2016

Does the Use of Positive End Expiratory Pressure (PEEP) During Surgery Decrease Respiratory Complications Twenty-Four Hours Post Operative?

Malgorzata Majewski
Rhode Island College, mmajewski_8034@email.ric.edu

DOES THE USE OF POSITIVE END EXPIRATORY PRESSURE (PEEP) DURING SURGERY DECREASE RESPIRATORY COMPLICATIONS TWENTY-FOUR HOURS POST-OPERATIVE?

A Major Paper Presented

by

Malgorzata Majewski

Approved:

Committee Chairperson _____ _____
(Date)

Committee Members _____ _____
(Date)

_____ _____
(Date)

Director of Master's Program _____ _____
(Date)

Dean, School of Nursing _____ _____
(Date)

DOES THE USE OF POSITIVE END EXPIRATORY PRESSURE (PEEP) DURING SURGERY DECREASE RESPIRATORY COMPLICATIONS TWENTY-FOUR HOURS POST-OPERATIVE?

by

Malgorzata Majewski

A Major Paper Submitted in Partial Fulfillment

of the Requirements for the Degree of

Master of Science in Nursing

in

The School of Nursing

Rhode Island College

2016

Abstract

General anesthesia can lead to pulmonary compromise during surgery. Nurse anesthetists in the operating room are responsible for minimizing pulmonary complications while managing ventilation through mechanical ventilation. Positive end-expiratory pressure (PEEP) can be used to improve oxygenation, prevent airway collapse and facilitate expansion of alveoli during each breath. Yet the use of PEEP varies among clinicians, as supported by the literature. The goal of this systematic review was to evaluate the impact of PEEP intra-operatively on selected respiratory outcomes. The research question was: Does the use of positive end expiratory pressure (PEEP) during surgery decrease respiratory complications 24 hours post-operative? This review was guided by the Preferred Reporting Items for Systematic Review (PRISMA) flow diagram and checklist. Within study quality was assessed with The Critical Appraisal Skills Programme (CASP) Randomised Controlled Trials Checklist and Popay's guidelines were followed for a narrative cross study synthesis. Seven studies were included in this systematic review. Results demonstrated less impaired gas exchange with higher PEEP and overall respiratory compliance was greater in subjects who were managed with PEEP. Most PEEP groups demonstrated less pulmonary infiltrates post operatively as well as less atelectasis and pleural effusions. Using PEEP intra-operatively generated higher oxygen saturation post-operatively and fewer patients who received PEEP needed 100% oxygen in the recovery unit. This review yielded evidence related to the intraoperative use of PEEP that nurse anesthetists may use to guide their anesthesia practice.

Table of Contents

Does The Use Of Positive End Expiratory Pressure (PEEP) During Surgery Decrease Respiratory Complications Twenty-Four Hours Post-Operative?

Background/Statement of the Problem

Postoperative respiratory complications can lead to longer hospital stays and increased health care costs. Morbidity and mortality are significantly increased following pulmonary complications after surgery. Postoperative respiratory failure leads to reintubation, the need for intensive care unit stay and the possibility of developing ventilator-associated pneumonia. Patients that are discharged later from a complication require more health care resources during a time when there is a shortage of health care professionals, which puts stress on the U.S. health care system (Neligan, 2012).

Preventing these complications is an important goal of intraoperative respiratory management by anesthesia providers. The goals of managing respiratory function via a ventilator during surgery include maintaining adequate minute ventilation, preventing air trapping, preventing airway collapse, and maintaining adequate oxygenation (Acosta, Santisbon, & Varon, 2007). Oxygenation can be improved by using PEEP, which also prevents airway collapse and allows easier expansion of alveoli during each breath (Acosta et al.). Positive end-expiratory pressure (PEEP) has been shown to limit atelectasis by improving oxygenation and keeping the alveoli open (Vargas et al., 2014).

The use of PEEP in intensive care units has been shown to improve patients' respiratory status. Acosta et al. (2007) described how PEEP decreases the work of breathing of respiratory muscles and also improves lung unit recruitment, compliance and oxygenation. Studies on PEEP used during surgery also suggest improved outcomes in

patients. The Almarakbi, Fawzi, and Alhashemi (2009) study found that PEEP used with recruitment maneuvers done every 10 minutes was more effective than PEEP alone. Kilpatrick and Slinger (2010) supported using both PEEP and recruitment maneuvers to minimize atelectasis. However, currently, using PEEP in the operating room is at an anesthesia provider's discretion and is not recognized consistently as imperative to the intra-op respiratory management of a patient (Canet & Mazo, 2010). Intra-op management is focused on maintaining adequate minute ventilation, end-tidal carbon dioxide (CO2) levels, and oxygen saturation as measured by a pulse oximeter (Acosta et al., 2007).

The use of PEEP during surgery needs to be explored. Using PEEP in the operating room may have the potential to improve respiratory status of patients and therefore reduce hospital stays. The goal of this systematic review is to evaluate the impact of PEEP intra-operatively on selected respiratory outcomes.

The review of the literature is presented in the next section.

Literature Review

The databases searched included MEDLINE and CINAHL. The keywords used included respiratory complications, pulmonary complications, surgery, mechanical ventilation, positive end-expiratory pressure, and anesthesia. Studies from 1999 to 2015 were included in the search.

Pulmonary Complications after Anesthesia

Pulmonary complications postoperatively are responsible for significant morbidity and mortality from anesthesia and surgery (Canet & Mazo, 2010). These complications include postoperative pneumonia, unexplained fever, respiratory failure requiring the support of a ventilator, excessive bronchial secretions, bronchospasm, productive cough, atelectasis, abnormal breath sounds, and hypoxemia. The incidence rates can vary from 2-40% and are dependent on the treatment setting and type of surgery. Surgical trauma, anesthesia effects, and the patient's prior health are factors that contribute to the development of postoperative pulmonary complications. Patients who have an abnormal immune response are more likely to develop complications and the overall health of the patient strongly influences the possibility of these complications (Canet & Mazo).

Patients that receive general anesthesia have a 90% rate of developing atelectasis (Kilpatrick & Slinger, 2010). Injury during mechanical ventilation is greatest in the non-atelectatic alveoli. This is due to tidal volume shifting to aerated alveoli and causing over-inflation during mechanical ventilation (Kilpatrick & Slinger). In 1964, Nunn (cited in Magnusson & Spahn, 2003) showed that there is an alteration of gas exchange by

shunting and unequal ratios of ventilation to perfusion during anesthesia. Atelectasis has been viewed as the result of oxygenation impairment that occurs during general anesthesia. Atelectasis that occurs during surgery may cause pulmonary complications. In major surgery, atelectasis has been found to continue for up to two days. Non-obese patients who undergo laparoscopic surgery will have atelectasis dissipate within 24 hours **(**Magnusson & Spahn).

Anesthesia causes a reduction in functional residual capacity (Canet & Mazo, 2010). There is an immediate atelectasis formation in the dependent lung regions. This occurs from surfactant function impairment, alveolar air absorption, and lung tissue compression. What follows is a mismatch of ventilation to perfusion leading to increased dead space, shunt, and hypoxemia. Changes to the central nervous system regulation of breathing, resulting from anesthetics further add to postoperative pulmonary complications. There is also a change of the neural drive that provides signals to the chest wall and upper airway muscles (Canet & Mazo).

Patients under general anesthesia do not take deep breaths periodically, which leads to atelectasis, decreased pulmonary compliance, and increased shunting (Magnusson & Spahn, 2003). This can be reversed by lung hyperinflation. Patients that do not receive supplemental oxygen during general anesthesia have a reduced arterial oxygen tension by 22%. Compliance of the lungs decreases by 15%. On average, atelectasis occurs in 15-20% of lung tissue near the diaphragm in patients receiving general anesthesia. Usually, atelectasis will be gone 24 hours after laparoscopic surgery. For major surgery, atelectasis may not dissipate until the third day post op (Magnusson & Spahn).

Other complications from general anesthesia include hypoxemia and pneumonia. Half of all patients will have arterial oxygen saturation between 85-90% for up to 30 minutes during elective surgery (Magnusson & Spahn, 2003). Hypoxic events can occur during induction, intraoperatively, and during emergence of anesthesia. Factors that contribute to hypoxemia during anesthesia were found to be hypovolemia, respiratory depression, anemia, reduced cardiac output, increased shunt, increased ventilation to perfusion mismatch, reduced alveolar volume, and hypoventilation. Lung changes related to atelectasis have been found to predispose patients to pneumonia. Reducing atelectasis formation may reduce the incidence of pneumonia post operatively (Magnusson & Spahn). Anesthesia induction decreases forced residual capacity of the lungs by 16-20% (Villars, Kanusky, & Levitzky, 2002). A cranial shift of the diaphragm occurs after induction. Normal forced residual capacity returns only after the anesthetic is terminated. Forced residual capacity is reduced during anesthesia due to three factors: diaphragmatic position; chest wall configuration; and blood volume distribution between the abdomen and thorax (Villars et al.).

There is no evidence that supports one type of anesthetic technique in place of another to reduce postoperative pulmonary complications (Canet & Mazo, 2010). No consensus or clear recommendations exist on best ventilation strategies to decrease complications either. It is suggested that low tidal volume be used for all patients. Patients at high risk for atelectasis should receive therapeutic strategies to prevent formation of atelectasis (Canet & Mazo).

It has been advised to avoid transfusion when possible due to an association of increased pulmonary complications post-op from transfusions (Canet & Mazo, 2010).

Other ways to diminish complications include decreasing the duration and surgical aggressiveness, not using new surgical techniques, and using minimally invasive surgery such as laparoscopic. Providing adequate analgesia post-op has been shown to reduce complications. Lung expansion such as incentive spirometry, deep breathing exercises, continues positive airway pressure (CPAP), postural drainage, and chest physical therapy can result in fewer complications. The best techniques, which are simple, include mobilization, cough stimulation, positioning, hydration, sleep, and ambulation (Canet & Mazo).

PEEP Use during Anesthesia

Several two-group designs were conducted that explored the use of PEEP during anesthesia, including the works of Choi et al. (2006), Weingarten et al. (2010), and Severgnini et al. (2013). The aim of the Choi et al. study was to examine the effects of mechanical ventilation on the alveolar hemostatic balance in patients who did not have lung injury (2006). Alveolar coagulation was the focus of this study. When there are procoagulant changes in the lungs, it causes fibrin to be deposited in the airways, which leads to pulmonary inflammation. Fibrin deposited in alveoli is a sign of acute lung injury. The sample of patients included those undergoing elective surgery lasting five hours or more. These patients received either a low tidal volume of 6 ml/kg with 10 cm H20 PEEP or a higher tidal volume of 12 ml/kg and no PEEP. The results showed that procoagulant changes occurred when no PEEP was used during larger tidal volume mechanical ventilation. The study demonstrated that using PEEP and smaller tidal volumes prevents procoagulant changes.

Weingarten et al. (2010) compared lung ventilation that consisted of two groups of 20 patients each. The recruitment maneuver group (RM) utilized recruitment maneuvers, tidal volumes of 6ml/kg and 12cmH20 of PEEP. The control group received conventional ventilation consisting of no recruitment, a higher tidal volume of 10ml/kg and no PEEP. The study found that the non-conventional method of ventilation improved oxygenation intra-operatively. The control group resulted in four patients having pleural effusions, while the RM group had just one. No patient in the RM group had hypercapnia in recovery, acute lung injury, pulmonary embolism, or prolonged respiratory failure. The control group, on the other hand, had one of each of those complications. The length of hospital stay was three days less on average in the RM group compared to the control group. The control group also utilized one extra day of supplemental oxygen compared to the RM group (Weingarten et al.).

The Severgnini et al. (2013) study was similar to the Weingarten et al. study. There were a total of 55 patients at the end of this study, 26 receiving standard ventilation and 27 receiving protective ventilation. The standard ventilation group received no PEEP and higher tidal volume of 9ml/kg. The protective ventilation group received 10cmH20 PEEP with lower tidal volumes of 7ml/kg. The group with PEEP and smaller tidal volume (protective ventilation group) had better outcomes post operatively. In the standard ventilation group, 12 out of 26 patients showed no infiltrate on their x-ray post op day 3. This was compared to the protective ventilation group that had 22 out of 27 patients with no infiltrate. While the protective group had no patients with purulent secretions post op day 3, the standard ventilation group had three patients with this finding. On post-operative day 0 pleural effusions occurred in two patients in the standard

ventilation group and in no patients in the protective ventilation group. The number of patients with cough after surgery was twice as high in the standard ventilation group compared to the protective ventilation group (Severgnini et al.).

It was common that patients with no PEEP received higher tidal volumes in all three studies (Choi et al., 2006; Severgnini et al., 2013; Weingarten et al., 2010). This made it difficult to understand which intervention, PEEP or higher tidal volume, caused the result. The Almarakbi, Fawzi, and Alhashemi (2009) study was the only study reviewed that utilized four groups. The first group (P) utilized 10 cmH20 PEEP during the entire surgery. Group R utilized an inspiratory pressure of 40 cm H20 once during surgery for 15 seconds with no PEEP. Group RP also applied the same inspiratory pressure as Group R, followed by 10 cmH20 of PEEP for the length of surgery. The last group, RRP, was similar to group R, expect that this group repeated the inspiratory pressure of 40 cmH20 every 10 minutes during the surgery. Group RRP also used 10 cmH20 PEEP during the entire surgery. The average oxygen saturation of group RRP after 1 hour in PACU was 97%. At the same time interval, the average oxygen saturation for group RP was 94%, and 93% for groups R and P. Group RRP was discharged the earliest, in 29.5 hours on average. Group RP was discharged in 52.8 hours, group R in 69 hours, and group P in 64.9 hours on average. The Almarakbi et al. study found that both PEEP and frequent recruitment maneuvers had best outcomes (group RRP).

Next, the framework that was used to guide this systematic review will be presented.

Theoretical Framework

Our health care system relies on systematic reviews to guide clinical practice (Moher, 2009). The quality of reporting these systematic reviews can vary. This puts limitations on the reader to properly assess for weakness and strengths in the systematic review. In the past, articles published in popular medical journals were found to lack quality in assessing the studies for scientific criteria. This lead an international group to develop a guidance statement focusing on randomized controlled trials' meta-analyses called QUOROM. QUOROM stands for Quality Of Reporting of Meta-analysis. These guidelines were revised and named PRISMA. PRISMA stands for Preferred Reporting Items for Systematic reviews and Meta-Analyses (Moher et al., 2009).

The PRISMA guidelines were used as a framework for this systematic review. A flow diagram consisting of four phases to help guide this systematic review adapted from PRISMA is included in Figure 1 on the next page (Moher et al., 2009). This diagram guided the writer in choosing the randomized control trials to include in this systematic review. The first phase of the flow diagram is identification. It identifies the number of records via a through database search. The next phase is screening, followed by eligibility. The final phase of the PRISMA flow diagram is termed 'included', which consist of the number of studies included in the synthesis. PRISMA was chosen during this systematic review to help improve reporting (Moher et al.).

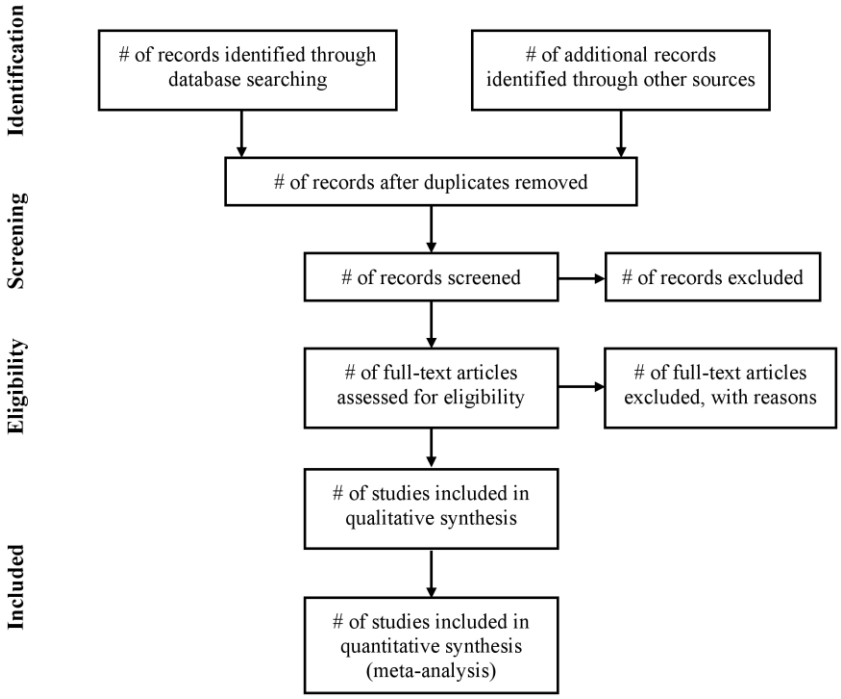

Figure 1. *Flow diagram for preferred reporting items for systematic reviews and meta-analyses (Moher et al., 2009)*

This systematic review followed the 27-item PRISMA checklist (Moher et al., 2009) as illustrated in Table 1 on the next page. The PRISMA checklist was utilized in that each item on the checklist was examined and considered as studies were reviewed for consideration.

Table 1

Check List for Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Moher et al., 2009)

Section/Topic	#	Checklist Item	Reported on Page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome-level assessment (see Item 12).	
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group and (b) effect estimates and confidence intervals, ideally with a forest plot.	
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., health care providers, users, and policy makers).	
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review level (e.g., incomplete retrieval of identified research, reporting bias).	
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	

doi:10.1371/journal.pmed.1000097.t001

The Critical Appraisal Skills Programme (CASP) Randomised Controlled Trials Checklist (CASP UK, 2013) was used during this systematic review to examine the research systematically and to carefully determine its trustworthiness, relevance and value. The CASP checklist consists of a total of 11 questions (CASP UK) (Table 2).

Table 2

Critical Appraisal Skills Programme (CASP) Randomised Controlled Trials Checklist

Study title 1				
Study ID				
(A) Are the results of the trial valid?		Yes	Can't tell	No
	1. Did the trial address a clearly focused issue?			
	2. Was the assignment of patients to treatments randomized?			
	3. Were patients, health workers and study personnel blinded?			
	4. Were the groups similar at the start of the trial?			
	5. Aside from the experimental intervention, were the groups treated equally?			
	6. Were all the patients who entered the trial properly accounted for at its conclusion?			
(B) What are the results?				
	7. How large was the treatment effect?			
	8. How precise was the estimate of the treatment effect?			
(C) Will the results help locally?		Yes	Can't tell	No
	9. Can the results be applied in your context or to the local population?			
	10. Were all clinically important outcomes considered?			
	11. Are the benefits worth the harms and costs?			

Validity, relevance, and results are three important components to examine when performing a critical appraisal. It is important to determine what the results mean for a specific group of people or patient population. Results that are biased or are of poor quality can lead to false conclusions and potentially harm the public. Looking at research

to make healthcare decisions (CASP UK, 2013), the CASP checklist answers questions such as “Are the results of the trial valid?” and “Did the trail address a clearly focused issue?” (CASP UK). The checklist examines if the participants involved in the study were blinded and if the groups were similar at that start, as well as if they were treated equally. Results are also examined in terms of the size of the effect and its precision and if the results can be applied to the local population and beyond. Finally, this methodology considers the outcome and examines if the benefits were worth the harm and costs (CASP UK).

A narrative synthesis was used for this systematic review. The guidelines used for this synthesis are based on the methods described by Popay et al. (2006). Table 3 on the next page outlines the main elements in Popay’s narrative synthesis. The first element involves theory development, specifically to the intervention and how it works. The second element is described as synthesis of preliminary findings. The next element deals with data relationships and the last addresses the errors of the synthesis. The guidelines describe placing studies in specific groups together, performing an analysis of each study as well as a cross comparison of the studies (Popay).

Table 3

The Main Elements in a Narrative Synthesis (Popay et al., 2006)

Main elements of synthesis	**Effectiveness Reviews**	**Implementation Reviews**
1. Developing a theoretical model of how the interventions work, why and for whom	***Purpose:*** i To inform decisions about the review question and what types of studies to review ii To contribute to the interpretation of the review's findings iii To assess how widely applicable those findings may be	***Purpose:*** • To inform decisions about the review question and what types of studies to review • To contribute to the interpretation of the review's findings • To assess how widely applicable those findings may be
2.Developing a preliminary synthesis	***Purpose:*** • To organise findings from included studies to describe patterns across the studies in terms of: o The direction of effects o The size of effects	***Purpose*:** • To organise findings from included studies in order to: o Identify and list the facilitators and barriers to implementation reported o Explore the relationship between reported facilitators and barriers
3. Exploring relationships in the data	***Purpose:*** • To consider the factors that might explain any differences in direction and size of effect across the included studies	***Purpose:*** • To consider the factors that might explain any differences in the facilitators and/or barriers to successful implementation across included studies • To understand how and why interventions have an effect
4. Assessing the robustness of the synthesis product	***Purpose:*** To provide an assessment of the strength of the evidence for: o Drawing conclusions about the likely size and direction of effect o Generalising conclusions on effect size to different population groups and/or contexts	***Purpose:*** • To provide an assessment of the strength of the evidence for drawing conclusions about the facilitators and/or barriers to implementation identified in the synthesis. Generalising the product of the synthesis to different population groups and/or contexts

A comparison was made, using the guidelines by Popay, between the studies. The studies were compared for: number of participants; types of interventions; types of

outcomes measured; aim of the studies; population; setting; inclusion criteria; exclusion criteria; severity of illness; outcomes; and the key conclusions of the study authors.

Next, the methodology that was used to guide the research will be discussed.

Method

Purpose/Clinical Question

The purpose of this systematic review was to evaluate the impact of PEEP intra-operatively on selected respiratory outcomes. The research question was: Does the use of positive end expiratory pressure (PEEP) during surgery decrease respiratory complications twenty-four hours post-operative?

Inclusion/Exclusion Criteria/Limits

Types of studies. Only randomized controlled trials (RCTs) published within the prior 20 years, in English and meeting the inclusion criteria, were included.

Types of participants. Studies with adult patients with an endotracheal tube and receiving mechanical ventilation during surgery were considered for this review. Inclusion criteria included patients who received general anesthesia with or without paralytics. For this review, adult was defined as 17 years of age or older. Patients younger than 17 years of age were excluded as their minute ventilation requirements differ from adults. Both genders were included. Studies with any of the following published in a manuscript were included: Pa02/Fi02 Ratio, respiratory system compliance, chest infiltrates post-op, atelectasis post-op, pleural effusions post-op, oxygen saturation post-op, and need for oxygen post-op. All studies needed to report the following: Tidal volume and PEEP.

Types of PEEP settings. At least one group with a higher PEEP compared to the control group of lower PEEP or no PEEP.

Types of outcomes. The following outcomes were examined: Pa02/Fi02 ratio; respiratory system compliance; chest infiltrates post-op; atelectasis post-op; pleural effusions post-op; oxygen saturation post-op; and need for oxygen post-op.

Search Strategy

The aim of the search strategy was to conduct a comprehensive search related to the stated purpose. CINAHL and MEDLINE databases were searched for phases and keywords in the titles and abstracts.

Terms searched included:

operation OR surgery OR intra-op OR operating room

AND

PEEP OR ventilator setting OR mechanical ventilation

AND

respiratory function OR lung function OR post-op

The search strategy followed the PRISMA flow diagram (Moher et al., 2009). First, the studies were identified via CINAHL and MEDLINE database searches. Duplicate records were excluded. The Preferred Reporting Items for Systematic reviews and Meta-Analyses flow diagram (PRISMA) was used to guide in choosing trials to include in this systematic review (Moher et al., 2009). The records were screened and later assessed for eligibility. The end result was seven studies that were included for synthesis.

Data Collection

Data collection was done utilizing a data extraction form (Appendix A) constructed by the author. The form was based on the 2014 Cochrane Collaboration's "Data collection form for intervention reviews: RCTs only". The form was modified to include pertinent data points to this systematic review, including: Title; author and year; journal; participants; types of intervention; types of comparison; types of outcomes; population description; inclusion criteria; exclusion criteria; total number randomized; severity of illness; outcome; and key conclusions of study authors.

The following outcomes were listed in the form under "Outcome": Pa02/Fi02 ratio; respiratory system compliance; chest infiltrates post-op; atelectasis post-op; pleural effusions post-op; oxygen saturation post-op; and need for oxygen post-op.

A calculated ratio to look at lung function is the Pa02/Fi02 ratio (Broccard, 2013). This ratio looks at the partial pressure of arterial oxygen (Pa02) to the fraction of inspired oxygen (Fi02). It is a widely used index signifying impairment to gas exchange. This index is also looked at when diagnosing ARDS. A Pa02/Fi02 ratio of less than or equal to 100 signifies severe ARDS. A Pa02/Fi02 ratio between 200 to 300 signifies mild ARDS (Broccard). Specifics related to the PaO2/FiO2 ratio and compliance will be briefly described next.

The respiratory system compliance can be calculated by tidal volume over the difference in peak inspiratory pressure minus PEEP (Weingarten et al., 2010). Lung compliance measures the ability of the organ to stretch (Barash et al., 2013). A stiff lung will have low compliance while high compliance is seen in a pliable lung. Decreased

lung compliance is seen in restrictive pulmonary disease. This is accompanied by smaller force residual capacity. Greater changes in intrapleural pressures are needed to generate the same tidal volume in a patient with reduced lung compliance. Patients who have increased lung compliance also have greater functional residual capacities known as gas trapping. This is seen in chronic obstructive lung disease (Barash et al.). According to Grinan and Truwit (2009), a normal compliance in a mechanically ventilated patient should be 50-100 ml/cmH20.

Assessment Criteria/Critical Appraisal Tool

Quality was assessed with The Critical Appraisal Skills Programme (CASP) Randomised Controlled Trials Checklist (Table 2). This checklist includes a total of 11 questions as described in the framework section. Studies were also assessed for validity before they were included in the review.

Data Synthesis

Using the Popay et al. guidelines (2006), a narrative synthesis was conducted. A comparison was made between no PEEP or low PEEP groups and higher PEEP groups. Data that related to the outcome of respiratory failure was collected. Several data points were compared between PEEP groups versus the control group on post-op day 1. The Pa02/Fi02 Ratio, respiratory system compliance, chest infiltrates post-op, atelectasis post-op, pleural effusions post-op, oxygen saturation post-op, and need for oxygen post-op were examined. Data was summarized and presented in a table. The level of PEEP that was used and how the level influenced respiratory function post-operatively was examined as well as how respiratory function was measured. The question – Does the use

of positive end expiratory pressure (PEEP) during surgery decrease respiratory complications twenty-four hours post-operative? – was answered in this systematic review.

Next, the results of this systematic review will be discussed.

Results

Using the PRISMA flow diagram (Moher et al., 2009), a total of 15 studies were identified through the initial database search. In this identification phase of the PRISMA flow diagram, no additional studies were found through other sources. There were no duplicate records. During the screening phase, five records were excluded. During the eligibility phase, three records were excluded. In the last phase of the PRISMA flow diagram, seven studies were identified to be included in this systematic review.

The seven studies (Tusman et al., 1999, Choi et al., 2006, Almarakbi et al., 2009, Talab et al., 2009, Weingarten et al., 2010, Karsten et al., 2011, Severgnini et al., 2013) in this review are presented in chronological order, with the oldest first. Each study was first summarized in the data extraction form (Appendix B) and then each trial was critically appraised using the Critical Appraisal Skills Programme (CASP) Randomised Controlled Trials Checklist (CASP UK, 2013) (Appendix C).

Individual Study Summaries and Critical Analysis

The Tusman[1] et al. trial (1999) (Appendix B-1) examined 30 patients with ASA II or III who were greater than 60 years of age. The aim of this study was to test the effectiveness of a recruitment strategy of the lungs and its effect on lung mechanics and oxygenation. Data were collected between 1996 to 1997 in a hospital in Argentina. Patients that had surgery, which was spinal, laparoscopic, upper abdominal, or thoracic were excluded from this study. Patients needed to have general anesthesia of greater than two hour duration. There was one comparison group called ZEEP which utilized no PEEP and had a tidal volume of 7-9 ml/kg. The intervention groups were the recruitment

group and the PEEP group. The PEEP group utilized the same tidal volume as the ZEEP group, but a PEEP of 5 cmH20. The recruitment group had a tidal volume that increased to 18 ml/kg for 10 breaths and then decreased back down to 7-9 ml/kg. This group had PEEP that ranged from 5 to 15 cmH20. The outcomes examined that pertained to this systematic review in the Tusman[1] et al. trial included respiratory compliance and the Pa02/Fi02 ratio.

The recruitment group had the highest compliance of 62 cmH20. This was significantly different ($P<0.05$) when compared to the ZEEP (43 cmH20) and PEEP (46 cmH20) groups. This was followed by the next highest of 46 cmH20 found in the PEEP group. The ZEEP group had the lowest compliance of 43 cmH20. The Pa02/Fi02 ratio was also highest in the recruitment group of 190. No significance level was reported. The PEEP group had a Pa02/Fi02 ratio of 152, while the ZEEP group had the lowest ratio of 128. The arterial oxygenation (Pa02) during anesthesia for the ZEEP group was 128mmHg. This was compared to the PEEP group with a Pa02 of 152mmHg and the recruitment group with a Pa02 of 190mmHg ($P<0.01$). The authors concluded that the arterial oxygenation increased with the recruitment strategy when utilized while patients were under anesthesia. The findings were thought to occur due to reversal of atelectasis when the recruitment maneuver was applied. The authors also stated that this study was small and that it is possible that the oxygenation in the PEEP group versus the ZEEP group may have occurred from chance alone (Tusman et al.).

The critical appraisal of the Tusman[1] et al. trial (1999) (Appendix C-1) suggested that not all outcomes which are clinically important were considered. Chest imaging to examine atelectasis or pleural effusions were not performed. The sample size was small,

with only 30 patients. This study had a small sample size but did report significant findings with a P value of <0.05 for lung compliance and P value of <0.01 for Pa02 results between the ZEEP, PEEP, and recruitment groups. However, the sample was very focused and specific: it included patients greater than 60 years of age who were categorized as an ASA II or III.

The Choi[2] et al. trial (2006) (Appendix B-2) had 41 patients within two groups. The aim of this study was to examine patients who did not have lung injury and evaluate the mechanical ventilation effects on the balance between lung tissue and homeostasis. The comparison group was the HVT/ZEEP group. This group had no PEEP and a tidal volume of 800 ml. The intervention group was the LVT/PEEP group, which utilized 10 cmH20 of PEEP and a tidal volume of 400 ml. Patients who were having elective surgery greater than five hours of duration were included in this study. Patients who were part of another trial, took immunosuppressive drugs, had lung disease, thromboembolic disease, recent infections, and recent intensive care stay with respiratory support were excluded from the study. The outcome that was pertinent for this systematic review was respiratory compliance.

The LVT/PEEP group had a higher compliance of 50 compared to the HVT/ZEEP group with a compliance of 38. No significance level was reported. The authors did not report compliance; rather, it was calculated from the reported tidal volume over the difference in peak inspiratory pressure minus PEEP. This study also examined thrombin-antithrombin complexes in bronchoalveolar fluid after a lavage and found that the LVT/PEEP group had a level of 0.8 ng/ml compared to the HVT/ZEEP of 0.95 ng/ml ($p<0.05$). The authors concluded that procoagulant changes, as seen with the thrombin-

antithrombin complexes, are promoted by using higher tidal volumes without PEEP during mechanical ventilation. Lower tidal volumes with PEEP use can prevent these procoagulant changes. This study documented an increase in procoagulant activity in the no PEEP, higher tidal volume group.

The critical appraisal (Appendix C-2) of the Choi[2] et al. trial revealed that with only 41 patients in the sample, the trial lacked precision in the ability to examine the treatment effect though a statistically significant change in thrombin-antithrombin complexes was detected. The appraisal also noted that not all outcomes which were clinically important were considered, includng Pa02/Fi02 ratio and chest imaging. This makes comparison of the effectiveness of this study to others in this trial more difficult.

The Almarakbi[3] et al. trial (2009) (Appendix B-3) studied 60 patients undergoing elective laparoscopic gastric banding surgery under general anesthesia. The aim of this study was to examine laparoscopic gastric banding of obese patients and Pa02 and respiratory compliance after lung recruitments with PEEP. Inclusive criteria included a BMI > 30 kg m^{-2} and age between 18 and 60 years. Exclusion criteria included having COPD, restrictive lung disease, asthma, history of smoking, or increased intracranial pressure. The comparison group was the R group which had no PEEP and one recruitment maneuver. The intervention groups included the RRP group, RP group, and P group. Four recruitment maneuvers with a PEEP of 10 cmH20 were used in the RRP group. The RP group had one recruitment maneuver, followed by 10 cmH20 of PEEP. The P group had a sustained 10cmH20 of PEEP with no recruitment maneuvers. All four groups had a tidal volume of 10ml/kg. This trial reported oxygen status in PACU as one of the outcomes.

The R group had the lowest oxygen saturation (92.5%), with the highest (97%) found in the RRP group (P<0.01). The RP group patients had an oxygen saturation of 94% as compared to that of the P group (93%) (P<0.01). The R and P group had respiratory compliance of 28 ml/cmH20, while the compliance for the RRP group was the highest (41 ml/cmH20); RP group compliance was 32 ml/cmH20 (P<0.01).The conclusion of the authors was that the group with 10cmH20 PEEP with four recruitment maneuvers (group RRP) showed the best respiratory compliance intraopertively and the highest Pa02. The p-value between the groups was reported as < 0.01 for both oxygen saturation and compliance in PACU (Almarakbi et al., 2009).

The critical appraisal of the Almarakbi[3] et al. trial (2009) (Appendix C-3) suggested that all groups may not have been treated equally. Except for the R group, which had no PEEP, the application of PEEP was done at different time intervals for the other groups. This trial also had an additional variable of recruitment maneuvers, which all groups, except for group P, received. The RRP group had more recruitment maneuvers then the R or RP group. Neither PEEP nor recruitment maneuver were the sole variable tested. The Almarakbi[3] et al. trial also did not consider all outcomes which were clinically important: the Pa02/Fi02 ratio and chest imagining were not considered. The sample size of 60 patients was small, but the findings were significant with a significance level of 1% (Almarakbi et al., 2009).

The Talab[4] et al. trial (2009) (Appendix B-4) consisted of 66 adult obese patients. The aim of this study was to prevent atelectasis post operatively by using VCMs (vital capacity maneuvers) with PEEP in patients having laparoscopic bariatric surgery. Patients with a BMI between 30 and 50 kg/m^2 were included in this study and the ages of

the participants varied between 20 to 50 years of age. To be included in this study, patients had to be undergoing laparoscopic bariatric surgery. The patients that were excluded were those with lung or heart disease, those requiring hospitalization after surgery for over 24 hours, those requiring laparotomy, and those with signs of cardiopulmonary disease. The comparison group was the ZEEP group, which had no PEEP. The intervention groups were PEEP 10 group (utilizing 10 cmH20 of PEEP) and the PEEP 5 group (utilizing 5 cmH20 of PEEP). All three groups used a tidal volume of 8-10 ml/kg of lean body weight. This study reported outcomes including chest infiltrates, atelectasis, and the oxygenation status in PACU (Talab et al., 2009).

No patients in the PEEP 10 group were found to have chest infiltrates post-operatively as compared to one patient each in the PEEP 5 and ZEEP group ($P<0.05$). Two patients in the PEEP 10 group had no atelectasis post-op while zero met this criteria in the PEEP 5 and ZEEP groups ($P<0.05$). The number of patients that required 100% oxygen in PACU in the PEEP 10 group was one patient as compared to three patients in the PEEP 5 group and five patients in the ZEEP group ($P<0.05$). The ZEEP group had a stay of 88 minutes in PACU compared to the PEEP 5 group of 78 minutes and the PEEP 10 group of 67 minutes ($P<0.05$) (Talab et al., 2009).

Postoperatively, the ZEEP group had an alveolar-arterial pressure gradient of 63 mmHg as compared to PEEP 5 with 53 mmHg, and PEEP 10 with 30 mmHg ($P<0.05$). . The authors concluded that lung atelectasis could be prevented with 10 cmH20 PEEP following a VCM intraopertively. This technique also resulted in increased oxygenation, less pulmonary complications in PACU, and shorter stays in PACU.

The critical appraisal of the Talab[4] et al. trial (2009) (Appendix C-4) suggested that not all clinically significant outcomes were considered. This trial did not consider the Pa02/Fi02 ratio. This trial was also the only trial out of the seven in this systematic review where compliance was not reported, nor was there a means of calculating it from the data available. The Talab[4] trial had a sample size of 66 patients but reported numerous significant findings. The sample recruitment was very specific: it included obese patients within a specific age group undergoing laparoscopic bariatric surgery; any patient with cardiopulmonary disease was excluded.

The Weingarten[5] et al. trial (2010) (Appendix B-5) had 20 patients each in two groups. The aim of this study was to assess if oxygenation and breathing mechanics improved after ventilator strategies in patients having open abdominal surgery. Patients in this study were greater than 65 years of age and had open abdominal surgery. The exclusion criteria included BMI of 35, abnormal spirometry, pulmonary disease, active asthma, oxygen therapy at home, prior lung surgery and cardiac dysfunction. The intervention group was the recruitment group which utilized a PEEP of 12 cmH20 and a tidal volume of 489 ml. The comparison group was the control group, which employed a PEEP of 2.6 cmH20 and a tidal volume of 776 ml.

The recruitment group had a higher respiratory compliance of 80 ml/cmH20 as compared to that of the control group of 58 ml/cmH20 ($P<0.05$). The Pa02/Fi02 ratio was also higher in the recruitment group than in the control group (409 vs. 300) ($P<0.01$). One patient in each group developed pneumonia post-operatively and one patient in the recruitment group developed atelectasis as compared to five in the control group ($P<0.50$). While one patient in the recruitment group suffered pleural effusions post-op,

this occurred in four in the control group (P<0.50). The authors concluded that subjects over age 65 tolerated lung recruitment and it allowed for improved oxygenation during laparotomy. Respiratory compliance was higher in the recruitment group (22 ml/cmH20) (P<0.05).

The critical appraisal of the Weingarten[5] et al. trial (2010) (Appendix C-5) identified the small sample size of 40 patients, though statistical significant results were reported in relation to some key variables. The sample was specific with extensive exclusion criteria. The results in this study can be applied to this very specific population. The Weingarten[5] trial did consider all important clinical outcomes including Pa02/Fi02 ratio, compliance, and chest imagining.

The Karsten[6] et al. trial (2011) (Appendix B-6) recruited 32 hospitalized patients with an ASA physical status of I or II. The aim of this study was to compare laparoscopic cholecystectomy patients who received no PEEP versus PEEP and to examine ventilation distribution between these two groups. The inclusion criteria for this study included ages between 18 and 75 years with normal spirometry and no cardiopulmonary disease. The intervention group was the PEEP group which utilized 10 cmH20 of PEEP and a tidal volume of 566 ml. The ZEEP group was the comparison group, which utilized no PEEP and a tidal volume of 586 ml (Karsten et al.).

Two outcomes were examined in the Karsten[6] trial that were relevant to this systematic review. This included the respiratory compliance, which was determined to be higher in the PEEP group (57 ml/cmH20) as compared to the ZEEP group (46 ml/cmH20) (P<0.006). The ZEEP group had a lower Pa02/Fi02 ratio (382) as compared

to the PEEP group (498). The p-value for the Pa02/Fi02 ratio was p=0.04. The authors concluded that 10cmH20 PEEP with a recruitment maneuver resulted in improved regional ventilation during laparoscopic surgery as evidenced by improved respiratory compliance and oxygenation (Karsten et al.).

The critical appraisal of the Karsten[6] et al. trial (2011) (Appendix C-6) suggested that not all clinically relevant outcomes were considered, in particular chest imagining as an outcome. The Karsten[6] trial had a small sample size of 32 patients, but identified significant findings. The sample selection was very specific and the results can be applied to this type of population (Karsten et al., 2011).

The Severgnini[7] et al. trial (2013) (Appendix B-7) consisted of 56 participants undergoing elective open abdominal surgery. The aim of this study was to compare PEEP to no PEEP in patients undergoing abdominal surgery between May 2006 to May 2008. The patients were selected through the clinical anesthesia services of the hospital. The inclusive criteria included patients greater than 18 years of age, having non-laparoscopic surgery of the abdomen and general anesthesia of greater than two hours duration. The exclusion criteria included: laparoscopic surgery; BMI > 40, emergency surgery; prior lung surgery; intractable shock; hemodynamic instability; COPD; corticosteroid use; sleep disorders; asthma; immunosuppressive drugs; recent radiation or chemo; severe cardiac disease; acute coronary syndrome; ventricular tachyarrhythmia; pregnancy; acute respiratory distress syndrome; postoperative prolonged mechanical ventilation needs; major clotting disorders; infection at procedure site; or neuromuscular disease. The intervention group in this study was the protective ventilation group which utilized a tidal

volume of 7.7 ml/kg and a PEEP of 10 cmH20. The standard ventilation group had a tidal volume of 9.5 ml/kg and no PEEP (Severgnini et al., 2013).

In the Severgnini[7] et al. trial, a Pa02/Fi02 ratio of > 240 was found in more patients in the protective ventilation group. This same group had zero patients with a ratio of < 240 (Severgnini et al., 2013). The p-value for the Pa02/Fi02 ratio among the groups in this trial was p=1.0. Respiratory compliance was the same between the two groups (p=0.45). Twenty-three patients in the protective ventilation group showed no infiltrate in PACU as compared to 20 patients in the standard ventilation group (P=1.0). Localized infiltrates as well as atelectasis were found in two patients in the protective ventilation group and in four patients in the control group (P=1.0). This study showed that four patients had pleural effusions post operatively in the standard group compared to none in the protective group (P=1.0). The authors concluded that study subjects with protective ventilation demonstrated an improved respiratory function (Severgnini et al., 2013).

The critical appraisal of the Severgnini[7] et al. trial (2013) (Appendix C-7) suggested that the small sample size of 56 patients lead to a lack of precision in the treatment effect and no statistically significant findings were reported. The Severgnini[7] et al. trial did consider all clinically relevant outcomes including the Pa02/Fi02 ratio, compliance, and chest imaging.

Cross Study Comparison and Analysis

Using the Popay et al. (2006) guidelines on performing a narrative synthesis (Table 3), a cross study comparison was performed (Appendix D). The Pa02/Fi02 ratio,

compliance, chest imaging, and oxygenation status were the outcomes compared among the seven studies. Not all outcomes were measured in every study.

Pa02/Fi02 Ratio. The Pa02/Fi02 ratio was examined in four trials (Tusman[1] et al., 1999; Weingarten[5] et al., 2010; Karsten[6] et al., 2011; Severgnini[7] et al., 2013) (Appendix D-1). In the Tusman[1] et al. and Karsten[6] et al. trials, the ratio was examined intra-operatively, while in the Weingarten[5] et al. and Severgnini[7] et al. trials, the ratio was examined in PACU. For the purpose of comparison, the Pa02/Fi02 was manually calculated from the given parameters (Pa02 and Fi02) in the Tusman[1] trial. Except for the Tusman[1] et al. trial (which had four groups), there were two groups per study. Appendix D-1 lists the Pa02/Fi02 ratios of the four trials. In all four trials, the higher the PEEP in the group, the higher the Pa02/Fi02 ratio: adding more PEEP yielded an increase in Pa02/Fi02 ratio (Appendix D-1).

Compliance. Appendix D-2 outlines compliance as compared to PEEP in each group of the six trials where compliance was either reported or calculated. Five trials reported respiratory compliance (Tusman[1] et al., 1999; Almarakbi[3] et al., 2009; Weingarten[5] et al., 2010; Karsten[6] et al., 2011; Severgnini[7] et al., 2013); a calculated respiratory compliance was derived from a sixth trial (Choi[2] et al., 2006). One trial reported no difference in compliance between the groups (Severgnini[7] et al., 2013): compliance for both of the standard and protective group of the Severgnini[7] et al. trial was 40 ml/cmH20. The Tusman[1] et al., Almarakbi[3] et al., Weingarten[5] et al., and Karsten[6] et al. trials showed that with an increase in PEEP, compliance also increased. The trial with the greatest difference in compliance among its groups was Weingarten[5] et al.: the

control group had a compliance of 58, while the compliance in the recruitment group was 80 ml/cmH20.

Chest Imaging. Three trials examined chest infiltrates post-operatively (Talab[4] et al., 2009; Weingarten[5] et al., 2010; Severgnini[7] et al., 2013) (Appendix D-3). Results demonstrated that in two of the three trials, the higher the PEEP setting, the less the number of infiltrates. In the Talab[4] trial, no patients in the PEEP 10 group had infiltrates, compared to one patient each in the other two groups, which had less than or no PEEP. In the Severgnini[7] trial, twice as many patients in the no PEEP group had infiltrates compared to the protective (PEEP 10) group. The Weingarten[5] trial reported no difference in the number of patients with infiltrates.

The same three trials that examined infiltrates also examined atelectasis post operatively (Talab[4] et al., 2009; Weingarten[5] et al., 2010; Severgnini[7] et al., 2013) (Appendix D-4). The Talab[4] et al., trial reported a total of 18 patients with atelectasis in the PEEP 10 group compared to 19 patients each in the PEEP 5 and ZEEP groups. The Weingarten[5] et al. trial demonstrated a lower rate of atelectasis in the recruitment group (four patients), compared to the control group (five patients). Two patients in the Severgnini[7] et al. protective ventilation group had atelectasis post-op; this rate was doubled in the standard ventilation group (Severgnini[7] et al., 2013).

Two trials examined pleural effusions post operatively (Weingarten[5] et al., 2010 and Severgnini[7] et al., 2013) (Appendix D-5). The results between the two trials were similar: the higher the PEEP setting, the less pleural effusions were reported. In the Weingarten[5] et al. trial, only one patient had a pleural effusion in the recruitment group,

compared to four patients in the control group. In the Severgnini[7] et al. group, no patients had pleural effusions in the protective ventilation group as compared to four patients in the standard ventilation group (Severgnini[7] et al., 2013).

Oxygenation status. Two studies referenced the oxygenation status post-op (Almarakbi[3] et al., 2009; Talab[4] et al., 2009) (Appendix D-6 and D-7). In the Almarakbi[3] et al. trial (Appendix D-6), the highest oxygen saturation was reported in the RRP group (97%) with the lowest (92.5%) in the R group. This demonstrated oxygenation increased with an increase in PEEP (Almarakbi[3] et al., 2009).

The Talab[4] et al. studies examined which patients needed 100% oxygen in PACU on the first day post-op (Appendix D-7). Only one patient in the PEEP 10 group needed 100% Fi02 in PACU on the first day as compared to five patients required 100% oxygen in the ZEEP group and three patients in the PEEP 5 group. These findings demonstrated that fewer patients needed oxygen in PACU when they received a higher PEEP setting intraopertively (Talab[4] et al., 2009).

Next, summary and conclusions will be addressed.

Summary and Conclusions

General anesthesia carries risks related to the pulmonary system post operatively (Neligan, 2012). These complications can result in increased health care costs and longer hospital stays (Neligan). One way anesthesia providers can prevent these complications is with the use of positive end expiratory pressure (PEEP) intra-operatively. Positive end expiratory pressure improves oxygenation by preventing airway collapse and allowing for easier alveoli expansion with each breath (Acosta et al., 2007). This is accomplished by keeping the alveoli open which results in an increase in time for gas exchange that occurs. Because there is a positive pressure at end of exhalation that is maintained, it allows for easier inflation of the alveoli with each subsequent breath (Vargas et al., 2014).

The purpose of this systematic review was to evaluate the impact of PEEP intra-operatively on selected respiratory outcomes. The research question was: Does the use of positive end expiratory pressure (PEEP) during surgery decrease respiratory complications 24 hours post-operative? The CINAHL and MEDLINE databases were searched during this systematic review process. The search strategy followed the procedures as identified within the PRISMA flow diagram and the 27-item PRISMA checklist (Moher et al., 2009). Seven randomized control trials were included in the review. Data collection was performed utilizing a data extraction form (Appendix A) constructed by the author. Quality was assessed with The Critical Appraisal Skills Programme (CASP) Randomised Controlled Trials Checklist (Table 2). Using the Popay et al. guidelines (2006), a narrative synthesis was conducted.

In all the studies that collected Pa02/Fi02 ratio data, the groups with the highest PEEP had the highest Pa02/Fi02 ratio (Appendix D-1). This index relates to impaired gas exchange, with a lower ratio suggesting more severe pulmonary disease (Broccard, 2013). In the Severgnini[7] trial, the protective ventilation group that utilized10 cmH20 of PEEP demonstrated no patients with a Pa02/Fi02 ratio below 240, while the group with no PEEP revealed two patients below 240 (Severgnini et al., 2013). Similar results were found in the Tusman[1] et al., Weingarten[5] et al., and Karsten[6] et al. studies (Appendix D-1).

There was less impaired gas exchange with higher PEEP as reflected by the Pa02/Fi02 ratio (Appendix D-1). This may be due to the fact that positive end expiratory pressure causes the alveoli to stay open and participate longer in gas exchange. In the groups that did not receive PEEP, there was a shorter time for gas exchange to occur. This correlated with a lower Pa02/Fi02 ratio that was found in all four studies in the no PEEP groups (Tusman[1] et al., 1999; Weingarten[5] et al., 2010; Karsten[6] et al., 2011; Severgnini[7] et al., 2013) (Appendix D-1).

Compliance was greater in the PEEP groups in five out of six trials where it was measured (Tusman[1] et al., 1999; Choi[2] et al., 2006; Almarakbi[3] et al., 2009;Weingarten[5] et al., 2010; Karsten[6] et al., 2011) (Appendix D-2). In the sixth Severgnini[7] et al. trial, there was no difference in compliance between the PEEP and non-PEEP groups. It is difficult to conclude why there was no difference in compliance between those two groups. In the Severgnini[7] et al. study, one group had a higher tidal volume and no PEEP, while the protective ventilation group had a lower tidal volume and PEEP. This was consistent in the other studies that examined compliance (Choi[2] et al., 2006; Weingarten[5]

et al., 2010; Karsten[6] et al., 2011) expect for the Tusman[1] et al. and Almarakbi[3] et al. studies (Appendix D-2). All studies (Tusman[1] et al., 1999; Choi[2] et al., 2006; Almarakbi[3] et al., 2009; Weingarten[5] et al., 2010; Karsten[6] et al., 2011) except for Severgnini[7] et al. found a correlation between higher PEEP and higher compliance (Appendix D-2). Further studies are needed to examine the relationship between lung compliance and intra-op use of PEEP.

Several studies examined chest imagining, including infiltrates (Talab[4] et al., 2009; Weingarten[5] et al., 2010; Severgnini[7] et al., 2013) (Appendix D-3), atelectasis (Talab[4] et al., 2009; Weingarten[5] et al., 2010; Severgnini[7] et al., 2013) (Appendix D-4), and pleural effusions (Weingarten[5] et al., 2010; Severgnini[7] et al., 2013) (Appendix D-5). The Talab[4] et al., 2009 and Severgnini[7] et al., 2013 trials both showed a correlation between less abnormal chest imagining results and higher use of PEEP (Appendix D-3). This was not true for the Weingarten[5] et al. study in which no difference between the outcomes of infiltrates on chest x-ray were detected. One patient in each group, the control group and the recruitment group, had pneumonia postoperatively. The degree and severity of pneumonia between the two groups was not reported. It is possible that had it been reported, the results might have been more similar to those in the Severgnini[7] et al. trial, which showed localized infiltrates to be higher in the standard ventilation group. Like the other trials, Weingarten[5] et al. trial did show less atelectasis and pleural effusions in their recruitment group, which utilized PEEP, compared to the control group (Appendix D-4 and Appendix D-5). This demonstrated that the use of PEEP intra-operatively would lead to less infiltrates, less atelectasis, and less pleural effusions.

Two studies examined oxygenation (Almarakbi[3] et al., 2009; Talab[4] et al., 2009) in the recovery unit (Appendix D-6 and Appendix D-7). Higher PEEP used during surgery correlated with a higher oxygen saturation in PACU (Almarakbi[3] et al., 2009) (Appendix D-6). This study was able to show that a combination of recruitment maneuvers and PEEP yielded higher oxygen saturation than either done alone. The Almarakbi[3] et al. study demonstrated that more than just PEEP can be implemented intra-operatively to improve the respiratory status post operatively. More studies need to be conducted to compare the use of PEEP and recruitment maneuvers. The Talab[4] et al. study also examined how many patients needed 100% Fi02 in PACU (Appendix D-7). Using higher levels of PEEP during surgery resulted in less oxygen requirements in the recovery unit. The ability to generalize findings from this review is limited by the small number of studies and the noted limitations of those study designs and methods.

There were several limitations during the execution of this systematic review. The sample sizes of the included studies were overall small. An additional limitation was the small number of trials discussing PEEP during anesthesia that were discovered during the data collection phase. This review included several trials which were not focused on PEEP alone, making it difficult to determine whether the recruitment maneuvers were responsible for the outcomes. Because the trials in this review did not consider all pertinent outcomes, comparison between the trials was limited. The inclusion and exclusion criteria varied among the trials, making the conclusion of this review limited as to which population can benefit the most or least. This review was not able to conclude which PEEP setting was most beneficial due to inconsistency of PEEP settings on the ventilators identified within the trials. Potential adverse effects associated with PEEP

utilization were not considered in this review. Further randomized controlled trials need to be conducted, with larger samples and also utilizing PEEP as the sole variable. Closer examination of optimal PEEP settings is also indicated.

In conclusion, a total of seven trials were examined to see if the use of PEEP intra-operatively resulted in less pulmonary compromise post-operatively (Tusman[1] et al., 1999; Choi[2] et al., 2006; Almarakbi[3] et al., 2009; Talab[4] et al., 2009; Weingarten[5] et al., 2010; Karsten[6] et al., 2011; Severgnini[7] et al., 2013). Factors that were examined included the Pa02/Fi02 ratio, respiratory system compliance, chest infiltrates, atelectasis, pleural effusions, oxygen saturation, and the need for 100% oxygen in PACU (Appendix D). The results showed that there is less impaired gas exchange with higher PEEP (Tusman[1] et al., 1999; Weingarten[5] et al., 2010; Karsten[6] et al., 2011; Severgnini[7] et al., 2013) (Appendix D-1). Overall compliance was greater in the PEEP groups (Tusman[1] et al., 1999; Choi[2] et al., 2006; Almarakbi[3] et al., 2009; Weingarten[5] et al., 2010; Karsten[6] et al., 2011) (Appendix D-2). Most PEEP groups also showed less pulmonary infiltrates post operatively (Talab[4] et al., 2009; Weingarten[5] et al., 2010; Severgnini[7] et al., 2013) (Appendix D-3). Using PEEP also resulted in less atelectasis (Talab[4] et al., 2009; Weingarten[5] et al., 2010; Severgnini[7] et al., 2013) (Appendix D-4) and less pleural effusions (Weingarten[5] et al., 2010; Severgnini[7] et al., 2013) (Appendix D-5) post operatively. Using PEEP intra-operatively resulted in higher oxygen saturation post-operatively (Almarakbi[3] et al., 2009) (Appendix D-6). Finally, fewer patients who received PEEP needed 100% oxygen in PACU (Talab[4] et al., 2009) (Appendix D-7).

Next, the recommendations and implications for advanced practice nurses will be discussed.

Recommendations and Implications for Advanced Nursing Practice

This systematic review yielded valuable information and evidence recommendations for nurse anesthesia practice. Current practice related to use of PEEP in the operating room is at the discretion of the provider; typically there is not a set policy or clear recommendations on when to use PEEP. While nurse anesthetists are aware that PEEP increases oxygenation, there is a lack of evidence-based knowledge related to the benefits of PEEP as well as how much PEEP to utilize.

This review was able to contribute to evidence-based knowledge related to intra-operative use of PEEP for nurse anesthetists. The findings of this review present an opportunity for teaching all anesthesia providers related to the use of PEEP intra-operatively. Because CRNAs in the operating room are dialing in ventilation settings on anesthesia machines as well as managing them, they are an excellent resource to educate all anesthesia providers related to evidence based outcomes of PEEP utilization. Nurse anesthetists could create PEEP guidelines based on the evidence provided in this review. Nurse anesthetists can lead the way in improving patient care by adhering to evidence based practice.

Because some facilities utilize electronic health care records in the operating room, previous anesthesia records are easily obtainable. This benefits the patient when he or she returns to the facility for another surgery. The APRN could potentially review t the previous anesthesia settings regarding PEEP and other parameters, such as oxygen saturation intraopertively and in PACU. Nurse anesthetists can be leaders in working to improve anesthesia charting, including PEEP documentation.

More research needs to be conducted on what PEEP setting is optimal intraoperatively. Nurse anesthetists are heavily involved in direct patient care, making this is a good leadership opportunity to conduct such research and share with the rest of the operating room team. Areas that need to be explored include the adverse effects of utilizing PEEP. It I important to know exactly what PEEP setting is considered too high and what the clinical effects of that setting are. Research that has one variable, PEEP, versus several (such as recruitment breaths and PEEP) would be better able to directly correlate the results to that one intervention. Trials with larger sample sizes than were examined in this systematic review are needed. All pertinent outcomes need to be considered. Since patients have different comorbidities, it would be helpful to conduct several trials with different inclusive criteria where PEEP may make a difference, which would better reflect the different patient population that CRNAs treat. Different inclusive criteria may contain but should not be limited to COPD, morbid obesity, lung cancer, and laparoscopic surgeries. Other inclusive criteria to consider would be different ethnic backgrounds because lung function can vary depending on the ethnic background of the patient.

Prompt recovery in PACU plays an important role in today's economy-conscience healthcare system. Based on the results of this review; utilizing PEEP to decrease respiratory complications post operatively is of benefit to patients. Specific guidelines related to the use of PEEP within the institution could be developed by the CRNA. The American Association of Nurse Anesthetists (AANA) provides the CRNA with multiple resources, such as guidelines and systematic reviews, from their website to assist the practitioner in utilizing evidence in their practice. To assist the CRNA in

making decisions on anesthesia practice, the AANA also publishes guidelines. Currently there is no guideline on using PEEP in the operating room. After doing more research, CRNAs can work with the AANA to publish a guideline on PEEP utilization in the operating room. This can lead to nurse anesthetists decreasing health care costs while decreasing postoperative respiratory complications.

References

Acosta, P., Santisbon, E., & Varon, J. (2007). The use of positive end-expiratory pressure in mechanical ventilation. *Critical Care Clinics*, *23*(2)*; 251-61.* doi: 10.1016 /j.ccc.2006.12.012

Almarakbi, W.A., Fawzi, H.M., & Alhashemi, J.A. (2009). Effects of four intraoperative ventilatory strategies on respiratory compliance and gas exchange during laparoscopic gastric banding in obese patients. *British Journal of Anaesthesia, 102*(6):*862–8.* doi:10.1093/bja/aep084

Barash, P.G., Cullen, B.F., Stoelting, R.K., Cahalan, M. K., Stock, M., & Ortega, R. (2013). *Clinical anesthesia.* Philadelphia, PA: Wolters Kluwer/Lippincott Williams & Wilkins.

Broccard, A.F. (2013). Making sense of the Pa02/Fi02 ratio in patients with acute respiratory distress syndrome. *OA Critical Care*, *01*(1):*1-15*. Retreived from https://www.researchgate.net/publication/257123115_Making_sense_of_the_PaO 2FIO2_ratio_in_patients_with_acute_respiratory_distress_syndrome

Canet, J., & Mazo, V. (2010). Postoperative pulmonary complications. *Minerva Anestesiologica*, *76*(2); *138-43.* Retreived from http://www.ncbi.nlm.nih.gov /pubmed/20150855

CASP UK (2013). Critical appraisal skills programme: 11 questions to help you make sense of a trial. Retrieved from http://media.wix.com/ugd/dded87_40b9ff0bf5 3840478331915a8ed8b2fb.pdf

Choi, G., Wolthuis, E.K., Bresser, P., Levi, M., Poll, T., Dzolijc, M., . . . Schultz, M. J. (2006). Mechanical ventilation with lower tidal volumes and positive end-

expiratory pressure prevents alveolar coagulation in patients without lung injury. *Anesthesiology, 105*(4):*689–95*. doi: 10.1097/00000542-200610000-00013

Cochrane Training (2014). Data collection form for intervention reviews: RCTs only. Retrieved from http://training.cochrane.org/authors/resources/checklists-and-forms

Grinnan, D.C., & Truwit, J.D. (2005). Clinical review: respiratory mechanics in spontaneous and assisted ventilation. *Critical Care 9*(5); *472-484.* doi: 10.1186/cc3516

Joanna Briggs Institute (2014). JBI Critical Appraisal Checklist for Randomised Control/ Pseudo-randomized Trial. Retrieved from http://joannabriggs.org/assets/docs /jbc/operations/criticalAppraisalForms/JBC_Form_CritAp_Rct.pdf

Karsten J., Luepschen H., Grossherr M., Bruch, H. P., Leonhardt, S., Gehring, H., & Meier, T. (2011). Effect of PEEP on regional ventilation during laparoscopic surgery monitored by electrical impedance tomography. *ACTA Anaesthesiologica Scandinavica, 55: 878-886.* doi:10.1111/j.1399-6576.2011.02467.x

Kilpatrick B. & Slinger P. (2010). Lung protective strategies in anesthesia. *British Journal of Anaesthesia, 105*(1):*i108–i116.* doi: 10.1093/bja/aeq299

Magnusson L. & Spahn D.R. (2003). New concepts of atelectasis during general anaesthesia. *British Journal of Anaesthesia, 91*(1); *61-72*. doi: 10.1093/bja/aeg085

Moher D., Liberati A., Tetzlaff J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analysis: The PRISMA statement. *PLoS Medicine.* http://dx.doi.org/10.1371/journal.pmed.1000097

National Heart, Lung, & Blood Institute ARDS Clinical Trails Network (2004). Higher

versus lower positive end-expiratory pressures in patients with the acute respiratory distress syndrome. *New England Journal of Medicine, 351: 327-336*. doi:10.1056/NEJMoa032193

Neligan, P (2012). Postoperative noninvasive ventilation. *Anesthesiology Clinics 30* (3): *495-511*. doi:10.1016/j.anclin.2012.07.002

Popay J., Roberts H., Sowden A., Petticrew, M., Arai, L., Rodgers, M., . . . Duffy, S. (2006). Guidance on the conduct of narrative synthesis in systematic reviews. Doi: 10.13140/2.1.1018.4643

Severgnini P., Selmo G., Lanza C., Chiesa, A., Frigerio, A., Bacuzzi, A., . . . Pelosi, P. (2013). Protective mechanical ventilation during general anesthesia for open abdominal surgery improves postoperative pulmonary function. *Anesthesiology, 118* (6):*1307–21*. doi:10.1097/ALN.0b013e31829102de

Talab H.F., Zabani I.A., Abdelrahman H.S., Bukhari, W., Mamoun, I., Ashour, M. A., . . . Sayed, S. I. (2009). Intraoperative ventilatory strategies for prevention of pulmonary atelectasis in obese patients undergoing laparoscopic bariatric surgery. *Anesthesia and Analgesia, 109*(5):*1511–6.* doi:10.1213/ANE.0b013e3181ba7945

Tusman G., Bohm S.H., Vazquez De Anda G.F., do Campo, J. L., & Lachmann, B. (1999). ’Alveolar recruitment strategy’ improves arterial oxygenation during general anaesthesia. *British Journal of Anaesthesia, 82*(1*):8–13.* doi: 10.1093/bja/82.1.8

Vargas M., Sutherasan Y., Gregoretti C., & Pelosi, P. (2014). PEEP role in ICU and operating room: From pathophysiology to clinical practice. *The Scientific World Journal, 2014*(1): *1-8.* doi: 10.1155/2014/852356

Villars P.S., Kanusky J.T., & Levitzky M.G. (2002). Functional residual capacity: The human Windbag. *American Association of Nurse Anesthetists Journal, 70*(5): *399-407.* Retrieved from https://www.aana.com/newsandjournal/Documents/399-407.pdf

Weingarten T.N., Whalen F.X., Warner D.O., Gajic, O., Schears, G. J., Snyder, M. R., . . . Sprung, J. (2010). Comparison of two ventilatory strategies in elderly patients undergoing major abdominal surgery. *British Journal of Anaesthesia, 104*(1):*16–22.* doi: 10.1093/bja/aep319

Appendix A

Data Extraction Form

Study title	
Study ID	
Study reference citation	
Participants	
Types of intervention	
Types of comparison	
Types of outcome measures	
Aim of study	
Population description	
Setting	
Inclusion criteria	
Exclusion criteria	
Total no. randomized	
Severity of illness	
Outcome (collected specifically for this systematic review)	
Key conclusions of study authors	

Appendix B

Results in Data Extraction Form

Study title 1	'Alveolar recruitment strategy' improves arterial oxygenation during general anaesthesia
Study ID	Tusman[1] et al. 1999
Study reference citation	Tusman G, Bohm SH, Vazquez De Anda GF, et al (1999). 'Alveolar recruitment strategy' improves arterial oxygenation during general anaesthesia. British Journal of Anaesthesia, 82(1):8–13. doi: 10.1093/bja/82.1.8
Participants	30 ASA II or III patients, > 60 years old
Types of intervention	▪ Recruitment group (PEEP 5-15 cmH20) o TV increased to 18ml/kg x 10 breaths then back down. ▪ =mean TV 1064ml ▪ PEEP group (5 cmH20 PEEP) o TV 7-9ml/kg and RR 10-12
Types of comparison	▪ ZEEP group (0 PEEP) o TV 7-9ml/kg and RR 10-12
Types of outcome measures	Pa02/Fi02 Ratio, respiratory compliance
Aim of study	Test "effect of an 'alveolar recruitment strategy' on arterial oxygenation and lung mechanics" between October 1996 to June 1997 (Tusman 1999).
Population description	30 patients ASA II or III, patients, > 60 years old
Setting	Hospital Privado de Communidad in Mar del Plata, Argentina
Inclusion criteria	Patients > 60 years of age, ASA II or III, supine during surgery, general anesthesia lasting > 2 hours, "patients undergoing elective operations not expected to directly affect thorax or position of diaphragm" (Tusman 1999).
Exclusion criteria	"Patients undergoing thoracic, upper abdominal, spinal, or laparoscopic surgery were excluded" (Tusman 1999).
Total no. randomized	30
Severity of illness	ASA II or III
Outcome (collected specifically for this systematic review)	▪ Respiratory compliance o Tusman 1999 cmH20 ▪ PEEP = 46 ▪ ZEEP = 43 ▪ Recruitment = 62 ▪ Pa02/Fi02 o Tusman 1999 ▪ PEEP = 152 ▪ ZEEP = 128 ▪ Recruitment = 190

Key conclusions of study authors	"The 'alveolar recruitment strategy' increased arterial oxygenation during general anesthesia. Treatment with PEEP 5 cm H20 alone, however, did not have same effect on oxygenation. The increase in arterial oxygenation after the recruitment maneuver suggests a reversal of anesthesia induced atelectatic and ventilation/perfusion inhomogeneity" (Tusman 1999).

Study title 2	Mechanical ventilation with lower tidal volumes and positive end-expiratory pressure prevents alveolar coagulation in patients without lung injury
Study ID	Choi[2] et al. 2006
Study reference citation	Choi G, Wolthuis EK, Bresser P, et al (2006). Mechanical ventilation with lower tidal volumes and positive end-expiratory pressure prevents alveolar coagulation in patients without lung injury. Anesthesiology, 105(4):689–95. doi: 10.1097/00000542-200610000-00013
Participants	41 patients
Types of intervention	• LVT/PEEP group = 10 cmH20 PEEP, TV 400 ml
Types of comparison	• HVT/ZEEP group = 0 PEEP, TV 800 ml
Types of outcome measures	Respiratory compliance
Aim of study	"to determine the effects of mechanical ventilation on the alveolar hemostatic balance in patients without preexistent lung injury" (Choi 2006).
Population description	41 patients
Setting	Hospital
Inclusion criteria	"Patients scheduled for an elective surgical procedure (lasting > 5 h)" (Choi 2006).
Exclusion criteria	"a history of any lung disease, use of immunosuppressive medication, recent infections, previous thromboembolic disease, recent admission to the intensive care unit for ventilatory support, and participation in another clinical trial" (Choi 2006).
Total no. randomized	41
Severity of illness	No lung disease
Outcome (collected specifically for this systematic review)	▪ Respiratory compliance o Choi 2006 ▪ LVT/PEEP = 50 ▪ HVT/ZEEP = 38
Key conclusions of study authors	"Mechanical ventilation with higher tidal volumes and no PEEP promotes procoagulant changes, which are largely prevented by the use of lower tidal volumes and PEEP" (Choi 2006).

Study title 3	Effects of four intraoperative ventilatory strategies on respiratory compliance and gas exchange during laparoscopic gastric banding in obese patients
Study ID	Almarakbi[3] et al. 2009
Study reference citation	Almarakbi WA, Fawzi HM, Alhashemi JA (2009). Effects of four intraoperative ventilatory strategies on respiratory compliance and gas exchange during laparoscopic gastric banding in obese patients. British Journal of Anaesthesia, 102(6):862–8. doi: 10.1093/bja/aep084
Participants	60 patients undergoing elective laparoscopic gastric banding under general anesthesia
Types of intervention	• RRP group = 4 recruitment maneuvers and 10 cmH20 PEEP, TV 10ml/kg • RP group = one recruitment maneuver, then 10 cmH20 PEEP, TV 10ml/kg • P group = 10 cmH20 PEEP sustained, no recruitment maneuver, TV 10ml/kg
Types of comparison	• R group (0 peep throughout, one recruitment maneuver, TV 10ml/kg)
Types of outcome measures	Respiratory compliance, oxygen status in PACU
Aim of study	"to determine whether repeated lung recruitment combined with PEEP improves respiratory compliance and arterial partial pressure of oxygen (Pa_{O_2}) in obese patients undergoing laparoscopic gastric banding" (Almarakbi 2009).
Population description	ASA II, 60 patients
Setting	Hospital
Inclusion criteria	patients 18–60 years of age with BMI > 30 kg m^{-2}
Exclusion criteria	"asthma, chronic obstructive pulmonary disease, restrictive lung disease, increased intracranial pressure, and/or history of smoking" (Almarakbi 2009).
Total no. randomized	60
Severity of illness	Healthy 16-80 years of age, no severe illness
Outcome (collected specifically for this systematic review)	▪ Respiratory compliance o Almarakbi 2009 ml/cmH20 ▪ RRP = 41 ▪ RP = 32 ▪ P = 28 ▪ R = 28 ▪ oxygen status in PACU ▪ Almarakbi 2009, oxygen saturation (%) • RRP = 97 • RP = 94 • P = 93 • R = 92.5
Key conclusions of study authors	"Group RRP recruitment strategy was associated with the best intraoperative respiratory compliance and Pa_{O_2} in obese patients undergoing laparoscopic gastric banding" (Almarakbi 2009).

Study title 4	Intraoperative ventilatory strategies for prevention of pulmonary atelectasis in obese patients undergoing laparoscopic bariatric surgery
Study ID	Talab[4] et al. 2009
Study reference citation	Talab HF, Zabani IA, Abdelrahman HS, et al (2009). Intraoperative ventilatory strategies for prevention of pulmonary atelectasis in obese patients undergoing laparoscopic bariatric surgery. Anesthesia and Analgesia, 109(5):1511–6. doi:10.1213/ANE.0b013e3181ba7945
Participants	"66 adult obese patients with a body mass index between 30 and 50 kg/m^2 scheduled to undergo laparoscopic bariatric surgery" (Talab 2009).
Types of intervention	• PEEP 10 group =10 cmH20 PEEP, TV 8-10ml/kg lean body weight • PEEP 5 group = 5 cmH20 PEEP, TV 8-10ml/kg lean body weight
Types of comparison	• ZEEP group = 0 cmH20 PEEP, TV 8-10ml/kg lean body weight
Types of outcome measures	Chest infiltrates, atelectasis, oxygenation status in PACU (needed 100% Fi02 in PACU)
Aim of study	"to evaluate the safety and efficacy of the VCM (vital capacity maneuver) followed by different levels of positive end-expiratory pressure (PEEP) used to prevent post- operative lung atelectasis in obese patients undergoing laparoscopic bariatric surgery" (Talab 2009).
Population description	66 adult obese patients
Setting	Hospital
Inclusion criteria	"with a body mass index (BMI) between 30 and 50 kg/m^2, aged between 20 and 50 yr, and scheduled to undergo laparoscopic bariatric surgery" (Talab 2009).
Exclusion criteria	"if they had been hospitalized more than 24 h before surgery, had a history of heart or lung diseases, had any clinical sign of cardiopulmonary disease during preoperative physical examination (jugular vein distension, gallop rhythm, hepatomegaly, tibial edema, or rales on auscultation of the chest, or any abnormalities in the preoperative 12-lead electrocardiogram or chest radiograph). If any complications occurred that necessitated laparotomy" (Talab 2009).
Total no. randomized	66
Severity of illness	No history of heart or lung disease
Outcome (collected specifically for this systematic review)	▪ Chest infiltrates o Talab 2009 (postop chest infection) ▪ PEEP 10 =0 patients ▪ PEEP 5 = 1 patients ▪ ZEEP = 1 patients ▪ Atelectasis o Talab 2009 postop ▪ Atelectasis Postoperative • PEEP 10 = 18 patients • PEEP 5 = 19 patients • ZEEP = 19 patients ▪ No Atelectasis Postoperative • PEEP 10 = 2 patients • PEEP 5 = 0 patients • ZEEP = 0 patients ▪ Oxygenation status in PACU (Needed 100% Fi02 in PACU) o Talab 2009 ▪ PEEP 10 = 1 patients ▪ PEEP 5 = 3 patients ▪ ZEEP = 5 patients
Key conclusions of study authors	"Intraoperative alveolar recruitment with a VCM followed by PEEP 10 cm H_2O is effective at preventing lung atelectasis and is associated with better oxygenation, shorter PACU stay, and fewer pulmonary complications in the postoperative period in obese patients undergoing laparoscopic bariatric surgery" (Talab 2009).

Study title 5	Comparison of two ventilatory strategies in elderly patients undergoing major abdominal surgery
Study ID	Weingarten[5] et al. 2010
Study reference citation	Weingarten TN, Whalen FX, Warner DO, et al (2010). Comparison of two ventilatory strategies in elderly patients undergoing major abdominal surgery. British Journal of Anaesthesia, 104(1):16–22. doi: 10.1093/bja/aep319
Participants	20 patients in each group
Types of intervention	Recruitment group (PEEP 12 cmH20, TV 489ml)
Types of comparison	Control group (PEEP 2.6 cmH20, TV 776ml)
Types of outcome measures	Pa02/Fi02, compliance, chest infiltrate (pneumonia), atelectasis, pleural effusion
Aim of study	"potential utility of an 'open lung' ventilatory strategy to improve intraoperative oxygenation and to reduce lung parenchymal injury"… to "test the hypothesis that an 'open lung' ventilatory strategy improves oxygenation and mechanics of breathing in elderly patients undergoing open abdominal surgery" (Weingarten 2010).
Population description	"Patients aged > 65 yr undergoing major open abdominal surgery" (Weingarten 2010).
Setting	Saint Mary's Hospital, Rochester, MN, USA,
Inclusion criteria	"Patients aged > 65 yr undergoing major open abdominal surgery" (Weingarten 2010).
Exclusion criteria	"significant pulmonary disease with abnormalities in spirometry consistent with either obstructive or restrictive pulmonary disease, active asthma (requiring chronic bronchodilator therapy), previous lung surgery, home oxygen therapy, significant cardiac dysfunction (left ventricular ejection fraction ,40%), or BMI 35 " (Weingarten 2010).
Total no. randomized	40
Severity of illness	No significant pulmonary disease
Outcome (collected specifically for this systematic review)	▪ Respiratory compliance o Weingarten 2010 ml/cmH20 ▪ Control = 58 ▪ Recruitment = 80 ▪ Pa02/Fi02 o Weingarten 2010 ▪ Control (n=20)= 300 ▪ Recruitment (n=20) = 409 ▪ Chest infiltrate (pneumonia) o Weingarten 2010 ▪ Control (n=20)= 1 ▪ Recruitment (n=20) = 1 ▪ Atelectasis o Weingarten 2010 overall ▪ Control (n=20)= 5 ▪ Recruitment (n=20) = 4 ▪ Pleural effusion o Weingarten 2010 overall ▪ Control (n=20)= 4 ▪ Recruitment (n=20) = 1
Key conclusions of study authors	"A lung recruitment strategy in elderly patients is well tolerated and improves intraoperative oxygenation and lung mechanics during laparotomy" (Weingarten 2010).

Study title 6	Effect of PEEP on regional ventilation during laparoscopic surgery monitored by electrical impedance tomography
Study ID	Karsten[6] et al. 2011
Study reference citation	Karsten J, Luepschen H, Grossherr M, et al (2011). Effect of PEEP on regional ventilation during laparoscopic surgery monitored by electrical impedance tomography. ACTA Anaesthesiologica Scandinavica, 55: 878-886. doi:10.1111/j.1399-6576.2011.02467.x
Participants	32 patients
Types of intervention	PEEP group (TV 566 ml, 10 cmH20 PEEP)
Types of comparison	ZEEP group (TV 586 ml, 0 PEEP)
Types of outcome measures	Pa02/Fi02 Ratio, respiratory compliance
Aim of study	Compare laparoscopic cholecystectomy patients who received no PEEP versus PEEP and examine ventilation distribution between two groups from 2005 to 2006
Population description	32 patients undergoing elective laparoscopic cholecystectomy. 18-75 years old, no history cardiopulmonary disease, normal spirometry , ASA I or II
Setting	Hospital
Inclusion criteria	"between ages 18 and 75 without a history of cardiopulmonary disease (ASA physical status I/II, NYHA I) and normal spirometry" (Karsten 2011).
Exclusion criteria	cardiopulmonary disease, patients 17 years old and younger, patients 75 years old and older, ASA III or IV, abnormal spirometry
Total no. randomized	32
Severity of illness	No abnormal spirometry or cardiopulmonary disease
Outcome (collected specifically for this systematic review)	▪ Respiratory compliance o Karsten 2011 ml/cmH20 ▪ PEEP =57 ▪ ZEEP = 46 ▪ Pa02/Fi02 o Karsten 2011 ▪ PEEP =498 ▪ ZEEP = 382
Key conclusions of study authors	"The effect of anesthesia, pneumoperitoneum, and different PEEP levels can be evaluated by EIT-based COV monitoring. An initial recruitment maneuver and a PEEP of 10 cmH_2O preserved homogeneous regional ventilation during laparoscopic surgery in most, but not all, patients and improved oxygenation and respiratory compliance" (Karsten 2011).

Study title 7	Protective mechanical ventilation during general anesthesia for open abdominal surgery improves postoperative pulmonary function
Study ID	Severgnini [7] et al. 2013
Study reference citation	Severgnini P, Selmo G, Lanza C, et al (2013). Protective mechanical ventilation during general anesthesia for open abdominal surgery improves postoperative pulmonary function. Anesthesiology, 118 (6):1307–21. doi: 10.1097/ALN.0b013e31829102de
Participants	56 patients undergoing elective open abdominal surgery
Types of intervention	TV 7.7ml/kg & 10 PEEP (Protective Ventilation group)
Types of comparison	TV 9.5ml/kg & 0 PEEP (Standard Ventilation group)
Types of outcome measures	Pa02/Fi02 Ratio, respiratory compliance, chest infiltrates, atelectasis, pleural effusions
Aim of study	Compare PEEP versus no PEEP in patients undergoing abdominal surgery between May 2006 to May 2008
Population description	56 patients undergoing elective open abdominal surgery selected through the clinical anesthesia service via hospital
Inclusion criteria	"Non-laparoscopic abdominal surgery under general anesthesia expected to last more than 2h and age more than 18 yr" (Severgnini 2013).
Exclusion criteria	"body mass index more than 40kg/m^2, laparoscopic surgery, need for surgery in emergency, previous lung surgery (any), persistent hemodynamic instability, intractable shock considered unsuitable for the study by the patient's managing physician, history of chronic obstructive pulmonary disease, repeated systemic corticosteroid therapy for acute exacerbations of chronic obstructive pulmonary disease, asthma or sleep disorders, recent immunosuppressive medication, need of chemotherapy or radiation therapy, less than 2 months after chemotherapy or radiation therapy, severe cardiac disease, New York Heart Association class III or IV, or acute coronary syndrome, or persistent ventricular tachyarrhythmias, pregnancy, acute lung injury or acute respiratory distress syndrome, expecting to require prolonged postoperative mechanical ventilation, any neuromuscular disease, contraindications to position an epidural catheter because of major clotting disorders" (Severgnini 2013).
Total no. randomized	56
Severity of illness	patients undergoing elective open abdominal surgery

Outcome (collected specifically for this systematic review)	• Pa02/Fi02 Ratio
	  ○ Severgnini 2013
	  ▪ >240
	  • Standard Ventilation group (n=26) = 24
	  • Protective Ventilation group (n=27) = 27
	  ▪ <= 240
	  • Standard Ventilation group (n=26) = 2
	  • Protective Ventilation group (n=27) = 0
	• Respiratory compliance
	  ○ Severgnini 2013 ml/cmH20
	  ▪ Standard Ventilation = 40
	  ▪ Protective Ventilation = 40
	• Chest infiltrates
	  ○ Severgnini 2013
	  ▪ No infiltrate
	  • Standard Ventilation group (n=26) = 20 patients
	  • Protective Ventilation group (n=27) = 23 patients
	  ▪ Patchy or diffuse infiltrate
	  • Standard Ventilation group (n=26) = 2 patients
	  • Protective Ventilation group (n=27) = 2 patients
	  ▪ Localized infiltrate
	  • Standard Ventilation group (n=26) = 4 patients
	  • Protective Ventilation group (n=27) = 2 patients
	• Atelectasis
	  ○ Severgnini 2013
	  ▪ Standard Ventilation group (n=26) = 4 patients
	  ▪ Protective Ventilation group (n=27) = 2 patients
	• Pleural effusions
	  ○ Severgnini 2013
	  ▪ Standard Ventilation group (n=26) = 4 patients
	  ▪ Protective Ventilation group (n=27) = 0 patients

Key conclusions of study authors	"A protective ventilation strategy during abdominal surgery lasting more than 2h improved respiratory function and reduced the modified Clinical Pulmonary Infection Score without affecting length of hospital stay" (Severgnini 2013)

Appendix C

Critical Appraisal

Study title 1	'Alveolar recruitment strategy' improves arterial oxygenation during general anaesthesia			
Study ID	Tusman[1] et al. 1999			
(A) Are the results of the trial valid?		Yes	Can't tell	No
	1. Did the trial address a clearly focused issue?			
	2. Was the assignment of patients to treatments randomized?			
	3. Were patients, health workers and study personnel blinded?			
	4. Were the groups similar at the start of the trial?			
	5. Aside from the experimental intervention, were the groups treated equally?			
	6. Were all the patients who entered the trial properly accounted for at its conclusion?			
(B) What are the results?				
	7. How large was the treatment effect? Compared to the ZEEP (0 PEEP) group with a 43 cmH20 compliance, the PEEP (5 cmH20 PEEP) group had a 46 cmH20 compliance and the recruitment group (with 5-15 cmH20 PEEP) had a compliance of 62 cmH20)			
	8. How precise was the estimate of the treatment effect? Due to the small sample size, the precision of the effect is lacking			
(C) Will the results help locally?		Yes	Can't tell	No
	9. Can the results be applied in your context or to the local population?			
	10. Were all clinically important outcomes considered?			
	11. Are the benefits worth the harms and costs?			

Study title 2	Mechanical ventilation with lower tidal volumes and positive end-expiratory pressure prevents alveolar coagulation in patients without lung injury
Study ID	Choi[2] et al. 2006

(A) Are the results of the trial valid?	Yes	Can't tell	No
1. Did the trial address a clearly focused issue?	■		
2. Was the assignment of patients to treatments randomized?	■		
3. Were patients, health workers and study personnel blinded?		■	
4. Were the groups similar at the start of the trial?	■		
5. Aside from the experimental intervention, were the groups treated equally?	■		
6. Were all the patients who entered the trial properly accounted for at its conclusion?	■		

(B) What are the results?

7. How large was the treatment effect?
The HVT/ZEEP group (0 PEEP) had a compliance of 38 compared to a compliance of 50 for the LVT/PEEP group (with 10 cmH20 PEEP).

8. How precise was the estimate of the treatment effect?

Due to the small sample size, the precision of the effect is lacking

(C) Will the results help locally?	Yes	Can't tell	No
9. Can the results be applied in your context or to the local population?	■		
10. Were all clinically important outcomes considered?			■
11. Are the benefits worth the harms and costs?	■		

Study title 3	Effects of four intraoperative ventilatory strategies on respiratory compliance and gas exchange during laparoscopic gastric banding in obese patients			
Study ID	Almarakbi[3] et al. 2009			
(A) Are the results of the trial valid?		Yes	Can't tell	No
	1. Did the trial address a clearly focused issue?			
	2. Was the assignment of patients to treatments randomized?			
	3. Were patients, health workers and study personnel blinded?			
	4. Were the groups similar at the start of the trial?			
	5. Aside from the experimental intervention, were the groups treated equally?			
	6. Were all the patients who entered the trial properly accounted for at its conclusion?			
(B) What are the results?				
	7. How large was the treatment effect? The P, RP, and RRP groups (each with 10 cmH20 PEEP) had compliances of 28-41 ml/cmH20, compared to the R group (0 PEEP) of compliance of 28 ml/cmH20.			
	8. How precise was the estimate of the treatment effect? Due to the small sample size, the precision of the effect is lacking			
(C) Will the results help locally?		Yes	Can't tell	No
	9. Can the results be applied in your context or to the local population?			
	10. Were all clinically important outcomes considered?			
	11. Are the benefits worth the harms and costs?			

Study title 4	Intraoperative ventilatory strategies for prevention of pulmonary atelectasis in obese patients undergoing laparoscopic bariatric surgery		
Study ID	Talab[4] et al. 2009		
(A) Are the results of the trial valid?	Yes	Can't tell	No
1. Did the trial address a clearly focused issue?	■		
2. Was the assignment of patients to treatments randomized?	■		
3. Were patients, health workers and study personnel blinded?		■	
4. Were the groups similar at the start of the trial?	■		
5. Aside from the experimental intervention, were the groups treated equally?		■	
6. Were all the patients who entered the trial properly accounted for at its conclusion?	■		
(B) What are the results?			
7. How large was the treatment effect? 1 patient in the PEEP 10 (10 cmH20 PEEP) required 100% Fi02 in PACU compared to 3 patients in the PEEP 5 (5cmH20 PEEP) group and to 5 patients in the ZEEP (0 PEEP) group.			
8. How precise was the estimate of the treatment effect? Due to the small sample size, the precision of the effect is lacking			
(C) Will the results help locally?	Yes	Can't tell	No
9. Can the results be applied in your context or to the local population?	■		
10. Were all clinically important outcomes considered?			■
11. Are the benefits worth the harms and costs?	■		

Study title 5	Comparison of two ventilatory strategies in elderly patients undergoing major abdominal surgery
Study ID	Weingarten[5] et al. 2010

(A) Are the results of the trial valid?	Yes	Can't tell	No
1. Did the trial address a clearly focused issue?	■		
2. Was the assignment of patients to treatments randomized?	■		
3. Were patients, health workers and study personnel blinded?		■	
4. Were the groups similar at the start of the trial?	■		
5. Aside from the experimental intervention, were the groups treated equally?		■	
6. Were all the patients who entered the trial properly accounted for at its conclusion?	■		

(B) What are the results?

7. How large was the treatment effect?
Compared to the Control group (2.6 cmH20 PEEP) with a compliance of 58 ml/cmH20, the Recruitment group (12 cmH20 PEEP) had a compliance of 80 ml/cmH20.

8. How precise was the estimate of the treatment effect?

Due to the small sample size, the precision of the effect is lacking

(C) Will the results help locally?	Yes	Can't tell	No
9. Can the results be applied in your context or to the local population?	■		
10. Were all clinically important outcomes considered?	■		
11. Are the benefits worth the harms and costs?	■		

Study title 6	Effect of PEEP on regional ventilation during laparoscopic surgery monitored by electrical impedance tomography			
Study ID	Karsten[6] et al. 2011			
(A) Are the results of the trial valid?		Yes	Can't tell	No
	1. Did the trial address a clearly focused issue?			
	2. Was the assignment of patients to treatments randomized?			
	3. Were patients, health workers and study personnel blinded?			
	4. Were the groups similar at the start of the trial?			
	5. Aside from the experimental intervention, were the groups treated equally?			
	6. Were all the patients who entered the trial properly accounted for at its conclusion?			
(B) What are the results?				
	7. How large was the treatment effect? Compared to the ZEEP group (0 PEEP) with a compliance of 46 ml/cmH20, the PEEP group (10 cmH20 PEEP) had a compliance of 57 ml/cmH20.			
	8. How precise was the estimate of the treatment effect? Due to the small sample size, the precision of the effect is lacking			
(C) Will the results help locally?		Yes	Can't tell	No
	9. Can the results be applied in your context or to the local population?			
	10. Were all clinically important outcomes considered?			
	11. Are the benefits worth the harms and costs?			

Study title 7	Protective mechanical ventilation during general anesthesia for open abdominal surgery improves postoperative pulmonary function
Study ID	Severgnini [7] et al. 2013

(A) Are the results of the trial valid?	Yes	Can't tell	No
1. Did the trial address a clearly focused issue?			
2. Was the assignment of patients to treatments randomized?			
3. Were patients, health workers and study personnel blinded?			
4. Were the groups similar at the start of the trial?			
5. Aside from the experimental intervention, were the groups treated equally?			
6. Were all the patients who entered the trial properly accounted for at its conclusion?			

(B) What are the results?

7. How large was the treatment effect?
Compared to the Standard group (0 PEEP), the Protective group (with a PEEP of 10) had the same compliance of 40 ml/cmH20.

8. How precise was the estimate of the treatment effect?

Due to the small sample size, the precision of the effect is lacking

(C) Will the results help locally?	Yes	Can't tell	No
9. Can the results be applied in your context or to the local population?			
10. Were all clinically important outcomes considered?			
11. Are the benefits worth the harms and costs?			

Appendix D

Comparison of Trials

D-1 STUDY:	GROUPS:	PEEP (cmH20):	Pa02/Fi02 Ratio (mmHg):
Severgnini[7] et al. 2013			
	Standard	0	> 240: 24 patients
	Protective	10	>240: 27 patients
Weingarten[5] et al. 2010			
	Control	2.6	300
	Recruitment	12	409
Karsten[6] et al. 2011			
	ZEEP	0	382
	PEEP	10	498
Tusman[1] et al. 1999			
	ZEEP	0	128
	PEEP	5	152
	Recruitment	5 to 15	190

D-2 STUDY:	GROUPS:	PEEP (cmH20):	Compliance:
Severgnini[7] et al. 2013			
	Standard	0	40 ml/cmH20
	Protective	10	40 ml/cmH20
Weingarten[5] et al. 2010			
	Control	2.6	58 ml/cmH20
	Recruitment	12	80 ml/cmH20
Karsten[6] et al. 2011			
	ZEEP	0	46 ml/cmH20
	PEEP	10	57 ml/cmH20
Tusman[1] et al. 1999			
	ZEEP	0	43 cmH20
	PEEP	5	46 cmH20
	Recruitment	5 to 15	62 cmH20
Almarakbi[3] et al. 2009			
	R	0 PEEP, 1 RM	28 ml/cmH20
	P	10 PEEP, 0 RM	28 ml/cmH20
	RP	10 PEEP, 1 RM	32 ml/cmH20
	RRP	10 PEEP, 4 RM	41 ml/cmH20
Choi[2] et al. 2006			
	HVT/ZEEP	0	38
	LVT/PEEP	10	50

D-3 STUDY:	GROUPS:	PEEP (cmH20):	Infiltrate (# of patients):
Severgnini[7] et al. 2013			
	Standard	0	4
	Protective	10	2
Weingarten[5] et al. 2010			
	Control	2.6	1
	Recruitment	12	1
Talab[4] et al. 2009			
	ZEEP	0	1
	PEEP 5	5	1
	PEEP 10	10	0

D-4 STUDY:	GROUPS:	PEEP (cmH20):	Atelectasis (# of patients):
Severgnini[7] et al. 2013			
	Standard	0	4
	Protective	10	2
Weingarten[5] et al. 2010			
	Control	2.6	5
	Recruitment	12	4
Talab[4] et al. 2009			
	ZEEP	0	19
	PEEP 5	5	19
	PEEP 10	10	18

D-5 STUDY:	GROUPS:	PEEP (cmH20):	Pleural effusions (#patients):
Severgnini[7] et al. 2013			
	Standard	0	4
	Protective	10	0
Weingarten[5] et al. 2010			
	Control	2.6	4
	Recruitment	12	1

D-6 STUDY:	GROUPS:	PEEP (cmH20):	Oxygen saturation (%):
Almarakbi[3] et al. 2009			
	R	0 PEEP, 1 RM	92.5
	P	10 PEEP, 0 RM	93
	RP	10 PEEP, 1 RM	94
	RRP	10 PEEP, 4 RM	97
D-7 STUDY:	GROUPS:	PEEP (cmH20):	100% Fi02 (# of patients):
Talab[4] et al. 2009			
	ZEEP	0	5
	PEEP 5	5	3
	PEEP 10	10	1