Effectiveness of positive end-expiratory pressure, decreased fraction of inspired oxygen (FiO₂) and vital capacity recruitment maneuver on prevention of pulmonary atelectasis in patients undergoing general anesthesia: a systematic review protocol

Deborah Garbee¹,²
Laura Bonanno¹,²
Jennifer Martin, CRNA, MN, DNP Student¹,²

1. Louisiana State University Health Sciences Center at New Orleans
2 Louisiana Center for Evidence Based Nursing at Louisiana State University Health Sciences Center at New Orleans: an Affiliate Center of the Joanna Briggs Institute

Corresponding Author
Deborah Garbee
dgarbe@lsuhsc.edu

Review question/objective

The objectives of this systematic review are to systematically review and synthesize research literature in order to identify the most effective interventions used by anesthesia providers in the reduction of pulmonary atelectasis. This review aims to answer the following specific question: In patients undergoing general anesthesia, what are the effects of peak end expiratory pressure (PEEP), a decreased fraction of inspired oxygen (FiO₂) delivery, and/or the use of a recruitment maneuver on the development of post-operative pulmonary atelectasis? More specifically, the objectives are to identify:

The effectiveness of PEEP, a decreased FiO₂ delivery, and/or the use of a recruitment maneuver on the development of post-operative pulmonary atelectasis in patients undergoing general anesthesia.

Background

General anesthesia is associated with impaired oxygenation and pulmonary atelectasis has been identified as a major cause.⁴ Atelectasis is the collapse of the lung's air sacs, known as alveoli, in all or part of the lungs. The effect of decreased FiO₂, the use of PEEP and a vital capacity recruitment maneuver to prevent post-operative atelectasis has been studied within the anesthesia community. However, the implications for anesthesia practice regarding these interventions have not been well defined. A common practice among anesthesia providers is to perform general anesthesia without the use of PEEP or a vital capacity maneuver and a 100% FiO₂ enduring the course of the anesthetic. A cursory review of the literature reveals that randomized clinical trials do exist regarding post-operative atelectasis and these interventions individually.⁸,⁹ Clinical trials on this subject have been conducted and are currently in progress.³ However, there is no systematic review to reveal data about the
proposed interventions and their effect of post-operative pulmonary atelectasis. This review’s purpose is to provide data on use of PEEP, decreased FiO₂, and/or a recruitment maneuver during general anesthesia in reducing the development of post-operative pulmonary atelectasis.

Central to this review are the key terms: PEEP and FiO₂ as well as ventilation/perfusion ratio (Va/Q), partial pressure of oxygen dissolved in arterial blood (PaO₂), functional residual capacity (FRC), and pulmonary vascular resistance (PVR). For the purposes of this review, these terms are defined as follows:

Positive end expiratory pressure, or PEEP, is used when oxygenation is not adequately maintained with mechanical ventilation alone. Positive end expiratory pressure has many well documented supportive benefits including: decreased shunting and dead space ventilation while improving functional residual capacity, compliance and arterial oxygenation. Shunt and dead space are terms used to describe extreme situations where either blood flow (perfusion) does not meet air flow (ventilation) in the lung. As a result, gas exchange cannot occur. More specifically, shunt is that part of the cardiac output that returns to the left side of the heart without being ventilated and oxygenated. The fraction of inspired oxygen, or FiO₂ is the percentage of oxygen delivered in the gas mixture administered to the patient. Ventilation/perfusion ratio is the match between capillary perfusion and alveolar ventilation - which must be very well executed. The ventilation/perfusion ratio is ideally equal to one. Functional residual capacity is the volume of gas which is left in the lungs at the end of a passive exhalation. Pulmonary vascular resistance, or PVR, increases with the incidence of any disease process that restricts pulmonary blood flow. Examples include chronic lung disease, pulmonary embolus, alveolar hypoxia, acidosis, hypoxemia and many vasoactive drugs.

Two reasons to prevent the formation of pulmonary atelectasis are a decrease in lung compliance and a decrease in the PaO₂. Research has demonstrated the occurrence of atelectasis formation in the most dependent parts of the lung in 90% of patients undergoing general anesthesia within minutes of induction. In addition, general anesthesia causes an increase in intrapulmonary shunt. This shunting can impair oxygenation and is directly correlated with the formation of atelectasis. Three causes of atelectasis will be discussed including compression, gas reabsorption and pulmonary surfactant impairment.

The intrathoracic and abdominal cavities are separated by the diaphragm, which when functioning normally, generates differential pressures in these two cavities. However, when general anesthesia is induced the work of the diaphragm is disabled as it relaxes and moves cephalad. This inhibits the maintenance of these two distinct cavity pressures causing the dependent lung to actually crush the adjacent lung causing compression atelectasis. There is a difference in diaphragmatic displacement between the anesthetized spontaneously breathing patient and the patient receiving positive-pressure ventilation with paralysis. The spontaneously breathing patient is able to overpower the weight of the abdominal contents by generating enough active tension. The paralyzed patient; however, has a passive diaphragm that gets displaced to the upper nondependent portion of the chest cavity by positive pressure ventilation. Lastly, the reduction in FRC may also be attributed to the loss of intercostal muscle function which contributes to the development of atelectasis as well.

The second cause of atelectasis, reabsorption atelectasis, occurs by two pathways. The first occurs after complete airway obstruction causing a gas pocket to collect and eventually collapse distal to the obstruction. The second occurs without airway obstruction and deals with low ventilation and perfusion...
ratios (Va/Q) in the zones of the lungs. As FiO₂ is increased the PaO₂ increases and oxygen moves from the alveoli to the capillary blood at an expedited rate. This efflux of oxygen out of the alveoli causes alveolar collapse and the lung tissue to become progressively smaller. To review, atelectasis is mostly likely to occur with a high FiO₂ and a low Va/Q.²

The third and last cause of atelectasis deals with pulmonary surfactant impairment during general anesthesia. Surfactant acts as a lubricant for the alveoli and is produced by alveolar type 2 cells. It prevents alveolar collapse by reducing alveolar surface tension and prohibits small alveolus from emptying into larger alveoli with a lower surface tension. This would result in a single alveolus and surfactant is the reason this phenomenon does not occur.⁵ General anesthesia decreases the production of surfactant; therefore, making patients more susceptible to alveolar collapse during this time. This mechanism is considered to be of least importance in the formation of perioperative atelectasis as compression and absorption are credited with the most involvement.⁴

A recruitment maneuver is performed by the anesthetist by inflating the patient’s lungs to an airway pressure of 40cm H₂O. This increased airway pressure must be maintained for duration of seven to eight seconds. This maneuver, also named a vital capacity maneuver, functions to re-expand all previously collapsed lung tissue. The recruitment maneuver functions to increase the patient’s lung volumes and restore their pulmonary function to a pre-anesthesia state. However, when the recruitment maneuver is followed by a FiO₂ of 1.0, the formation of new atelectasis occurs within 10 minutes. In summary, the recruitment maneuver should be followed with a moderate FiO₂ in order to eliminate atelectasis formation and shunting. Therefore, this will lessen the need for an increased FiO₂ prior to the patient’s extubation.⁵

The adverse effects of perioperative atelectasis include decreased lung compliance, impairment of oxygenation, increased PVR, and development of lung injury. These effects can persist into the post-operative period and last for two days causing an impact on patient recovery.⁵ Atelectasis formation in the perioperative patient is liable to be a cause of infection and a contributor to pulmonary complications. This occurrence increases the length of hospitalization which in turn increases health care cost. In addition, patient satisfaction with their overall surgical and anesthesia experience is dampened in light of this preventable occurrence.⁶ In conclusion, it is of utmost importance for the anesthesia provider to reverse the effects or prevent the formation of perioperative atelectasis in order to prevent pulmonary complications in the postoperative patient.

Keywords
Anesthesia; pulmonary function; atelectasis; fractional oxygen concentration; peak end expiratory pressure

Inclusion criteria

Types of participants

This review will consider studies that include patients regardless of gender, race, or nationality, who have been administered a general anesthetic for their surgery, regardless of the type of surgery being performed. This review will be limited to adult patients aged 18 to 65 years having an ASA classification of I, II, or III. The American Society of Anesthesiologists (ASA) Physical Status classification system assesses the degree of the patient’s preoperative physical status. Classifications include: ASA I-
healthy patient, ASA II- mild systemic disease, ASA III- severe systemic disease.\(^1\) This review will exclude those patients hospitalized for greater than 24 hours before surgery or patients with significant heart or lung disease; therefore, excluding patients with ASA IV or V classification.

**Types of interventions**

This review will consider studies that evaluate the use of PEEP, decreased \(\text{FiO}_2\) and/or a recruitment maneuver during general anesthesia in comparison to general anesthesia performed without the use of PEEP, decreased \(\text{FiO}_2\) and/or a recruitment maneuver.

**Types of outcomes**

This review will consider studies that include the following outcome measure: post-operative pulmonary complications, specifically the incidence of post-operative pulmonary atelectasis.

**Types of studies**

This review will consider both experimental and epidemiological study designs including randomized controlled trials, non-randomized controlled trials, quasi-experimental, and if necessary before and after studies, prospective and retrospective cohort studies, case control studies that evaluate the effectiveness of interventions addressing the management of pulmonary atelectasis during general anesthesia 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 PubMed and CINAHL will be undertaken followed by analysis of the text words contained in the title and abstract, and of the index terms used to describe article. A second search using all identified keywords and index terms will then be undertaken across all included databases. Thirdly, the reference list of all identified reports and articles will be searched for additional studies. Studies published in English will be considered for inclusion in this review. Studies published through March 2013 will be considered for inclusion in this review.

The databases to be searched include:

CINAHL
PubMed
ISI Web of Science
EMBASE.

The search for unpublished studies will include: theses and dissertations; reports; non-independent research, or other documents produced and published by government agencies, academic institutions and other groups that are not distributed or indexed by commercial publishers; and unpublished scholarly papers. This search will include ProQuest and www.clinicaltrials.gov.

Initial keywords to be used will be:

anesthesia
pulmonary function
atelectasis
pulmonary shunt
radiology
oxygen index
fractional oxygen concentration
peak end expiratory pressure
intraoperative complications/etiology, prevention and control
postoperative complication/etiology, prevention and control
postoperative complications/prevention and control
oxygen inhalation therapy/adverse effects.

Assessment of methodological quality
Quantitative papers selected for retrieval will be assessed independently by two 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 collection
Quantitative data will be extracted from papers 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. Attempts to contact authors of primary studies for missing information or to clarify unclear data will be made.

Data synthesis
Quantitative papers will, where possible, be pooled in statistical meta-analysis using JBI-MAStARI. All results will be subject to double data entry. Effect sizes expressed as odds ratio (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 Chi-square and also explored using subgroup analyses based on the different quantitative 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 where appropriate.

Conflicts of interest
There are no conflicts of interest.

Acknowledgements
This review contributes to the Doctor of Nursing Practice degree award for Jennifer Martin.
References


Appendix I: Appraisal instruments

MAStARI appraisal instrument

<table>
<thead>
<tr>
<th>JBI Critical Appraisal Checklist for Randomised Control / Pseudo-randomised Trial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reviewer: ---------</td>
</tr>
<tr>
<td>Author: ---------</td>
</tr>
<tr>
<td>1. Was the assignment to treatment groups truly random?</td>
</tr>
<tr>
<td>2. Were participants blinded to treatment allocation?</td>
</tr>
<tr>
<td>3. Was allocation to treatment groups concealed from the allocator?</td>
</tr>
<tr>
<td>4. Were the outcomes of people who withdrew described and included in the analysis?</td>
</tr>
<tr>
<td>5. Were those assessing outcomes blind to the treatment allocation?</td>
</tr>
<tr>
<td>6. Were the control and treatment groups comparable at entry?</td>
</tr>
<tr>
<td>7. Were groups treated identically other than for the named interventions</td>
</tr>
<tr>
<td>8. Were outcomes measured in the same way for all groups?</td>
</tr>
<tr>
<td>9. Were outcomes measured in a reliable way?</td>
</tr>
<tr>
<td>10. Was appropriate statistical analysis used?</td>
</tr>
</tbody>
</table>

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

Comments (Including reason for exclusion)
________________________________________________________________________
________________________________________________________________________
# JBI Critical Appraisal Checklist for Descriptive / Case Series

**Reviewer**  
**Date**

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

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

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

**Comments (Including reason for exclusion)**

---

doi: 10.11124/jbisrir-2013-902
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? ☐ ☐ ☐ ☐
2. Are the patients at a similar point in the course of their condition/illness? ☐ ☐ ☐ ☐
3. Has bias been minimised in relation to selection of cases and of controls? ☐ ☐ ☐ ☐
4. Are confounding factors identified and strategies to deal with them stated? ☐ ☐ ☐ ☐
5. Are outcomes assessed using objective criteria? ☐ ☐ ☐ ☐
6. Was follow up carried out over a sufficient time period? ☐ ☐ ☐ ☐
7. Were the outcomes of people who withdrew described and included in the analysis? ☐ ☐ ☐ ☐
8. Were outcomes measured in a reliable way? ☐ ☐ ☐ ☐
9. Was appropriate statistical analysis used? ☐ ☐ ☐ ☐

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

Comments (Including reason for exclusion)

________________________________________

________________________________________

doi: 10.11124/jbisrir-2013-902
Appendix II: Data extraction instruments

MAStARI data extraction instrument

**JBI Data Extraction Form for Experimental / Observational Studies**

Reviewer: ___________________________ Date: ___________________________

Author: ___________________________ Year: ___________________________

Journal: ___________________________ Record Number: ___________________________

**Study Method**

RCT □ Quasi-RCT □ Longitudinal □

Retrospective □ Observational □ Other □

**Participants**

Setting

Population

**Sample size**

Group A □□□□□□□□ Group B □□□□□□□□

**Interventions**

Intervention A

Intervention B

Authors Conclusions:

Reviewers Conclusions:
Study results

Dichotomous data

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Intervention ( ) number / total number</th>
<th>Intervention ( ) number / total number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Continuous data

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Intervention ( ) number / total number</th>
<th>Intervention ( ) number / total number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>