Effect of peak inspiratory pressure on the development of postoperative pulmonary complications in mechanically ventilated adult surgical patients: a systematic review protocol

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Review question/objective: The objective is to identify the effect of peak inspiratory pressure on the development of postoperative pulmonary complications. More specifically, the objective is to identify the effect of maintaining intraoperative peak inspiratory pressure less than or equal to 30 cmH₂O compared with peak inspiratory pressure greater than 30 cmH₂O on the incidence of postoperative atelectasis, pneumonia and acute respiratory distress syndrome in mechanically ventilated adult surgical patients.

Keywords: acute respiratory distress syndrome; airway pressure; atelectasis; mechanical ventilation; pneumonia; postoperative pulmonary complication

Background

Most patients undergoing general anesthesia require ventilation assistance which is most often provided by a mechanical ventilator. Mechanical ventilators function by providing external positive pressure to force medical gases such as air, oxygen, nitrous oxide and anesthetic agents into the lungs. Early mechanical ventilators were very basic and operated using a volume-based mode. The only means to regulate the amount of medical gas being delivered to a patient in a volume-based mode was to manipulate the volume of each breath, called the tidal volume, and the rate of ventilation. Modern mechanical ventilators include a pressure-based mode that make it possible to more precisely control the volume and the pressure of the medical gas being delivered to the patient. As a result of having more options and finer control of mechanical ventilation, there has been a wealth of research targeted at determining the most effective way to mechanically ventilate a patient while minimizing both the incidence and severity of negative physiological complications.

Postoperative pulmonary complications (PPCs) are alterations in normal lung physiology and have been identified as the most significant type of complication leading to morbidity and mortality for postoperative patients. To be considered a PPC, the pulmonary complication must develop within seven days after surgery and can encompass a wide range of fatal to nonfatal complications, including atelectasis, pneumonia and acute respiratory distress syndrome (ARDS). Atelectasis is the collapse of the small airways and alveoli that make up the site of gas exchange within the lungs, and it is one PPC that has been directly related to the mode of mechanical ventilation. If peak inspiratory pressure is too high, the excess pressure can cause overdistention of the alveoli to the point that they lose structural integrity and collapse. Atelectasis leads to the initiation of local inflammation and can precipitate pneumonia and ARDS as edema, alveolar epithelial damage and the disruption of gas exchange progresses within the lungs.

Approximately 10% of all surgical patients, and as many as 30–40% of thoracic or abdominal surgery patients develop PPC. It has been reported that about 50% of the risk for developing PPC is related to the patients’ health condition, and the remaining 50% is attributed directly to the surgical procedure, the administration of anesthesia and...
Given the frequency and significance of PPC, determination of optimal mechanical ventilation strategies to prevent the development of PPC is a paramount goal for intraoperative patient care.

Conventional mechanical ventilation tidal volume in the range of 10–15 ml/kg was the original standard to ensure adequate gas exchange and to prevent intraoperative hypoxemia. Recently, a new mechanical ventilation approach called protective ventilation was shown to reduce the incidence of mortality in critically ill ARDS patients in the ICU. Utilization of a lower tidal volume of 6 ml/kg and maintenance of a plateau pressure less than 30 cmH₂O showed significant improvement in the effectiveness of mechanical ventilation, maintenance of adequate oxygenation and subsequent recovery of patients diagnosed with ARDS. Lower tidal volume and plateau pressure maximums were effective in treating ICU patients diagnosed with ARDS because it decreased the volume-induced stress within the lungs and prevented damage to the endothelium and epithelium lining of alveoli. This, in turn, reduced the widespread pulmonary inflammation cascade frequently caused by conventional mechanical ventilation.

Given the success of protective mechanical ventilation strategies in managing ARDS patients in the ICU, the technique was expanded into the operating room. The intention was to prevent the occurrence of ARDS as a PPC in patients with otherwise healthy lungs. Several variations of protective ventilation techniques have evolved to include the addition of positive end-expiratory pressure (PEEP) and/or recruitment maneuvers. Recruitment maneuvers briefly increase peak inspiratory pressure as high as 40–50 cmH₂O to reopen collapsed alveoli, and PEEP maintains a low residual pressure at end expiration to prevent complete exhalation and alveolar collapse.

Research exploring the effectiveness of intraoperative protective ventilation as a means to prevent the development of PPC has been done and has generally compared a lower tidal volume of less than 10 ml/kg, with or without PEEP and the utilization of recruitment maneuvers, with conventional mechanical ventilation settings of higher tidal volume greater than 10 ml/kg. Although lower tidal volume ventilation is intended to deliver an overall lower peak inspiratory pressure, it does not guarantee a lower pressure ceiling without an appropriate setting for maximum peak inspiratory pressure. Similarly, the utilization of high PEEP and recruitment maneuvers, without the safeguard of an inspiratory pressure maximum, have not been shown to decrease PPC. Protective ventilation strategies have the potential to produce a peak inspiratory pressure greater than 30 cmH₂O, despite the utilization of lower tidal volume.

Modern mechanical ventilators in the operating room can now independently measure and manipulate peak inspiratory pressures, and set pressure maximums in both volume-based and pressure-based modes. A peak inspiratory pressure maximum can be concurrently utilized with protective ventilation settings to ensure that neither PEEP nor recruitment maneuvers create excessive peak inspiratory pressure greater than 30 cmH₂O within the lungs. Data relating peak inspiratory pressure and the incidence of PPC exists but have not been synthesized to determine the significance of the relationship. An initial search of the Cochrane Database of Systematic Reviews and the JBI Database of Systematic Reviews and Implementation Reports indicated that no systematic review currently exists on this topic or is in progress at this time. We will synthesize primary research results to determine a recommendation for the utilization of a peak inspiratory pressure maximum which could impact intraoperative mechanical ventilation practices and reduce the incidence of PPC.

Inclusion criteria
Types of participants
The review will consider studies that include mechanically ventilated adult surgical patients over 18 years receiving general anesthesia for any surgical procedure. Patients with a preexisting diagnosis of atelectasis, pneumonia or ARDS will be excluded.

Types of intervention(s)/phenomena of interest
The review will consider studies that evaluate mechanical ventilation strategies, including protective ventilation strategies in either pressure-based or volume-based modes, with or without the use of PEEP or alveolar recruitment maneuvers that include peak inspiratory pressure and PPC data. Peak inspiratory pressures less than or equal to 30 cmH₂O will be compared with peak inspiratory pressures greater
than 30 cmH₂O to determine the incidence of post-operative atelectasis, pneumonia and ARDS in mechanically ventilated adult surgical patients.

Outcomes
The review will consider studies that include the following outcomes in the first seven postoperative days: PPCs, specifically atelectasis, pneumonia and ARDS.

Types of studies
The review will consider experimental study designs, including randomized controlled trials, non-randomized controlled trials, quasi-experimental studies, before and after studies, prospective and retrospective cohort studies, case-control studies and analytical cross-sectional studies for inclusion.

Search strategy
The search strategy aims to find both published and unpublished studies. A three-step search strategy will be utilized in this review. An initial limited search of Embase, MEDLINE Complete, ProQuest Nursing and Allied Health and Web of Science will be undertaken followed by an analysis of the text words contained in the title and abstract and the index terms used to describe the article. A second search using all identified keywords and index terms will then be undertaken across all included databases. Third, the reference list of all identified reports and articles will be searched for additional studies. Only research published in the English language will be considered for inclusion in this review. Studies published from January 1980 to present will be considered for inclusion in this review because mechanical ventilators did not include a pressure-based mode or the ability to manipulate peak inspiratory pressure until early 1980s.¹

The databases to be searched include: Embase, MEDLINE Complete, ProQuest Nursing and Allied Health and Web of Science.

The search for unpublished studies will include: MedNar.com (website), GreyLit.org (by the New York Academy of Medicine) (website), ProQuest Dissertations and Theses (database) and ClinicalTrials.gov (website).

Initial keywords to be used will be: mechanical ventilation OR artificial ventilation; protective ventilation; inspiratory pressure; airway pressure; tidal volume; PPC; atelectasis; pneumonia; acute respiratory distress syndrome (ARDS).

Assessment of methodological quality
Studies selected for retrieval will be assessed by two independent reviewers for methodological validity prior to inclusion in the review using standardized critical appraisal instruments from the Joanna Briggs Institute Meta-analysis of Statistics Assessment and Review Instrument (JBI-MAStARI) (Appendix I). Any disagreements that arise between the reviewers will be resolved through discussion or with a third reviewer.

Data extraction
The data extracted will include specific details about the interventions, populations, study methods and outcomes of significance to the review question and specific objectives. Quantitative data will be extracted from studies included in the review using the standardized data extraction tool from JBI-MAStARI (Appendix II). The data extracted will include specific details about the interventions, populations, study methods and outcomes of significance to the review question and specific objectives.

Data synthesis
Quantitative data will, wherever possible, be pooled in statistical meta-analysis using JBI-MAStARI. All results will be subject to double data entry. Effect sizes expressed as relative risk (for categorical data) and weighted mean differences (for continuous data) and their 95% confidence intervals will be calculated for analysis. Heterogeneity will be assessed statistically using the standard χ² and also explored using subgroup analyses based on the different study designs included in this review. Where statistical pooling is not possible, the findings will be presented in narrative form, including tables and figures to aid in data presentation, wherever appropriate.

Acknowledgements
Special thanks to Dr. Dru Riddle for his support and guidance and also to Alysha Sapp and Bogi Huddleston, Health Reference Librarians, for their help with the literature search for this topic.

References


Appendix I: Appraisal instruments

**MAStARI appraisal instrument**

### JBI Critical Appraisal Checklist for Randomised Control / Pseudo-randomised Trial

**Reviewer**  
**Date**

**Author**  
**Year**  
**Record Number**

<table>
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<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
<th>Unclear</th>
<th>Not Applicable</th>
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<td>1. Was the assignment to treatment groups truly random?</td>
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<td>2. Were participants blinded to treatment allocation?</td>
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<td>3. Was allocation to treatment groups concealed from the allocator?</td>
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<td>4. Were the outcomes of people who withdrew described and included in the analysis?</td>
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<td>5. Were those assessing outcomes blind to the treatment allocation?</td>
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<td>6. Were the control and treatment groups comparable at entry?</td>
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<td>7. Were groups treated identically other than for the named interventions</td>
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<td>8. Were outcomes measured in the same way for all groups?</td>
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<td>9. Were outcomes measured in a reliable way?</td>
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<td>10. Was appropriate statistical analysis used?</td>
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**Overall appraisal:**  
Include  
Exclude  
Seek further info.

**Comments (Including reason for exclusion)**

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SYSTEMATIC REVIEW PROTOCOL

JBI Critical Appraisal Checklist for Descriptive / Case Series

Reviewer ___________________________ Date ___________________________

Author ___________________________ Year __________ Record Number __________

1. Was study based on a random or pseudo-random sample? [ ] Yes [ ] No [ ] Unclear [ ] Not Applicable
2. Were the criteria for inclusion in the sample clearly defined? [ ] Yes [ ] No [ ] Unclear [ ] Not Applicable
3. Were confounding factors identified and strategies to deal with them stated? [ ] Yes [ ] No [ ] Unclear [ ] Not Applicable
4. Were outcomes assessed using objective criteria? [ ] Yes [ ] No [ ] Unclear [ ] Not Applicable
5. If comparisons are being made, was there sufficient descriptions of the groups? [ ] Yes [ ] No [ ] Unclear [ ] Not Applicable
6. Was follow up carried out over a sufficient time period? [ ] Yes [ ] No [ ] Unclear [ ] Not Applicable
7. Were the outcomes of people who withdrew described and included in the analysis? [ ] Yes [ ] No [ ] Unclear [ ] Not Applicable
8. Were outcomes measured in a reliable way? [ ] Yes [ ] No [ ] Unclear [ ] Not Applicable
9. Was appropriate statistical analysis used? [ ] Yes [ ] No [ ] Unclear [ ] Not Applicable

Overall appraisal: [ ] Include [ ] Exclude [ ] Seek further info

Comments (including reason for exclusion) ___________________________________________
JBI Critical Appraisal Checklist for Comparable Cohort/Case Control

Reviewer __________________________ Date __________________________

Author __________________________ Year __________ Record Number ______

1. Is sample representative of patients in the population as a whole? □ Yes □ No □ Unclear □ Not Applicable
2. Are the patients at a similar point in the course of their condition/illness? □ Yes □ No □ Unclear □ Not Applicable
3. Has bias been minimised in relation to selection of cases and of controls? □ Yes □ No □ Unclear □ Not Applicable
4. Are confounding factors identified and strategies to deal with them stated? □ Yes □ No □ Unclear □ Not Applicable
5. Are outcomes assessed using objective criteria? □ Yes □ No □ Unclear □ Not Applicable
6. Was follow up carried out over a sufficient time period? □ Yes □ No □ Unclear □ Not Applicable
7. Were the outcomes of people who withdrew described and included in the analysis? □ Yes □ No □ Unclear □ Not Applicable
8. Were outcomes measured in a reliable way? □ Yes □ No □ Unclear □ Not Applicable
9. Was appropriate statistical analysis used? □ Yes □ No □ Unclear □ Not Applicable

Overall appraisal: Include □ Exclude □ Seek further info. □

Comments (Including reason for exclusion)
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Appendix II: Data extraction instruments

MAStARI data extraction instrument

JBI Data Extraction Form for Experimental / Observational Studies

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<td>Observational</td>
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<tr>
<td>Other</td>
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Participants

Setting

Population

Sample size

Group A ____________________  Group B ____________________

Interventions

Intervention A

Intervention B

Authors Conclusions:

Reviewers Conclusions:
## Study results

### Dichotomous data

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### Continuous data

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