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Lung-Protective Ventilation Across the Lifespan: Implementation of an Intraoperative Protocol for Adults and Pediatrics

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Executive Summary

Introduction

Prevention of ventilator-induced lung injury (VILI) has been a concern for centuries (Slutsky, 2015). Various intraoperative ventilation strategies have been utilized. Unfortunately, traditional strategies have been shown to cause stretch injury to lung parenchyma and lead to the development of VILI (Güldner et al., 2015; Hess, Kondili, Burns, Bittner, & Schmidt, 2013). The primary goals of current lung-protective ventilation (LPV) strategies are minimizing atelectasis and atelectrauma, avoiding oxygen toxicity, and preventing lung injury resulting from volutrauma or barotrauma. Providers at a large tertiary regional medical center discussed concerns about anesthesia staff not using current LPV strategies perioperatively for adults and pediatrics. The aim of this project was to review contemporary LPV strategies, discuss findings with anesthesia staff, implement findings as default ventilator settings, and provide a laminated reference infographic for the anesthesia machines to increase compliance.

Literature Review

LPV includes low tidal volume (V_T), moderate levels of positive end-expiratory pressure (PEEP), recruitment maneuvers (RMs) routinely and as needed, and low fraction of inspired oxygen (FiO_2). Recommendations for pediatric ventilatory support vary only slightly from adult recommendations due to anatomical differences between pediatric and adult airways. Utilizing a bundle of LPV strategies intraoperatively improves patient outcomes and decreases the incidence of postoperative pulmonary complications.

A review of current literature revealed low V_T of 6-8 mL/kg based on ideal body weight is appropriate for LPV in adults (Guay, Ochroch, & Koch, 2018; Futier et al., 2013; Sundar et al., 2013). In pediatrics, low V_T ventilation is a topic that has yet to come to a consensus due to the lack of evidence. The recommendation by the Pediatric Acute Lung Injury Conference Group regarding V_T is 5-8 ml/kg based on predicted body weight (Imber et al., 2019). Similarly, the Pediatric Mechanical Ventilation Consensus Conference (PEMVECC) recommends V_T less than 10 mL/kg (Kneyber et al., 2017).

Low V_T alone has shown variable outcomes, so low V_T ventilation is recommended as part of an LPV bundle with PEEP and RMs, rather than alone. PEEP helps maintain a positive transpulmonary pressure, which keeps alveoli inflated (Eichler et al., 2018). An optimal level of PEEP decreases driving pressure, improves respiratory compliance and oxygenation, and decreases atelectasis (Pereira et al., 2018). Optimum PEEP provides the best tidal volume at the lowest driving pressure (Garcia- Fernández et al., 2018). Most of the information regarding PEEP in pediatrics is related to those children suffering from pediatric acute respiratory distress syndrome (PARDS), so intraoperative PEEP for healthy pediatrics is frequently extrapolated from adult ventilation and PARDS data.

Recruitment maneuvers can be applied in various ways. These include manual delivery of a few high-volume breaths using a bag valve face mask, continuous insufflation of high pressure for 10-40 seconds either manually or by a ventilator setting, or stepwise increase of PEEP with maintained V_T or driving pressure (García-Fernández et al., 2018). Manual RMs are more likely to cause injury, so ventilator-based vital capacity breaths or incremental RMs are preferred.

High FiO_2 has been associated with major respiratory complications and 30-day mortality (Staehr-Rye et al., 2017). The British Thoracic Society recommended an oxygen saturation goal of 94-98% in healthy patients (O'Driscoll et al., 2017). For patients with severe chronic obstructive pulmonary disease and risk for hypercapnic respiratory failure, oxygen saturation should be maintained at 88-92%, or at a patient-specific target.

Project Methods

Evidence-based research regarding current LPV strategies for both adults and children was disseminated to anesthesia providers at the tertiary regional medical center via an educational presentation at a departmental meeting in summer 2020. In addition, the anesthesia machines at this medical center were reprogrammed with LPV settings per the evidence-based recommendations. Finally, a laminated infographic page was created and placed in the anesthesia machines to encourage compliance.

Evaluation

Following the educational presentation, a 10-question survey was provided to staff members. True or false and Likert-scale questions were used to assess current knowledge, reception of the information, understanding of key components, current ventilation habits, likelihood of implementing recommendations, and barriers to implementation. Respondents were also asked for their title and years of experience. The anonymous questionnaires were completed voluntarily and collected by a third party.

Overall, survey results showed a large majority of respondents reported confidence that implementing LPV strategies would improve patient outcomes. Even more respondents indicated willingness to support implementation of these strategies. The results implied at least good intentions for adoption of the protocol. Additional follow-up is needed to determine the true extent to which recommendations were implemented.

Limitations of this project included sampling bias, time constraints, and questionnaire design. A convenience sample of anesthesia staff in attendance at a monthly meeting at a large teaching hospital was utilized, which was only a portion of the total number of anesthesia staff at the facility. The educational presentation was limited to 20 minutes, which allowed for only brief discussion of each LPV component. While most of the staff in attendance filled out surveys as requested, they had a limited time to do so before moving on to other obligations. The authors later discovered the questionnaire allowed for ambiguous answers, leading to difficulty in analyzing the efficacy of the educational presentation.

Generalizing conclusions to all populations may be problematic due to the small sample size and nature of the facility. The participants were staff members of a large teaching hospital and were accustomed to updating practice based on new evidence. Their response may or may not be different from anesthesia professionals practicing at other facilities. Whether they are more likely or less likely to enact lasting change would be difficult to determine and is beyond the scope of this project.

Embracing and implementing change is always difficult. For experienced clinicians with a long history of successful intraoperative ventilation and postoperative extubation, updating ventilation practices may be especially challenging. Survey results implied participants were open to trying new RM techniques and LPV strategies as a bundle, which bodes well for this project’s overall impact.

Impact on Practice

This project resulted in an increase in staff knowledge regarding LPV strategies. The analysis of the survey results led the authors to believe the evidence-based information regarding incremental RMs and optimizing PEEP based on either an incremental approach or using pressure-volume loops was well received. Because the incremental RMs were the most complex portion of the presentation, more time was spent discussing them than any of the other concepts. Survey results indicated an overall acceptance and willingness to incorporate the basics of LPV strategies into the daily routines of the anesthesia staff.

A second impact of this project included reprogramming ventilators at the host facility with more evidence-based LPV functions. First, an "exit PEEP" was added to the vital capacity breath function. When the vital capacity breath is chosen, the ventilator provides 30 cm H_2O of pressure for 30 seconds, after which a PEEP of 6 cm H_2O is provided until the ventilator switches back to the chosen baseline mode. Second, two versions of preprogrammed incremental RMs were added: one for average, healthy patients and one for patients who require more pressure (e.g., patients with high body mass index).

Conclusions

Prevention of lung injury and postoperative pulmonary complications is the responsibility of the anesthesia provider. Continually updating knowledge of current LPV strategies is vital to maintaining excellence in anesthesia care. The predicted long-term impact of this project is the continued use of LPV strategies for perioperative patients at the host facility. This information may spread organically as providers at the host facility move to other locations. In addition, the evidence-based recommendations provided in the project could be easily distributed to other facilities. Continuation of this project would involve updating this collection of evidence and recommendations as necessary and distributing findings to the host anesthesia group as well as other facilities. Widespread implementation of these recommendations would help prevent postoperative pulmonary complications in perioperative patients across the lifespan, further increasing the safety of undergoing anesthesia and improving patient outcomes.

Recommendations for future projects include updating the collection of evidence-based recommendations as they become available. Maintaining and encouraging use of new evidence-based knowledge through hands-on or small group training sessions covering driving pressure, pressure-volume loops, incremental recruitment maneuvers, and the ways these concepts can be used to optimize administration of PEEP. Annual inservices on ventilator programmed settings and updates can provide opportunities to gain new knowledge on current recommendations. Opportunities to expand on the evidence can include provider observations up to and including implementation of research studies that evaluate the effectiveness of LPV as a bundle and as individual components.

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