syndrome. Evidence shows this ventilation strategy should be implemented when caring for patients under general anesthesia (Futier et al., 2013). The current evidence-based best practice focuses on a more patient-specific approach, including physiologic tidal volumes (Vt), based on a patient's ideal body weight (IBW), individualized PEEP, and alveolar recruitment maneuvers (Tsumura et al., 2021).

The purpose of lung protective ventilation is to help protect the pulmonary epithelial and vascular endothelial cells from the inflammatory process that occurs with traditional ventilation strategies (Tsumura et al., 2021). Using Vt based on patient IBW (6-8 ml/kg) decreases the risk of volutrauma and barotrauma (Tsumura et al., 2021). Volutrauma occurs when there is over-distention in the alveoli, and barotrauma occurs when there are high transpulmonary pressures (Tsumura et al., 2021). Determining IBW is essential when calculating Vt because it is a better predictor of lung size than actual body weight (Tsumura et al., 2021). Individualizing PEEP maintains functional residual capacity (FRC) and reduces the risk of atelectotrauma (Tsumura et al., 2021). Driving pressures during ventilation equals plateau pressure minus PEEP; higher driving pressures have been associated with lower survival rates (Meier et al., 2020). To help decrease driving pressures, PEEP should be increased, and Vt decreased, or a combination of both (Meier et al.,2020). LPV incorporates increased PEEP and lower Vt, which helps decrease driving pressures during mechanical ventilation. Alveolar recruitment maneuvers are crucial in LPV because they recruit collapsed alveoli, increase gas exchange, and improve oxygenation (Hartland et al., 2015). Incorporating these ventilation strategies together decreases the risk of postoperative pulmonary complications.

To decrease the risk of postoperative pulmonary complications and improve patient outcomes, educating anesthesia providers and encouraging them to adopt LPV strategies is crucial. This project aims to increase the use of LPV by anesthesia providers.

Purpose

This DNP project aims to educate anesthesia providers on the benefits of lung protective ventilation and increase its utilization in the intra-operative period. There is a wide variation in how anesthesia providers ventilate their patients. This project aims to promote the adoption of lung protective ventilation techniques by providing education emphasizing current evidence-based best practices.

Review of Current Literature

A search was conducted through PubMed and CINHAL. Search terms included Lung protective ventilation, improved patient outcomes, general anesthesia, open lung ventilation, low tidal volume ventilation, recruitment maneuvers, atelectasis, and postoperative pulmonary complications. A review of articles references from the four systematic reviews and meta-analyses were analyzed. Of the articles included, four were a systematic review of the literature and/or a meta-analysis, six were randomized controlled trials, one was an observational hospital-based study, one was a multi-center quality improvement project, and two were scholarly journal articles. Nine of the articles were level I or level II evidence. Inclusion criteria were articles published within the last ten years (2013-2023) and studies conducted on adults undergoing general anesthesia. Exclusion criteria included articles published before 2013, studies on animals, pediatric cases, and articles focusing on one-lung ventilation.

Conventional Ventilation

Conventional ventilation methods emphasized high tidal volumes, zero PEEP, and no recruitment maneuvers (Tsumura et al., 2021). Tsumura mentions that this strategy leads to ventilator-induced lung injury by causing volutrauma, barotrauma, and atelectotrauma. The article also states that volutrauma occurs from alveolar over-distention from high volumes, atelectotrauma from the repeated opening and closing of the alveoli, and barotrauma from high transpulmonary pressures. With general anesthesia, atelectasis occurs in almost all patients; conventional ventilation strategies do not correct the atelectasis that occurs (Hartland et al., 2015; Tsumura et al., 2021). Due to the negative consequences of the conventional ventilation strategy, changes need to be made to help minimize PPCs.

Postoperative Pulmonary Complications

Lung-protective ventilation (LPV) has been shown to reduce postoperative pulmonary complications (PPCs). A double-blind, parallel-group trial of low tidal volume ventilation (Futier et al. 2013) demonstrated a significant decrease in major pulmonary and extrapulmonary complications within the first seven days post-operation. Their study included patients having laparoscopic colorectal cancer resection surgery. In the LPV group, twenty-one patients experienced complications compared to fifty-five in the conventional ventilation (CV) group (Futier et al., 2013). Futier et al. (2013) also noted that only ten patients in the LPV group required noninvasive or invasive ventilation assistance compared to thirty-four in the CV group. Twenty-four patients in the LPV group had major pulmonary and extrapulmonary complications, fewer than the CV group, in which forty-three patients experienced complications. In a systemic review conducted by Serpa et al., patients who received ventilation with a PEEP of at least 5 cm H_2O and Vt of 7 mL/kg or less predicated body weight (PBW) had fewer PPCs compared to a group receiving Vt greater than 10 mL/kg PBW without PEEP. In the Futier et al. (2013), study and the Yang et al. (2016) meta-analysis of intraoperative ventilation strategies, LPV helped reduce hospital lengths of stay. Kuzkov et al. (2016) evaluated protective ventilation in patients undergoing pancreatoduodenal surgery, demonstrating shorter hospital LOS with an average of 28 days compared to the conventional group with an average LOS of 42 days.

Atelectasis can lead to increased postoperative pulmonary complications, an increased risk for pneumonia, or acute respiratory failure. In a study by Severgini et al. (2013), a significant difference in atelectasis on the chest X-rays was observed on postoperative days 1, 3, and 5. The LPV group in this study had significantly less atelectasis than the CV group (Severgnini et al., 2013). Kuzkov et al. (2016) showed similar results, where the CV group had six patients with atelectasis, compared to the LPV group, which had one patient with atelectasis.

Preventing and/or minimizing atelectasis in patients during general anesthesia can help reduce PPCs.

Recruitment Maneuvers

Recruitment maneuvers are a crucial element in LPV strategy. Recruitment maneuvers recruit collapsed alveoli and restore functional residual capacity (FRC) (Hartland et al., 2015; Tsumura et al., 2021). In a systematic review, Hartland et al. (2015) found recruitment maneuvers increased intra-operative PaO_2 and PaO_2/FiO_2 in three of four studies. Hartland et al. (2015) found that recruitment maneuvers yielded no significant difference in the postoperative period, but Yang et al. (2016) found recruitment maneuvers did decrease postoperative atelectasis.

With recruitment maneuvers and PEEP, there is an increased risk of intra-operative hypotension. The risk of hypotension occurs secondary to increased intrathoracic pressure, which decreases venous return. Hartland et al. (2015) found recruitment maneuvers led to increased use of vasopressors. In a randomized controlled trial by Li et al. (2021), patients who received PEEP and recruitment maneuvers had an increased need for vasopressors; twenty-one patients in this group required intra-operative vasopressors compared to six in the conventional ventilation group. Severgnini et al. (2013) noted eight patients with systolic blood pressures below 90 torr for longer than 3 minutes after recruitment maneuvers. These studies found that although the vasopressor requirements were higher during the intra-operative period, there were no significant differences in adverse outcomes in the postoperative period (Hartland et al., 2015; Li et al., 2021; Severgnini et al., 2013).

Improved Intra-operative Pulmonary Compliance

LPV not only improves patient outcomes in the postoperative period but also improves intra-operative pulmonary compliance. In a randomized controlled trial of patients undergoing laparoscopic surgeries, Nguyen et al. (2021) found the group receiving LPV had a higher PaO_2, higher PaO_2/FiO_2, and lower A-aO_2 difference than the CV group. Overall, the LPV group had better intra-operative oxygenation, improved pulmonary compliance, and reduced driving pressures (Nguyen et al., 2021). Liu et al. demonstrated similar results, showing the LPV group had a lower A-aO_2 and higher SpO_2 in the intra-operative and post-operative periods (Liu et al., 2020). LPV improved oxygenation and lung compliance and reduced driving pressures in the intra-operative period (Liu et al., 2021).

Low Tidal Volume Ventilation

LPV includes low Vt, application of PEEP, and periodic recruitment maneuvers. Most studies define low Vt ventilation as 6-8mL/kg IBW or PBW. However, some studies define low Vt ventilation as 10 mL/kg IBW or PBW. Many studies evaluated whether low Vt ventilation decreases PPCs or if PEEP and recruitment maneuvers are required. Guay et al. (2018) evaluated whether low-volume ventilation would decrease postoperative complications. They found low tidal volumes lead to a decreased risk of pneumonia and decreased the need for invasive or noninvasive ventilation post-operatively. The study data suggested that post-operatively, a slight decrease in hospital LOS occurred when PEEP and recruitment maneuvers were used with low tidal volumes (Gauy et al., 2018). Yang et al. (2016) observed that only a decrease in postoperative lung infections was demonstrated when low tidal volume ventilation was used without PEEP or recruitment maneuvers. However, when low Vt, PEEP, and recruitment maneuvers were used together, there was a significant decrease in postoperative lung infections, atelectasis, and hospital LOS (Yang et al., 2016). To achieve a maximum decrease in PPCs and improve patient outcomes, low Vt ventilation needs to be used with PEEP and recruitment maneuvers.

PEEP

A common question is, what level of PEEP is required during the LPV method to receive the best outcome? A study of laparoscopic colorectal cancer resection patients found patients had better outcomes when a PEEP of 6-8 cm H_2O was used with recruitment maneuvers compared to zero PEEP without recruitment maneuvers (Li et al., 2021). Ladha et al. (2015) found that a PEEP of 5 cm H_2O with low driving pressures decreased PPCs. A systematic review of protective lung ventilation compared to conventional ventilation methods showed moderate levels of PEEP, 6 to 8 cm H_2O, did not significantly increase nor decrease PPCs, and higher levels of PEEP were not adequate for decreasing PPCs (Serpa et al., 2015). Serpa et al. (2015) and Tsumura et al. (2021) suggest more research is needed on the PEEP levels required to reduce PPCs and the optimal PEEP for surgical patients. Tsumura et al. (2021) suggested individualized PEEP should be used for the patient based on their chest wall and lung mechanics.

Driving Pressures and Transpulmonary Pressures

Driving pressures are the plateau pressure minus PEEP; the lower the driving pressure the better the patient outcomes (Williams et al., 2020). Williams mentions how recent studies have shown that driving pressures explain clinical outcomes related to LPV better than tidal volumes in intra-operative and intensive care settings. Driving pressures are the measure of lung stress and strain. Lung strain is the change in lung volume (Vt) relative to the initial volume (FRC), which increases with general anesthesia due to the reduction of FRC (Tsumura et al., 2021). Lung stress is the pressure of force applied to a given area, and high transpulmonary pressures and high driving pressures imply excessive lung stress (Tsumura et al., 2021). Transpulmonary pressures are the plateau pressure minus the esophageal pressure at end-expiration, and lower transpulmonary pressures have also been associated with better patient outcomes (Willams et al., 2020). However, transpulmonary pressures are much harder to assess in the intra-operative period. Following LPV guidelines and incorporating PEEP and low Vt based on patients' IBW can decrease driving and transpulmonary pressures, improving patient outcomes.

Conclusion

Consensus in the literature suggests low tidal volumes, recruitment maneuvers, PEEP, and lower driving pressures decrease postoperative pulmonary complications and improve intraoperative pulmonary compliance. Although recruitment maneuvers can increase intra-operative hypotension, they reduce atelectasis and PPCs and improve intra-operative lung compliance. Intraoperative hypotension did not lead to significant adverse effects in the postoperative period. Studies that assessed intra-operative lung compliance found the lung-protective ventilation method improved intra-operative compliance. While the application of PEEP is beneficial in preventing PPCs, additional studies are needed to determine the optimal level of PEEP during LPV. LPV should include recruitment maneuvers and PEEP for low tidal volumes to be beneficial. The data suggest LPV helps reduce PPCs and improve intra-operative lung compliance compared to high tidal volume ventilation methods.

Conceptual Framework

Many conceptual theories of change can be credited to Kurt Lewin, who developed the three-stage model of planned change. Lewin’s three stages include unfreezing, changing, and refreezing. In the unfreezing stage, current attitudes and practices are encouraged to be replaced with the new desired methods. Lewin believed that for this step to work, the change must occur within the employees and not through management (Anusi et al., 2022). The second phase is the change phase when organizational change occurs. Management must create a strong support and communication system during this phase because resistance often occurs here (Anusi et al., 2022). The final refreezing phase is when the change is accepted and the new normal is made. This final phase ensures employees do not revert to old habits (Anusi et al., 2022). For this project, these three steps will be imperative if the change is to occur. The current habits of high Vt ventilation and no PEEP need to be replaced with the LPV strategy. Education will be provided to employees to show the benefits of this change and hopefully begin the unfreezing stage. During the changing phase, support will be provided with educational materials that will provide information on how to utilize LPV, and the PI will aid as support for this project. Refreezing could occur if this project is successful, but it could also take additional efforts in future projects to help implement an LPV protocol for the site.

Methods

Design

This quality improvement project evaluates changes in how anesthesia providers ventilate patients after an educational session. A pre and post-test survey will be administered to the providers. A "badge buddy" will be handed out to the hospital anesthesia staff, focusing on the crucial elements of lung protective ventilation. The sample design will be convenience sampling. Selection criteria will be based on if they are an anesthesia provider. CRNAs, AAs, and Anesthesiologists will be allowed to participate in the project. To recruit participants, breakfast will be provided to those who attend the educational session.

Translational Framework

The Johns Hopkins Evidence-Based Practice appendix is the framework for this DNP project. This widely used model helps implement change in the healthcare setting. This model is based on three main phases: Practice Question, Evidence, and Translation. The first phase is to identify the practice question, which includes six steps. These initial steps help to recruit an interprofessional team, define the problem, and develop the evidence-based practice question. This step was completed by developing a PICOT question and working with the project team leader and the project site. The second phase is searching for evidence, which includes five steps. These steps focus on finding evidence that relates to the problem, appraising the evidence, and synthesizing the evidence. This occurred by looking at the current literature related to LPV and synthesizing the evidence of the LPV literature. The final phase of this model is the transition into the practice phase, which includes eight steps. These steps focus on creating and implementing an action plan, evaluating outcomes, and reporting the findings. This was completed by administering a pre-and post-intervention survey, presenting an in-service educational session, providing badge buddies to the staff, and reporting the findings. This model is beneficial in developing this project because it provides a guideline for implementing this DNP project best and assessing if practice change occurs after implementation.

Setting and Population

This project was conducted at a 208-bed level III trauma center in the southeastern U.S. This non-profit medical center offers various services to the community. This facility contains 13 operating rooms and an endoscopy suite. This facility works in a care team model and is staffed with CRNAs, Anesthesiologist Assistants, and Anesthesiologists. This facility performs surgeries on a wide variety of patients, including many bariatric surgeries, making this facility an excellent place to implement this DNP project. All anesthesia providers employed at this facility were invited to participate in the QI project.

Project Implementation

Anesthesia staff at the 208-bed hospital facility received a pre-education survey, and following the initial survey, an in-person educational intervention on LPV was presented. The presentation focused on some of the critical elements of LPV and consisted of information from current literature. The presentation focused on how low-volume ventilation, PEEP, and recruitment maneuvers benefit the patient in the intra-operative and post-operative periods. Discussions were also had about identifying poor lung mechanics in the intra-operative period and how to help improve those mechanics with LPV techniques. Following the in-person educational session, a badge buddy was provided to the staff, which focused on the elements of LPV that were discussed. Four weeks later, a post-intervention survey was emailed to participants, and the survey was printed out and posted in the break room for participants to fill out. The pre- and post-surveys then went through statistical analysis.

Data Collection

Procedures. Approval from the Institutional Review Board (IRB) was obtained from the University of North Carolina at Greensboro and the project site before conducting this DNP project. The IRB did not consider this project to be human-subject research. As a result, signed consent was optional before implementation. An informative flyer about the project was provided to all potential subjects. The flyer mentioned that completing the pre- and post-intervention surveys implied consent to participate. Breech in confidentiality was considered a small risk and appropriate steps were taken to minimize the risk. A four-digit code linked the pre and post-surveys to allow for statistical analysis; this code was only known by the individual filling out the survey. The survey contained no identifiers, such as names, employee numbers, or gender.

A pre-and post-survey collected data to evaluate participants' knowledge and attitude towards LPV. The pre- and post-surveys were completed through UNCGs Qualtrix online survey system. The pre-survey was administered in the morning before the educational session. Four weeks after the educational session, a post-survey was administered to the participants via email and a QR code printed in the anesthesia break room. Only the principal investigator and DNP faculty had access to the raw data.

Instruments. Two surveys were administered to the participants, the pre-survey contained eleven questions, and the post-survey contained twelve questions. The questions on these two surveys were identical so that statistical analysis could occur. The only exception to this was that the post-survey contained a question that focused on the limitations of the implementation of LPV. Participants were asked to identify themselves as CRNAs, anesthesia assistants (AAs), or anesthesiologists and how long they had been in practice. Participants were asked about alveolar recruitment maneuvers, driving pressures, and if they currently implemented LPV in practice (see Appendix A & B).

Data Analysis

Qualitative data was collected for this project. The pre and post-surveys were paired via the four-digit identifier code. After pairing the surveys, they were examined to see if changes occurred after the educational session and the use of the LPV badge buddy. The information from the pre- and post-surveys was compiled into an Excel file. Statistical analysis occurred through a McNemar test and qualitative analysis.

Results

There were fifteen participants for this quality improvement project; fourteen were CRNAs, and one was an AA. Each participant completed the pre- and post-survey, and the results were compared. The McNemar test was performed on question #8 and question #11. The remaining questions used qualitative analysis. Question #8 assessed if participants used the LPV strategy, and question #11 asked if participants assessed driving pressures during intra-op ventilation. Table 1 presents the results of the McNemar test of LPV use, which was used to assess binary paired data. Table 2 presents the results of the McNemar test of driving pressure assessment in the intra-operative period, which was used to assess binary paired data. The null hypothesis states no difference between the pre- and post-intervention surveys. The McNemar test revealed acceptance of the null hypothesis for LPV use but rejected the null hypothesis for driving pressure assessment. Question #4 asked what the appropriate Vt range was for LPV. The pre-intervention survey had 53.5% answer 6-8 mL/kg IBW. The post-intervention survey had 67% of participants answer correctly at 6-8 mL/kg IBW. Question #5 assessed the components that contributed to VILI. The pre-intervention survey had 73.3% of participants answer volutrauma, barotrauma, and atelectrauma. The post-intervention survey had 86.6% of participants answer correctly to all three components of VILI. Question #6 asked about the definition of driving pressure. The pre-intervention survey had 60% of participants answer plateau pressure minus PEEP. The post-intervention survey had 73.3% of participants answer the question correctly. Question #7 asked participants how RM benefits the patient. 86.6% of participants answered that RM helps to expand collapsed alveoli by a controlled increase in transpulmonary pressures, which leads to improved gas exchange, decreased atelectasis, and improved lung compliance. The post-intervention survey had 100% of participants answer the question correctly. Question #9 asked if participants used RM in their current practice, and if yes, how they performed RM. 80% of participants answered yes to using RM in current practice. They answered to using manual RMs, a stepwise increase in Vt, vital capacity breaths, and a combo of the RM techniques. 80% of participants also answered yes to using RM on the post-intervention survey. Question #10 asked if the provider currently used PEEP in practice and what the best method to determine PEEP was. 40% of participants answered yes to PEEP and calculated it using BMI x 0.3. The post-intervention survey had 80% of participants answer yes to using PEEP and calculate it based on BMI x 0.3.

Table 1

McNemar Test SPSS

Pre and Post-test Crosstabulation

LPV Use Pre & Post Education

	Post	
Pre	No	Yes
No	3	3
Yes	0	9

Test Statistics[a]

	Pre & Post
N	15
Exact Sig. (2-tailed)	.250[b]

a. McNemar Test

b. Binomial distribution used.

Table 2

Pre and Post-test Crosstabulations

Driving Pressure Assessment Pre & Post Education

	Post	
Pre	No	Yes
No	5	8
Yes	0	2

Test Statistics[a]

	Pre & Post
N	15
Exact Sig. (2-tailed)	.008[b]

a. McNemar Test

b. Binomial distribution used.

Barriers and Limitations

There were multiple barriers to this QI project. One barrier being that there was a significant staffing turnover in the anesthesia department. This turnover occurred during the original project's timeline, resulting in delivering the post-educational survey sooner than initially planned. Another barrier was the small sample size. This small sample size was due to the lack of participation and needs to be more significant. Despite having numerous people attending the educational in-service, only 15 of the attendees completed both the pre-and post-educational surveys. Printouts of the educational material were provided to staff who could not attend the session in hopes that it would increase participation. However, this did not increase the number of participants. This project needs more generalizability due to the small sample size. The post-education survey contained a question asking participants what barriers kept them from implementing the LPV strategy. One answered, "Too confusing from listening to multiple SRNAs talk about the subject," and another answered, "I use some PEEP and occasional RM, but do not follow all recommendations. I do not think patients need that much PEEP". Some clinicians also voiced concerns about barotrauma during the presentation about the use of high PEEP and high pressures during RM.

Discussion

This QI project assessed provider knowledge and implementation of LPV in the intra-operative period before and after an educational in-service session. Survey results showed a slight increase in provider use of the LPV strategy in the intra-operative period. However, the barriers preventing the implementation of this QI project make it uncertain if the intervention improved implementation and knowledge of LPV. The survey also showed that while providers may understand the elements of LPV, they are hesitant to use high levels of PEEP and pressure needed to perform RMs. The post-intervention survey had 100% of participants correctly answer why RMs benefit the patient. However, even though 100% of participants answered why they benefited the patient, only 80% implemented them in practice. They were also provided with educational materials that contained current practice recommendations. However, resistance still occurred to implementing higher levels of PEEP and positive pressure during RMs. Question #11 asked if participants assessed driving pressures during the intra-operative period; this question showed an area of excellent improvement post-intervention. The pre-intervention survey had only 13.3%% of providers answer yes to assessing driving pressures, while the post-intervention survey had 66.6% of providers answer yes. The McNemar test results also rejected the null hypothesis, showing that education made a difference. Keeping driving pressures low in the intra-operative period is a great way to minimize VILI and PPCs in the postoperative period. Based on comments in question #12 of the post-intervention survey, it may have been beneficial to work with the anesthesia providers during cases to assist in implementing the LPV strategy.

Conclusion

Lung protective ventilation is a growing area of interest in the anesthesia community and continues to gain acceptance in anesthesia practice. LPV has shown to be very beneficial in increasing intra-operative lung compliance and oxygenation while minimizing VILI and PPCs in the postoperative period. The inconsistency of appropriate levels of PEEP shows that additional studies need to be conducted to find the most beneficial level of PEEP. Many providers also have hesitancy when it comes to implementing the high levels of PEEP suggested. This project showed that providers could all identify why PEEP benefited the patient, but barriers still limited provider implementation of all LPV techniques. The results of this project suggest that although providers may know about the elements of LPV, continued education on its importance needs to occur. Hands-on guidance should also be provided to clinicians to assist in implementing the LPV technique during the intra-operative period.

References

Anusi, H.i., & Mutambara, E. (2022). A Conceptual Framework of Organisational Change Process in Hospitals. *Academy of Entrepreneurship Journal*, *28*(4), 1–11.

Futier, E., Al., E., Group*, for the I. M. P. R. O. V. E. S., Author AffiliationsFrom the Département d'Anesthésie et Réanimation, Others, B. S.-T. and, Others, A. C. and, Others, F. L. and, Others, N. B. and, H. N. Altarawneh and Others, & Others, F. L. and. (2013, November 7). A trial of intraoperative low-tidal-volume ventilation in abdominal surgery: Nejm. New England Journal of Medicine. https://www.nejm.org/doi/full/10.1056/NEJMoa1301082

Guay, J., Ochroch, E. A., & Kopp, S. (2018). Intraoperative use of low volume ventilation to decrease postoperative mortality, mechanical ventilation, lengths of stay and lung injury in adults without acute lung injury. *The Cochrane database of systematic reviews*, *7*(7), CD011151. https://doi.org/10.1002/14651858.CD011151.pub3

Hartland, B. L., Newell, T. J., & Damico, N. (2015). Alveolar recruitment maneuvers under general anesthesia: a systematic review of the literature. *Respiratory care*, *60*(4), 609–620. https://doi.org/10.4187/respcare.03488

Kuzkov, V. V., Rodionova, L. N., Ilyina, Y. Y., Ushakov, A. A., Sokolova, M. M., Fot, E. V., Duberman, B. L., & Kirov, M. Y. (2016). Protective Ventilation Improves Gas Exchange, Reduces Incidence of Atelectases, and Affects Metabolic Response in Major Pancreatoduodenal Surgery. Frontiers in medicine, 3, 66. https://doi.org/10.3389/fmed.2016.00066

Ladha, K., Vidal Melo , M. F., McLean , D. J., Wanderer, J. P., Grabitz, S. D., Kurth, T., & Eikermann, M. (2015, July). Intraoperative protective mechanical ventilation and risk of postoperative respiratory complications: Hospital based registry study. BMJ (Clinical research ed.). https://pubmed.ncbi.nlm.nih.gov/26174419/

Li, H., Zheng, Z. N., Zhang, N. R., Guo, J., Wang, K., Wang, W., Li, L. G., Jin, J., Tang, J., Liao, Y. J., & Jin, S. Q. (2021). Intra-operative open-lung ventilatory strategy reduces postoperative complications after laparoscopic colorectal cancer resection: A randomised controlled trial. *European journal of anaesthesiology*, *38*(10), 1042–1051. https://doi.org/10.1097/EJA.0000000000001580

Liu, J., Huang, X., Hu, S., Meng, Z., & He, H. (2020). Individualized lung protective ventilation vs. conventional ventilation during general anesthesia in laparoscopic total hysterectomy. Experimental and therapeutic medicine, 19(4), 3051–3059. https://doi.org/10.3892/etm.2020.8549

Meier, A., Sell, R. E., & Malhotra, A. (2020). Driving Pressure for Ventilation of Patients with Acute Respiratory Distress Syndrome. *Anesthesiology*, *132*(6), 1569–1576. https://doi.org/10.1097/ALN.0000000000003195

Nguyen, T. K., Nguyen, V. L., Nguyen, T. G., Mai, D. H., Nguyen, N. Q., Vu, T. A., Le, A. N., Nguyen, Q. H., Nguyen, C. T., & Nguyen, D. T. (2021). Lung-protective mechanical ventilation for patients undergoing abdominal laparoscopic surgeries: A randomized controlled trial. BMC Anesthesiology, 21, 95. https://doi.org/10.1186/s12871-021-01318-5

Serpa Neto, A., Hemmes, S. N., Barbas, C. S., Beiderlinden, M., Biehl, M., Binnekade, J. M., Canet, J., Fernandez-Bustamante, A., Futier, E., Gajic, O., Hedenstierna, G., Hollmann, M. W., Jaber, S., Kozian, A., Licker, M., Lin, W. Q., Maslow, A. D., Memtsoudis, S. G., Reis Miranda, D., Moine, P., … PROVE Network Investigators (2015). Protective versus Conventional Ventilation for Surgery: A Systematic Review and Individual Patient Data Meta-analysis. Anesthesiology, 123(1), 66–78. https://doi.org/10.1097/ALN.0000000000000706

Severgnini, P., Selmo, G., Lanza, C., Chiesa, A., Frigerio, A., Bacuzzi, A., Dionigi, G., Novario, R., Gregoretti, C., de Abreu, M. G., Schultz, M. J., Jaber, S., Futier, E., Chiaranda, M., & Pelosi, P. (2013). Protective mechanical ventilation during general anesthesia for open abdominal surgery improves postoperative pulmonary function. *Anesthesiology*, *118*(6), 1307–1321. https://doi.org/10.1097/ALN.0b013e31829102de

Trethewey, B. N., Bukowy, B. M., Bodnar, S. J., Migliarese, J. E., Falyar, C. R., Harris, E. M., Simmons, V. C., & Silva, S. G. (2021). Certified Registered Nurse Anesthetists' Adherence to an Intraoperative Lung Protective Ventilation Protocol. *AANA journal*, *89*(5), 419–427.

Tsumura, H., Harris, E., Brandon, D., Pan, W., & Vacchiano, C. (2021). Review of the Mechanisms of Ventilator Induced Lung Injury and the Principles of Intraoperative Lung Protective Ventilation. AANA journal, 89(3), 227–233.

Williams, E. C., Motta-Ribeiro, G. C., & Vidal Melo, M. F. (2019, July). Driving pressure and transpulmonary pressure: How do we guide safe mechanical ventilation?. Anesthesiology. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6639048/

Yang, D., Grant, M. C., Stone, A., Wu, C. L., & Wick, E. C. (2016). A Meta-analysis of Intraoperative Ventilation Strategies to Prevent Pulmonary Complications: Is Low Tidal Volume Alone Sufficient to Protect Healthy Lungs?. *Annals of surgery*, *263*(5), 881–887. https://doi.org/10.1097/SLA.0000000000001443

Appendix A: Information Sheet

Project Title: Education on Lung Protective Ventilation and Anesthesia Provider Perception in the Intraoperative Period

Principle Investigator: Anna Ruse

Faculty Advisor: Terry Wicks

What is this about?
I am asking you to participate in this QI project because lung protective ventilation is well studied, yet inconsistencies continue to occur in practice. This QI project will only take about 30 minutes and will involve you completing a pre and post intervention survey and attending an in-service education session. Your participation in the QI project is voluntary.

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

What do I get out of this QI project?
You and your colleagues will get an overview of the current evidence-based literature regarding lung protective ventilation strategies. It will enhance your anesthesia practice and potentially improve patient outcomes.

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

How will confidentiality be maintained?
I will do everything possible to ensure 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. I will use a unique ID number, pseudonyms and/or maintain computer firewalled data storage on personal computers. In addition, the data will be loaded into box.uncg for faculty review. No one else will have access to the raw data.

What if I do not want to be a part of this QI project?
You do not have to be part of this QI project. This project is voluntary, and it is up to you to decide to participate in this QI 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 questions to Anna Ruse aeruse@uncg.edu, and/or Terry Wicks tcwicks@uncg.edu about the project. If you have concerns about how you have been treated in this QI project call the Office of Research Integrity Director at 1-855-251-2351.

Appendix B: Pre- and Post- Intervention Survey

Q1: Please select a 4 digit ID code- this code will be used to link the pre and post survey responses together. Please do not forget this code and use the same code on both surveys.

Q2: Are you a:
-CRNA
-AA
-Anesthesiologist

Q3: How long have you practiced anesthesia?
-0-3 years
-4-7 years
-Over 7 years

Q4: What Vt range is appropriate for lung protective ventilation (LPV)?
-10-12 mL/kg actual body weight
-6-8 mL/kg actual body weight
-10-12 mL/kg ideal body weight (IBW)
-6-8 mL/kg ideal body weight (IBW)

Q5: Select all that apply: Which of the following components contribute to Ventilator Induced Lung Injury (VILI)?
-Volutrauma
-Atelectrauma
-Barotrauma

Q6: What are driving pressures?
-The alveolar pressure above atmospheric pressure exists at the end of expiration.
-The plateau airway pressure minus PEEP.
-A pressure that measures the force of inhalation generated by contraction of the diaphragm.
-The difference between the alveolar pressure and the intrapleural pressure.

Q7: How do alveolar recruitment (ARM) benefit the patient?
-ARM apply the highest level of pressure during inspiration to improve oxygenation.
-ARM help expand collapsed alveoli by a controlled increase in transpulmonary pressure, which leads to improved gas exchange, decreased atelectasis, and improved lung compliance.
-ARM apply positive pressure at the end of each expiration breath to ensure alveoli do not collapse.

Q8: Do you use the LPV strategy currently in your practice?
-Yes
-No

Q9: Do you currently use ARM? If yes, do you perform them?
-No, I do not use them
-Yes, I use a manual ARM technique
-Yes, I use a Vital capacity Breath technique
-Yes, I use a stepwise increase in Vt to a plateau pressure of 30-40 cmH_2O in PCV mode.
-Yes, I use a combo of the above techniques

Q10: Do you use PEEP in current practice? If yes, how do you initially determine the appropriate PEEP for the patient?

-I do not use PEEP in current practice
-PEEP is determined by patients BMI x 0.3
-Set PEEP to 5 cmH_2O
-Other

Q11: Do you currently assess patients driving pressure to adjust ventilator settings?

-Yes
-No

*Q12: If you have not adopted LPV into practice what are the barriers limiting you from doing so?

(*This question was only on the post-intervention survey)