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An Education Module for the Utilization of Pulmonary Recruitment Maneuvers During Trocar Removal to Improve Post-Laparoscopic Shoulder Pain

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An Education Module for the Utilization of Pulmonary Recruitment Maneuvers During Trocar Removal to Improve Post-Laparoscopic Shoulder Pain

A DNP Project Presented to the Faculty of the Nicole Wertheim College of Nursing and Health Sciences

Florida International University

In partial fulfillment of the requirements
For the Degree of Doctor of Nursing Practice

By

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Approval Acknowledged _______________________________, DNA Program Director

Date:_____________________________

Approval Acknowledged:______________________________, DNP Program Director

Date:_____________________________
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ABSTRACT

Background: Post-laparoscopic shoulder pain occurs in up to 80% of patients undergoing laparoscopic abdominal and/or pelvic surgery and is not as responsive to analgesics as wound pain is. Therefore, prevention is a more effective management technique for this type of pain. Pulmonary recruitment maneuvers (PRM) have shown some benefit in reducing post-laparoscopic shoulder pain (PLSP).

Objectives: The systematic review aimed to assess the best present randomized-controlled trials (RCTs) and meta-analysis regarding the efficacy of PRM to decrease PLSP. The education module aimed to inform anesthesia providers of the benefits of PRMs in the management of PLSP.

Data Sources: Investigators used CINAHL, MedLine, and EMBASE databases to answer the PICO question: (P) In patients undergoing laparoscopic surgery, does utilizing (I) pulmonary recruitment maneuvers compared to (C) manual abdominal compression to remove residual CO2 upon trocar removal decrease (O) postoperative shoulder pain intensity? Data from the pre- and post-test surveys in the education module were collected in Qualtrics and exported to SPSS statistical software for analysis.

Methodology: Ten RCTs and meta-analysis of RCTs were included in this systematic review. The combined sample size was 2,264 patients, and these studies found patients who received PRM to have superior PLSP management. This information was incorporated into an education module. Anesco provided an email list of CRNAs. These CRNAs were emailed an anonymous link to the education module containing a pre- and post-test along with a voiced-over PowerPoint video.

Results: Statistical analysis via SPSS showed that the average on the post-test increased from the pre-test with a p-value of 0.423, indicating a lack of statistical significance of these results. There was an increase in the likelihood of CRNAs to recommend the use of PRMs after viewing the education module.

Conclusions: The empirical evidence shows that PRM provides a reduction in post-laparoscopic shoulder pain scores. Implementing an evidence-based PRM project can lead to positive patient outcomes and potential increased patient satisfaction, and reduced opioid consumption. Lastly, CRNA providers benefit from an educational module presenting current evidence-based information on the newest PLSP management techniques. The knowledge increase also led to providers being more likely to recommend PRMs to reduce PLSP.

Keywords: pulmonary recruitment maneuvers, laparoscopic surgery, post-laparoscopic shoulder pain, referred shoulder pain, shoulder-tip pain, quality improvement, education module
INTRODUCTION

Description of Problem

Laparoscopy is used to perform many abdominal and gynecologic surgeries due to its many advantages, such as a significant reduction in surgical incision wound size, less wound-related pain, minimal trauma and injury, smaller scars, rapid recovery time, a shorter hospital stay, and an earlier return to daily activities and work compared with conventional exploratory laparotomy. Although laparoscopy is thought to cause less pain than exploratory laparotomy, up to 80% of patients still have severe pain after surgery and require pain relief. Post-laparoscopic pain has led to significant increases in analgesia use, extended hospital stays, and slower recovery.

Uncontrolled pain causes respiratory complications, including atelectasis, pneumonia, ventilation/perfusion mismatch, hypoxia, and hypoventilation due to impaired respiratory function, presenting as decreased tidal volume, vital capacity, total lung capacity, and functional residual capacity, and ability to clear secretions. Acute pain stimulates the sympathetic nervous system. By increasing systemic vascular resistance, heart rate, blood pressure, contractility, and the heart's workload, pain can be detrimental to certain patient populations, including elderly patients or patients with a history of ischemic heart disease. Furthermore, the pain associated with laparoscopy is different from pain experienced after exploratory laparotomy. One major pain type that can occur after laparoscopic surgery is shoulder-tip pain, which is sharp referred shoulder pain that tends to be more severe than surgical wound pain.

Background

Shoulder-tip pain (STP), also referred to as post-laparoscopic shoulder pain (PLSP), is not entirely understood, but three theories have been proposed for its etiology. One theory is that the carbonic acid that forms from the carbon dioxide used for insufflation irritates the peritoneum, diaphragm, and phrenic nerve. The second theory is that retained pockets of carbon dioxide cause loss of negative pressure in the peritoneal cavity, resulting in traction on the ligaments of
the liver. The third theory, neuropraxia theory, attributes STP in part to the stretching and tearing of the peritoneum, diaphragm, nerves, and blood vessels from the carbon dioxide and the resulting release of inflammatory mediators. All three theories attribute STP to carbon dioxide in some way. Therefore, carbon dioxide has a significant role in STP, and many studies have shown this to be true.

In addition to high levels of pain associated with STP, studies have shown that analgesics provide significantly less pain relief for STP than for relief of wound pain. Also, STP occurs in about 80% of patients undergoing laparoscopy—even with manual compression of the abdomen in Trendelenburg position to release the pneumoperitoneum—and is less responsive to analgesics when compared to wound pain. Therefore, it is vital to prevent this pain in patients undergoing laparoscopy rather than treating it once it has already occurred. Additionally, a study by Song et al. found that STP and its intensity are positively correlated with the volume of residual pneumoperitoneum. Consequently, it may be beneficial to focus on other methods that facilitate better carbon dioxide removal to prevent STP.

**Systematic Review Rationale**

Several methods have been proposed to decrease STP and/or aid in the release of a pneumoperitoneum, including the use of an alternative insufflating gas, the use of a low-pressure pneumoperitoneum, gasless laparoscopy, the use of warm and humidified carbon dioxide, local intraperitoneal anesthesia, intraperitoneal drainage, intraperitoneal saline instillation, and pulmonary recruitment maneuvers. Other gases can be used for insufflation, including argon, room air, nitrogen, helium, and nitrous oxide. These other gases are not as soluble as carbon dioxide and increase the risk for venous or arterial air embolization. Results are inconsistent when using other gases, so there may be safety issues with alternative insufflation gases. The knowledge gap of the unknown safety profile of other gases prevents these options.

Gasless laparoscopy (i.e. Laprolift system), low-pressure pneumoperitoneum (i.e. 7-8mmHg versus the standard pressure of 15mmHg), and local intraperitoneal anesthesia have
shown no statistically significant improvement in STP scores. However, the use of warm, humidified carbon dioxide has reduced STP, but there is a gap in this method's benefit/cost ratio. Other methods in reducing STP are intraperitoneal drainage, pulmonary recruitment maneuvers (PRMs), and intraperitoneal fluid instillation. Studies are limited and more evidence is needed to verify the usefulness of these techniques. A knowledge gap exists in the systematic reviews and meta-analysis with the number of breaths of pulmonary recruitment that lead to a significant reduction in STP. Current literature does not address the lowest pressure at which the pulmonary recruitment maneuver can reduce STP. This is an important fact to address because the greater the pressure used, the greater the risk for barotrauma.

Several studies and multiple systematic reviews and meta-analyses have indicated that pulmonary recruitment maneuvers can decrease STP pain scores. Shoulder-tip pain reduction helps prevent the problems associated with increased pain, such as increases in analgesia use, extended hospital stays, slower recovery, respiratory complications, and sympathetic nervous system stimulation. There is no consensus on the technique that is the most advantageous in creating the greatest reduction in STP while maintaining patient safety. Therefore, it would be beneficial to determine the best technique for reducing STP.

**Objectives of Systematic Review**

The purpose of this systematic review is to identify and evaluate the available evidence on the efficacy of pulmonary recruitment maneuvers using various techniques with different pressures and number of breaths on reducing the severity of shoulder-tip pain. Consequently, this review aims to assess pulmonary recruitment maneuvers versus traditional manual compression of the abdomen in their efficacy in releasing a carbon dioxide pneumoperitoneum at the end of laparoscopic surgery. To fulfill this objective, a PICO (patient population, intervention or issue of interest, comparison intervention or group, and outcome) question will be used to guide the search of high-level evidence. The PICO question that this review aims to answer is: (P) In patients undergoing laparoscopic surgery, does utilizing (I) pulmonary recruitment maneuvers...
compared to (C) manual abdominal compression to remove residual CO2 upon trocar removal
decrease (O) postoperative shoulder pain intensity? The findings to this research question will
then be used to create an evidence-based protocol.

METHODOLOGY OF LITERATURE REVIEW

Search Strategy and Sources

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)
Checklist was used to guide the search of this systematic review. The search was conducted using
the Cumulative Index of Nursing and Allied Health Literature (CINAHL), Medline (ProQuest),
and Excerpta Medica Database (EMBASE) electronic databases. A detailed table describing the
exact terms and subject headings used to search in each database is shown below in Table 1. Due
to the low yield of the initial search results, no filters were applied to the searches. The PICO
question format was used to create the research question that was then used to guide the search
and develop the keywords provided in the database search table (Table 1). A total of 73 articles
came from the three searches: the MEDLINE database yielded 26 results, CINAHL generated 10
articles, and EMBASE produced 37 articles. The removal of duplicate articles resulted in 37
articles being appraised.

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<td><strong>Concepts/Topics</strong></td>
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<td>CINAHL</td>
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Study Selection and Screening of Evidence

An investigator screened titles and abstracts found with the preliminary PICO question. The investigator then organized the articles found in the search via EndNote X9 into “Irrelevant”, “Background”, and “Relevant” folders. Three articles were placed in the “Background” folder, six into the “Irrelevant” folder, and 28 into the “Relevant” folder. Articles were deemed not relevant if they did not include any component of the PICO question. Duplicates were removed manually when the search was completed, so no further intervention was required in this regard.

The investigator then completed a full-text screening process on the 28 relevant articles based on the inclusion and exclusion criteria listed in Table 2 below. The inclusion criteria...
included: double-blind randomized controlled trials (RCTs), patients undergoing laparoscopic surgery, any type of laparoscopic surgery, articles on the use of the pulmonary recruitment maneuver, the primary outcome of postoperative shoulder pain, articles published in the English language, systematic reviews, meta-analyses, and prospective cohort studies. The pulmonary recruitment maneuver is defined as airway pressure applied upon removing the trocars in laparoscopic surgery. This increase in airway pressure can be completed through manual breaths by setting the anesthesia machine to “bag” or through ventilator-initiated breaths by setting the anesthesia machine to the “ventilator” mode. Postoperative shoulder pain includes any shoulder pain that the patients feel after laparoscopic surgery. The inclusion criterion includes articles that either address the incidence or intensity of postoperative pain or both. The intensity of pain can be quantified using any pain scoring scale. All other results were excluded from this review.

Several studies were excluded for numerous reasons, including the wrong study design and measuring the incorrect outcomes. For example, one study was a dissertation, and another was a study protocol. Also, numerous studies combined the use of the pulmonary recruitment maneuver with one or multiple interventions, making it impossible to determine the benefit of the pulmonary recruitment maneuver specifically on postoperative shoulder pain. Eleven studies met the eligibility requirements and were included in this systematic review. Appendix A is a PRISMA flow diagram that provides a visual representation of the screening process using the inclusion and exclusion criteria.

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<td><strong>Inclusion</strong></td>
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<tr>
<td>Population:</td>
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<tr>
<td>• Patients undergoing laparoscopic surgery</td>
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<tr>
<td>Type of procedure:</td>
</tr>
<tr>
<td>• Any type of laparoscopic surgery</td>
</tr>
<tr>
<td>Intervention:</td>
</tr>
<tr>
<td>• Studies that utilize the pulmonary recruitment maneuver, including both manual and ventilator-assisted recruitment breaths</td>
</tr>
<tr>
<td>Primary Outcome:</td>
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<tr>
<td>-------------------------------------------------------------------------------</td>
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<tr>
<td>• Postoperative shoulder pain/shoulder-tip pain – Studies including</td>
</tr>
<tr>
<td>postoperative shoulder pain intensity and/or incidence by utilizing any pain</td>
</tr>
<tr>
<td>scoring tool will be included.</td>
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<tr>
<td>Type of study:</td>
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<tr>
<td>• English language</td>
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<tr>
<td>• Randomized controlled trials</td>
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<tr>
<td>• Systematic reviews</td>
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<tr>
<td>• Meta-analyses</td>
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<td>• Prospective cohort studies</td>
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The studies selected via the PRISMA method were then evaluated using the John Hopkins Research Evidence Appraisal Tool. This tool contains questions that help determine the level and quality of primary studies included in a systematic review. The level of evidence is rated as I through V. Level I evidence is RCT studies, meaning that the study manipulated an independent variable, had a control group, and randomly assigned subjects to groups. Experimental studies and systematic reviews of RCTs with or without meta-analysis also fall under the level I category. Level II evidence consists of quasi-experimental studies and systematic reviews that contain a combination of RCTs and quasi-experimental studies or quasi-experimental only, with or without meta-analysis. In addition, level III evidence includes non-experimental studies; systematic reviews of a combination of quasi-experimental and nonexperimental or non-experimental only, with or without meta-analysis; and qualitative studies or meta-synthesis. To further appraise the evidence, articles can be given quality ratings, including A (i.e., high quality), B (i.e., good quality), and C (i.e., low quality or major flaws). Quality A describes studies that contain consistent and generalizable results, and have a sufficient sample size, adequate control, definitive conclusions, and consistent recommendations. Quality B includes studies that contain a sufficient sample size, some control, reasonably consistent results, fairly definitive conclusions, and reasonably consistent recommendations. A quality C rating is given to studies with an insufficient sample size and little evidence with inconsistent results. As a result, conclusions cannot be drawn from C quality studies. The data were collected and analyzed from the selected studies, and an evaluation table was made to summarize and critique findings from each study and characterize individual study characteristics.

The information obtained and evaluated for each study included: (1) the study method and design, (2) study setting, (3) sample size and characteristics, (4) surgery type, (5) American Society of Anesthesiologists physical status classification of the patients, (6) interventions and comparisons, (7) outcomes measures, (8) analysis methods, (9) study findings, (10) study conclusion. After the evaluation, each study was assigned an evidence and quality rating based on
John Hopkins Research Evidence Appraisal Tool. The John Hopkins evidence and quality ratings, along with the author names, year, study design, participants, setting, interventions, and pulmonary recruitment maneuver group findings, are included in the matrix in Appendix L.

RESULTS OF LITERATURE REVIEW

Study Selection

A total of 73 articles resulted from the three databases initially. Eighteen duplicates or triplicates were removed, and a total of 37 articles were left. After further review of the titles and abstracts, nine articles were eliminated, and 28 articles were assessed for eligibility. The exclusion and inclusion criteria were used to complete a full-text analysis, resulting in the exclusion of 17 articles. These articles were excluded because they were studies other than RCTs, systematic reviews, meta-analyses, and prospective cohort studies; they measured outcomes other than postoperative pain; or they utilized interventions other than pulmonary recruitment maneuvers. A manual assessment of the search results’ reference lists did not identify additional RCTs that met the criteria for this systematic review. Ultimately, the study selection resulted in 10 RCTs and one network meta-analysis to be included in this systematic qualitative review to answer the PICO question: “In patients undergoing laparoscopic surgery, does utilizing pulmonary recruitment maneuvers compared to manual abdominal compression to remove residual CO2 upon trocar removal decrease postoperative shoulder pain intensity?” All 11 articles were level 1 evidence according to Johns Hopkins’ appraisal scale. The matrix in Appendix L provides a summary of all RCTs included in the systematic review.

Study Characteristics

The selected RCTs and network meta-analysis included a combined total of 2,264 patients who underwent laparoscopic surgery and received pulmonary recruitment maneuvers and other interventions, including passive exsufflation and manual compression. All studies were published between 2008 to 2020 and were published in the English language. The patient demographic characteristics were somewhat varied. The studies only included patients with ASA
(American Society of Anesthesiologists) physical status I and II. Some studies included both sexes, while some only included females. In addition, the age ranges varied. The age ranges of the studies were 18 years or older, 20-65 years, 15-65 years, 19-65 years, and 18-70 years. Even though all studies involved laparoscopic procedures, the type of laparoscopic procedures performed varied between studies.

**Patient demographics.** Eight of the eleven studies identified the patients as female, while three included both males and females. All patients were classified as either ASA status 1 or 2. All patients enrolled were scheduled for laparoscopic surgery; however, the type of laparoscopic surgery differed. Two studies were completed on patients undergoing laparoscopic cholecystectomies, appendectomies, and inguinal hernioplasties, and another study was conducted on patients undergoing laparoscopic bariatric surgery.\(^9\)\(^-\)\(^11\) The other studies involved some form of laparoscopic gynecologic surgery: three studies utilized laparoscopic oncologic gynecologic surgery, and five studies utilized benign gynecologic surgery. Only two studies mentioned exclusion criteria. The study by Gungorduk et al. excluded patients who had previous major bowel surgery, and Phelps et al. excluded patients who had a previous laparotomy.\(^12\)\(^,\)\(^13\) The patients' ages ranged from 15 to 70 years old, and the sample sizes of the 10 RCTs were small to moderate in size, ranging from 72 to 150 patients. The network meta-analysis sampled 11 RCTs, which is a smaller sample size as well.

**Study Setting Demographics.** The RCTs were conducted in hospitals, tertiary care centers, and ambulatory centers around the world. Garteiz-Martinez et al. performed their study at a tertiary care center in Mexico City. Three RCTs were completed in Turkey, two of which were at the same hospital, called Istanbul Health Sciences University, Kanuni Sultan Suleyman Education and Research Hospital in Turkey.\(^14\)\(^,\)\(^15\) The other study in Turkey was carried out at two hospitals simultaneously, including Istanbul Bakirkoy Sadi Konuk Education and Research Hospital and Izmir Tepecik Education and Research Hospital.\(^12\) One trial was performed in South Korea at the Kangbuk Samsung Hospital, and another was performed in Sweden at the Vrinnevi
There was a trial completed in Tehran, Iran at a referral hospital, but the hospital's name was not identified. Lee et al. performed their study in a university hospital, and Phelps et al. performed theirs at a hospital-affiliated ambulatory center. Still, the name and location of either place were not mentioned. Khanna et al. did not state the name, location, or the setting of their study. The network meta-analysis did not provide the settings of the RCTs that were included.

**Methodology.** Personnel conducting the study interventions in the 10 RCTs included only anesthesiologists. All studies used some form of pulmonary recruitment maneuver, but the pressures of the PRM employed varied. Four studies utilized PRMs at 60 cmH2O of pressure. Three out of four studies used five manual PRM breaths, while one only used two manual PRM breaths. Three studies applied PRM to the patients at 40 cmH2O with varied numbers of breaths, including 2, 4, and 6 breaths. One trial made use of 30 cmH2O of pressure for 5 PRM breaths. The remaining two RCTs compared the efficacy of different pressures of pulmonary recruitment maneuvers: one study evaluated 60 cmH2O versus 40 cmH2O versus passive exsufflation, and the other assessed 30 to 40 cmH2O versus 15 cmH2O. Some studies compared PRMs to various other interventions, including 20mL of 7.5% ropivacaine intraperitoneal instillation, passive exsufflation, intraperitoneal normal saline infusion 1.5-2mL/kg of body weight at 37 degrees Celsius, and abdominal compression. Seven RCTs involved the anesthesiologists performing the PRM on the patients in the Trendelenburg position at 30 degrees, while one RCT was conducted using PRM in a 30-degree semi-fowler’s position. Three studies did not mention the position. One study attempted to determine the effects of position on the success of the PRM in reducing post-laparoscopic shoulder pain by comparing PRM at 40 cmH2O in the neutral position, PRM in semi-fowler’s position, and the neutral position without PRMs.
Definitions and Outcomes

The primary outcome investigated in this review was the effect of PRMs at different pressures on PLSP. The studies also measured the incidence of subdiaphragmatic pneumoperitoneum present on a chest x-ray, postoperative shoulder pain measured by a 10-point visual analog scale or a numerical rating scale of 0-10, rate of nausea and vomiting, upper and lower abdomen pain, lower abdominal surgical pain intensity, the height of residual pneumoperitoneum on chest x-ray, pulmonary complications, postoperative analgesic requirement, time to unassisted ambulation, PLSP incidence, and severity of nausea on a scale of 0-10. Garteiz-Martinez et al. showed that a PRM of 60 cmH2O versus intraperitoneal ropivacaine administration reduced the incidence of subdiaphragmatic pneumoperitoneum and shoulder pain. This study also mentioned that the volume of subdiaphragmatic CO2 volume was positively correlated to shoulder pain intensity, indicating that PRM’s benefit on PLSP may be due to its ability to decrease residual CO2. Kyoungho et al. showed a significant decrease in residual pneumoperitoneum at both 40 cmH2O and 60 cmH2O for the PRM versus passive exsufflation. This study also revealed a reduction in PLSP at both PRM pressures, but there was no significant difference in the PLSP intensity between the two different pressures, indicating that a maximum inspiratory pressure of 40 cmH2O is sufficient to reduce PLSP. Pulmonary recruitment maneuvers did not affect wound pain and did not cause any pulmonary complications in this study. Residual pneumoperitoneum was also analyzed in the study by Yilmaz et al., and this study compared the residual pneumoperitoneum between PRMs of 15 cmH2O and 30-40 cmH2O. The study showed that the height of the pneumoperitoneum on a chest x-ray was equal between a low-pressure PRM of 15 cmH2O and a moderate-pressure PRM of 30 to 40 cmH2O. Low-pressure PRM with a maximal inspiratory pressure of 15 cm H2O pressure also provides similar benefit on PLSP, wound pain, the height of pneumoperitoneum, time to ambulation, and length of hospital stay when compared to a moderate-pressure PRM with a maximal inspiratory pressure of 30–40 cm H2O in patients undergoing gynecologic laparoscopic surgery.
Gungorduk et al., Lee et al., Khanna et al., and Phelps et al. compared PRM to passive exsufflation. Gungorduk et al. demonstrated that PRM with a positive pressure of 40 cmH2O at the end of surgery was associated with a significant reduction in the incidence of shoulder and upper abdominal pain and pain scores at 12 and 24 hours. In addition, analgesic requirements and the incidence of postoperative nausea and vomiting did not differ between the PRM and the passive exsufflation groups. Lee et al. had similar results at a lower pressure, illustrating that low-pressure PRM using 30 cm H2O reduced PLSP significantly in patients who underwent laparoscopic gynecologic surgery. Both Khanna et al. and Phelps et al. showed a reduction in PLSP with 60 cmH2O PRMs compared to passive exsufflation.

Risk of Bias

Cochrane Handbook Collaboration’s Risk of Bias tool was used to assess for bias in all eleven studies included in this systematic review. This tool showed that there were several sources of bias in these studies. Nine studies had an overall low risk of selection bias since all samples were randomly selected. Garteiz-Martinez et al. had a higher risk of selection bias because five patients were declined for surgery after random allocation. Their assigned intervention was revealed so that these patients could be replaced by another patient who received the same intervention. In other words, the investigators were no longer blinded to the intervention these patients were receiving. All other studies used a random sequence generation. All the authors discussed their concealment method, including computer-generated random tables, permuted block randomization via web-based response system, random allocation software, or utilizing sequentially number, opaque, sealed envelopes.

Performance bias was another concern. All studies were blinded so that the participants did not know what treatment they were receiving, and the individuals who measured the outcomes in each study were also blinded to the treatment. However, the anesthesiologists could not be blinded to the treatment because they were the ones who had to administer it. The surgeons in the studies by Garteiz-Martinez et al. and Davari-Tanha et al. also could not be
blinded as they were involved in administering the treatments of intraperitoneal anesthetic instillation and the intraperitoneal normal saline infusion. Gartez-Martinez et al. also contained performance bias as five of the participants had to be unmasked. Consequently, no one was blinded to the intervention that those participants were supposed to receive.

Another bias assessed in Cochrane’s tool is attrition bias. Gartez-Martinez et al. declined five patients for surgery due to various factors. As a result, this study is at high risk of attrition bias and must be considered for bias because of incomplete data collection. Reporting bias may have occurred in studies due to selective reporting of results. None of the studies stated the possibility of selective outcome reporting and the plan for its prevention.

DISCUSSION OF LITERATURE REVIEW

Summary of Evidence

Ten RCTs and one meta-analysis with a total of 2,264 patients were included in this systematic review. Several studies were excluded for numerous reasons, including measuring different primary outcomes (i.e., did not include postoperative pain), utilizing interventions that did not include pulmonary recruitment maneuvers, involving surgery types besides laparoscopic surgery, or using the incorrect study design. Due to larger sample sizes, well-defined methodology and inclusion criteria, and rigorous statistical methods, nine articles met the criteria for high-quality level 1 evidence. The remaining two articles were appraised by the Johns Hopkins’ tool as medium-quality level 1 evidence had a potentially small sample size due to the failure to complete a power analysis or had a partially compromised randomization due to the unmasking of patients to replace ones that had been declined. The results of this systematic review are summarized below:

- At 6, 12, and 24 hours postoperatively, the lowest PLSP scores were recorded in patients who received the PRM in the semi-Fowler position (head of the bed elevated 30 degrees) compared with those receiving the PRM in the neutral position and passive exsufflation.
• There were decreased PLSP scores relative to passive exsufflation in patients receiving PRMs at:
  5 manual pulmonary inflations at 60 cmH2O for 5 seconds
  5 manual pulmonary inflations at 30 cmH2O for 5 seconds
  5 manual pulmonary inflations at 40 cmH2O for 5 seconds
  5 manual pulmonary inflations at 15 cmH2O for 5 seconds
• PLSP at 24 h and 48 h after surgery were not significantly different between PRM at 40 cmH2O and 60 cmH2O.
• A single study reported no significant differences in wound pain score, PLSP, number of rescue analgesics used, IV analgesics used, total analgesic dosages used, ambulation time, length of hospital stay, and height of the pneumoperitoneum measured on chest x-ray between administering PRM at 15 cm H2O and 30 cm H2O.

Limitations of the Literature Review

The investigators must acknowledge the limitations of this systematic review. Part of the inclusion criteria was solely peer-reviewed articles in English, which can cause language bias and may lead to a flawed conclusion. Another limitation was the unpreventable high heterogeneity among the studies. There were several dissimilarities between the 10 RCTs and the one meta-analysis included, which has the potential to influence the reliability of this systematic review negatively. One fundamental difference was the various definitions for pulmonary recruitment maneuver across the studies. By having differing definitions of the independent variable, there is a possibility of skewing the results reported in this systematic review. For example, one study referred to pulmonary recruitment maneuvers as the patient receiving pressure-controlled ventilation with six breaths with a positive inspiratory force of 20 cmH2O and a positive end-expiratory pressure of 20 cmH2O. On the other hand, the study by Phelps et al. defined pulmonary recruitment maneuvers as five manual breaths at 60 cmH2O where the fifth breath is held for five seconds and Lee et al. defined pulmonary recruitment maneuvers as five manual
pulmonary inflations that are held for five seconds each with a pressure of 30 cmH2O. In other words, the pressure, method, number of breaths at which the breaths were delivered, and the length of time the pulmonary inflation was held varied between studies. The different methods can affect postoperative shoulder pain incidence or severity and make the comparison between studies difficult.

Additionally, there was heterogeneity in the time intervals for data collection. One study only collected the shoulder visual analog pain scores at 6 hours. Gungorduk et al. measured postoperative shoulder pain at 12, 24, and 48 hours. Two studies measured the pain on a 10-point visual analog scale at the 24-hour and 48-hour mark. The meta-analysis by Kietpeerakool et al. only included studies that measured PLSP at 24 and 48 hours. Phelps et al. determined the pain scores at 12, 24, 36, and 48 hours via a questionnaire using a 100-point visual analog scale, unlike the 10-point visual analog scale used in the other RCTs. Two studies assessed PLSP at 6, 12, and 24 hours. Davari-Tanha et al. determined pain scores at 2, 6, 12, and 24 hours and Pasquier et al. monitored pain scores at 4, 12, 24, 36, and 48 hours. Although there were many overlapping times between these studies, most of the studies did not assess pain at the same time intervals. Also, pulmonary recruitment maneuvers were compared to different interventions in the studies. The other interventions that pulmonary recruitment maneuvers were compared to were intraperitoneal anesthetic administration, intraperitoneal saline administration, passive carbon dioxide evacuation, and manual abdomen compression. Overall, the heterogeneity between studies may question the reliability of this systematic review appraisal.

The study participants were healthy ASA I and II adult patients. The results of this limited population cannot accurately be applied to unhealthy ASA III and above patients, so the pulmonary recruitment maneuver effects shown in these studies cannot be generalized to all adult populations. The patients included in these studies had uncomplicated laparoscopic surgery and were excluded from the study if there were complications or findings that could complicate the
surgery, such as multiple adhesions, septic contamination of the peritoneal cavity, hemoperitoneum, or if conversion to open surgery was required. Additionally, eight of the eleven studies were limited to gynecologic laparoscopic procedures, limiting the ability to generalize the results to males and other laparoscopic procedures. Four of those studies involving laparoscopic gynecologic procedures limited the patients they studied to those having procedures for benign conditions, further limiting the generalizability of these results. Despite these limitations, this systematic review supports the use of pulmonary recruitment to reduce post-laparoscopic shoulder pain in ASA 1 and 2 adults undergoing laparoscopic surgery.

**Recommendations for Future Research**

To further determine the best use of PRMs in decreasing PLSP, more well-designed studies examining the specific use of different pressures in different positions are needed. Larger scale RCTs with a larger sample size should be conducted to ensure the generalizability of the results. Additionally, these studies should include patients with high ASA physical statuses. Patients with more comorbidities should not be excluded from receiving a PRM unless adequate research or comorbidity demonstrates a contraindication. Future RCTs should also include gynecologic oncology procedures that are not for benign conditions since PLSP is not exclusive to healthy patients. The goal should be to provide a new and better pain management technique to as many patients as possible, ideally the entire population of patients undergoing laparoscopic procedures. Another recommendation is to conduct studies on a wider variety of procedures, including procedures that are more inclusive of men.

**CONCLUSION OF LITERATURE REVIEW**

A literature review was conducted, which examined CINAHL, EMBASE, and MEDLINE (ProQuest) databases. The search resulted in 73 articles, which were thoroughly reviewed and examined. Ultimately, ten RCTs and one meta-analysis were included in the literature review. One RCT analyzed PRM versus intraperitoneal ropivacaine instillation, six analyzed PRM versus a control, one analyzed PRM at a pressure of 15 cmH2O versus 30-40
cmH2O, one analyzed PRM administered in semi-Fowler position versus PRM in neutral position versus a control, and one analyzed PRM versus intraperitoneal normal saline infusion. The meta-analysis analyzed RCTs that compared PRM versus abdominal compression. All studies found patients who received PRM to have superior post-laparoscopic shoulder pain management. In addition, the studies that compared different pressures of PRM found similar efficacy at lower pressures. Increased effectiveness of the PRM was shown in the semi-Fowler position compared to the neutral position.

**METHODODOLOGY OF QUALITY IMPROVEMENT**

**Setting**

The setting is a hospital system in Broward County, Florida. The hospital system contains four hospitals. Broward Health Coral Springs contains 250 beds, Broward Health Imperial Point contains 204 beds, Broward Health Medical Center contains 716 beds, and Broward Health North contains 409 beds. The Salah Foundation Children’s Hospital within Broward Health Medical Center contains 125 beds.

**Recruitment and Participants**

The certified registered nurse anesthetists (CRNAs) that provide anesthesia services within the Broward Healthcare system are employed by Aneasco and not the Broward Healthcare System. The target population consisted of all the CRNAs employed by Aneasco, an anesthesia company. Participants were identified via an employee email list supplied by Aneasco. All Aneasco CRNAs were emailed an invitation to participate in the education module. Aneasco CRNAs were eligible to participate in the educational module. All Broward Hospital employees were excluded from participation in the study. Aneasco anesthesia employees who met inclusion criteria were allowed to take the voluntary pre-test and post-test questionnaires and view the education module (See Appendix G and Appendix H).
**Intervention and Procedures**

An educational intervention about pulmonary recruitment maneuvers in patients undergoing laparoscopic surgery can increase knowledge and understanding, which can increase its use and, thereby, potentially decrease the incidence and severity of post-laparoscopic shoulder pain. Education is critical to motivating anesthesia staff to change their actual practice behaviors. The education module about the benefits of pulmonary recruitment maneuvers instructed the staff on proper PRM techniques and how this technique can reduce PLSP. The education module included a pre-test questionnaire, a YouTube video created using a voice-over PowerPoint, and a post-test questionnaire. The goal is for CRNAs to understand better the benefits of using PRMs. This technique in reducing post-laparoscopic shoulder pain is easy to perform and has shown no adverse effects in patients. The educational session’s content is reflected in the pre- and post-test questions to engage the learner and gauge the learners’ knowledge before and after viewing the education module. The pre-test questions aim to focus the learners on the most important content. In contrast, the post-test questions ensure the educational module properly taught the information and the learner gained appropriate knowledge.

Institutional Review Board (IRB) exemption status was applied for at Florida International University and Broward Health and received by both institutions. Anesco provided an email list of Anesco employees. An informational letter was then sent via email to all the CRNAs employed by Anesco, inviting them to participate in the project. An anonymous link to the pre-intervention survey was included in the email. The CRNAs completed the pre-test questionnaire on their mobile devices or computers via the Qualtrics survey platform. A unique, random code identifier was created for the survey, while no personally identifiable information was captured. Following these procedures protected the privacy of those who volunteered to participate in the project, as there was no way to link responses to identifying information. Those who chose to participate in the educational module could listen to and view the video at their leisure and then fill out the post-test questionnaire on their mobile phone or computer.
The education module video was embedded into the Qualtrics survey. The participants could fill out the pre-test questionnaire, complete the education module, and fill out the post-test questionnaire whenever was convenient for them. All activities took place virtually, and the pre- and post-test questionnaires were completed via Qualtrics. Each participant received an anonymous link in their email, and once the link was accessed, the respondent created a unique identifier that linked their pre-test to the post-test.

Protection of Human Subjects

By using unique, random code identifiers, CRNAs participating in the study remained anonymous and the data secured. In addition, the link that the CRNAs clicked on in their email was anonymous, meaning that no identifying information was captured, including the email that was used to access the link. A laptop password and spyware protected the digital data collected from the pre-test and post-test. These protective measures ensured the safety of the data.

Measurement and Analysis

The pre-test questionnaire consisted of eight questions directly related to the educational content, six personal questions such as age, gender, ethnicity, position/title, level of education, and years of being an anesthesia provider, and two Likert scale questions (see Appendix G). The post-test questionnaire just contained the questions related to the educational content. No information collected could lead to identifying the participant. The ten knowledge-based questions were all multiple-choice questions or select all that apply. Two questions used the Likert scale with answer options from very likely to very unlikely. An increase in knowledge from pre-test to post-test was determined by how many questions the participant got right on the pre-test compared to the number of correct answers on the post-test. Additionally, the Likert questions were used for analysis about whether anesthesia providers would be likely or not likely to adopt PRMs or other alternative methods to decrease post-laparoscopic shoulder pain.

The data was exported from Qualtrics to IBM SPSS version 26 statistical software, and analysis was conducted using this same software. Descriptive statistics were used to analyze the
responses from the pre- and post-test questionnaires. A paired t-test was conducted to determine if there was a significant change in the knowledge, attitudes, and behaviors of the CRNAs about using PRMs to decrease PLSP on patients undergoing laparoscopic surgery after participating in the virtual education module.

RESULTS OF QUALITY IMPROVEMENT

Demographics

There were four participants in the pre-test demographics, and all four completed the entire study, including both pre- and post-test components. The gender of the participants revealed that 3 (75.00%) were female and 1 (25.00%) was male. There was also a range of ethnicities represented: African American (n=1, 25.00%), White (n=2, 50.00%), and Other (n=1, 25.00%). Information was obtained regarding the participant’s highest level of education. It was found that there was an unequal mix of those who had received either a master's (n=3, 75.00%) and those who had received a doctorate (n=1, 25.00%). The participants were questioned about the length of time practicing, finding that the practice period ranged from 5 to 10 years (n=2, 50.00%) and >10 years (n=2, 50.00%). The demographic information described is included in Table 3 below.

Table 3. Demographics

<table>
<thead>
<tr>
<th>Demographic</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Participants</td>
<td>4 (100.00%)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1 (25.00%)</td>
</tr>
<tr>
<td>Female</td>
<td>3 (75.00%)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>2 (50.00%)</td>
</tr>
<tr>
<td>African American</td>
<td>1 (25.00%)</td>
</tr>
<tr>
<td>American Indian</td>
<td>0 (0.00%)</td>
</tr>
<tr>
<td>Asian</td>
<td>0 (0.00%)</td>
</tr>
<tr>
<td>Other</td>
<td>1 (25.00%)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
</tr>
<tr>
<td>18-25</td>
<td>0 (0.00%)</td>
</tr>
<tr>
<td>26-40</td>
<td>2 (50.00%)</td>
</tr>
<tr>
<td>Age Group</td>
<td>Count (Percentage)</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------</td>
</tr>
<tr>
<td>41-55</td>
<td>0 (00.00%)</td>
</tr>
<tr>
<td>&gt;55</td>
<td>2 (50.00%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Education</th>
<th>Count (Percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bachelors</td>
<td>0 (0.00%)</td>
</tr>
<tr>
<td>Masters</td>
<td>3 (75.00%)</td>
</tr>
<tr>
<td>Doctorate</td>
<td>1 (25.00%)</td>
</tr>
<tr>
<td>Other</td>
<td>0 (0.00%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Years of Experience</th>
<th>Count (Percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>0 (00.00%)</td>
</tr>
<tr>
<td>2-5</td>
<td>0 (00.00%)</td>
</tr>
<tr>
<td>5-10</td>
<td>2 (50.00%)</td>
</tr>
<tr>
<td>&gt;10</td>
<td>2 (50.00%)</td>
</tr>
</tbody>
</table>

**Pre-Test and Post-Test Sample**

Four CRNAs completed both the pre- and post-test surveys. The average overall scores for the pre-test were 5.25 (SD=1.708), and the overall scores for the post-test were 6.25 (SD=2.21736). The average post-test score increased by 1 point from the pre-test. The results demonstrate a P-value of 0.423, which indicates that these results were not statistically significant. Although the increased averages on the post-test surveys indicate an overall increase in knowledge due to the education module provided to the participants, the paired T-test demonstrates that this increase in knowledge base was not statistically significant. Please see Appendix K for the full T-test figures and statistics.

**Pre-Test Knowledge**

The pre-test results provide information regarding the common beliefs and pre-existing knowledge regarding PLSP in patients undergoing laparoscopic surgery and about alternative pain management methods that can be used to address this type of pain. All the participants underestimated the incidence of post-laparoscopic shoulder pain—which is 80%—and believed that the incidence was either 20% (n=1, 25%), 40% (n=2, 50%), or 60% (n=1, 25%). Most of the participants, except for one, did not know or understand the proposed etiologies for PLSP. However, every participant knew that wound pain is more responsive to analgesics than PLSP and that intraoperative morphine administration is not an appropriate treatment for PLSP. Some
of the participants incorrectly believed that premedication with gabapentin (n=2, 50%) and
transversus abdominus plane (TAP) blocks (n=2, 50%) were effective treatments for PLSP. Three
participants correctly chose intraperitoneal local anesthetic administration and pulmonary
recruitment maneuvers as methods for decreasing PLSP, and all four correctly chose
intraperitoneal saline administration. Every participant knew the signs of uncontrolled pain and
that pulmonary recruitment maneuvers at 15 cmH2O are as effective at decreasing PLSP as using
higher pressures are. In addition, all but one participant knew the multiple potential benefits of
PRMs besides a reduction in PLSP, including decreased nausea and vomiting, reduced upper
abdominal pain, and decreased incidence and reduced volume of subdiaphragmatic CO2.
However, only one participant knew that semi-fowlers position used in conjunction with PRMs is
associated with an even greater reduction in PLSP.

Post-Test Knowledge

On the post-test, two participants (50%) correctly identified that the incidence of PLSP
after laparoscopic surgery is up to 80%. Only one participant (25%) correctly selected that
residual carbon dioxide putting pressure on the diaphragm and peritoneum is not a proposed
etiology for PLSP. The same participants who got this question wrong on the pre-test also got that
question wrong on the post-test, indicating a lack of increase in knowledge on this topic. All the
participants already knew the implications of uncontrolled pain, so they got this question correct
on the pre- and post-test, illustrating no percent increase in knowledge. A greater understanding
of the proposed methods for reducing PLSP and the pressures of PRMs that have been studied
was reached with one participant (25%) choosing the correct answer to these two questions that
everyone got incorrect on the pre-test. There was also a 25% increase in correct answers chosen
for the questions on PRMs in the semi-fowler’s position being more efficacious in decreasing
PLSP than PRMs in the neutral position, other possible benefits of PRMs, and the lowest pressure
at which PRMs have shown to be effective. On the latter two questions, all participants chose the
correct answer on the post-test. Unfortunately, there were two questions where every participant
answered the pre-test correctly, but then one participant changed their answer on the post-test to an incorrect answer. As a result, the post-test score decreased from 100% to 75%, showing a 25% decrease in knowledge. All participants were able to identify the correct answer on the pre-test, so it stands to reason that the one participant who changed their answer to an incorrect answer did so in haste or by misreading the question. By all four participants selecting the correct answers on the pre-test, it is reasonable to assume the participants already had base knowledge on the fact that PLSP does not respond better to analgesics than wound pain. It seems that the participants were able to deduce from either the way the question was asked or from personal experience that PRMs administered at 15 cmH2O are as effective in reducing PLSP as higher pressures. Therefore, it seems that changing an answer to an incorrect answer on the post-test was likely a mistake. Most of the other questions had at least a 25% improvement in scores from the pre-test to the post-test. There were only two questions that were the exception and had no change in score from the pre-test to the post-test, but one of these exceptions was a question in which all participants got the question correct on the pre-test and the post-test. The score cannot increase when it is already 100%. See Table 4 and Graph 1 for the difference in responses from the pre- to post-test. Average overall pre-test and post-test scores are also displayed below in Graph 2.

**Table 4. Difference in Pre- and Post-Test Findings**

<table>
<thead>
<tr>
<th>Finding</th>
<th>Pre-Test</th>
<th>Post-Test</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depending on patient risk factors, the incidence of shoulder pain after laparoscopic surgery can be as high as: 80%</td>
<td>0.00%</td>
<td>50.00%</td>
<td>50.00%</td>
</tr>
<tr>
<td>The residual carbon dioxide in the abdomen putting pressure on the diaphragm and peritoneum is not a proposed etiology for post-laparoscopic shoulder pain</td>
<td>25.00%</td>
<td>25.00%</td>
<td>00.00%</td>
</tr>
<tr>
<td>Post-laparoscopic shoulder pain does not respond better to analgesics than wound pain</td>
<td>100.00%</td>
<td>75.00%</td>
<td>-25.00%</td>
</tr>
<tr>
<td>Uncontrolled pain can cause increased blood pressure, atelectasis, hypoventilation, and increased cardiac workload</td>
<td>100.00%</td>
<td>100.00%</td>
<td>00.00%</td>
</tr>
<tr>
<td>Local intraperitoneal anesthesia, intraperitoneal saline administration, and pulmonary recruitment maneuvers are some proposed methods for reducing post-laparoscopic pain and/or reducing residual pneumoperitoneum</td>
<td>0.00%</td>
<td>25.00%</td>
<td>25.00%</td>
</tr>
<tr>
<td>Pulmonary recruitment maneuvers with a pressure of 10 cmH2O have not been studied or supported by research</td>
<td>0.00%</td>
<td>25.00%</td>
<td>25.00%</td>
</tr>
<tr>
<td>The pulmonary recruitment maneuver administered in semi-fowler’s position is shown to have a greater effect on post-</td>
<td>25.00%</td>
<td>50.00%</td>
<td>25.00%</td>
</tr>
</tbody>
</table>
laparoscopic pain than the pulmonary recruitment maneuver administered in the neutral position.

<table>
<thead>
<tr>
<th>Pulmonary recruitment maneuvers at 15 cmH2O are as effective in their reduction of post-laparoscopic shoulder pain as higher pressures</th>
<th>100.00%</th>
<th>75.00%</th>
<th>-25.00%</th>
</tr>
</thead>
</table>

Some other possible benefits of pulmonary recruitment maneuvers in addition to post-laparoscopic pain reduction are to reduce the incidence of subdiaphragmatic CO2, decrease upper abdomen pain, reduce the volume of subdiaphragmatic CO2, and decrease postoperative nausea and vomiting.

<table>
<thead>
<tr>
<th>15 cmH2O is the lowest pressure used in a pulmonary recruitment maneuver that has been shown to reduce post-laparoscopic shoulder pain</th>
<th>75.00%</th>
<th>100.00%</th>
<th>25.00%</th>
</tr>
</thead>
</table>

Graph 1

Pre-Test/Post-Test Knowledge

- Incidence
- Etiology
- PLSP vs. wound pain response to analgesics
- Methods to decrease PLSP
- 10cmH2O not studied or supported
- Position
- PRM at 15cmH2O as effective as higher pressures
- PRM Benefits
- Lowest pressure used in PRM
Perspective of Use in Practice

On the pre-test, all four participants identified in either the somewhat likely or very likely category for their likelihood to use alternative methods to decrease PLSP. Two participants were somewhat likely to utilize alternative pain management methods, while two participants were very likely. After viewing the education module, the participants had the same likelihood of using alternative pain management to decrease PLSP. Two participants indicated a somewhat likelihood of using alternative methods, and two participants were very likely to use alternative methods. In the final Likert questions, one participant was very likely, and two participants were somewhat likely to recommend the usage of PRMs for PLSP. On the other hand, one participant was very unlikely to recommend PRMs. After the education module, all participants were either somewhat or very likely to recommend the use of PRMs for PLSP. Three participants stated they were somewhat likely to recommend PRMs, and one participant was very likely to recommend PRM use. In other words, even though the participants did not indicate that they were any more likely to utilize alternative pain management methods, 25% of the participants increased their likelihood
of recommending the use of PRMs to decrease PLSP. This information is visually represented in Graph 3 and Graph 4.

Table 5 represents the pre- versus post-test likelihood of participants who are somewhat or very likely to use alternative pain management methods for treatment of PLSP or to recommend the use of PRMs to decrease PLSP. The one participant who did not select very or somewhat likely chose very unlikely. However, this participant changed their likelihood of recommending pulmonary recruitment maneuvers to somewhat likely on the post-test. The education module successfully demonstrated to CRNAs the benefit of PRMs to decrease PLSP with its 25.00% increase in providers' likelihood of recommending PRMs, as shown in Table 5.

<table>
<thead>
<tr>
<th>Table 5: Difference in Pre- and Post-Test Confidence</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>How likely are you to use alternative methods to decrease post-laparoscopic shoulder pain?</td>
<td>100.00%</td>
<td>100.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>How likely are you to recommend the use of pulmonary recruitment maneuvers?</td>
<td>75.00%</td>
<td>100.00%</td>
<td>25.00%</td>
</tr>
</tbody>
</table>
DISCUSSION OF QUALITY IMPROVEMENT

Evidence-based alternatives to pain management for PLSP, including PRMs, not only provide superior pain relief but can also reduce the incidence and severity of PLSP and the utilization of opioids. Providing CRNAs with an education module on alternative PLSP management techniques with a focus on PRMs was shown to increase their knowledge overall on
the incidence of PLSP, the techniques used to decrease or reduce the incidence of PLSP, and the benefits of PRMs. In addition, after viewing the education module, all participating CRNAs indicated that they were either somewhat or very likely to utilize alternative pain management methods for PLSP and that they were somewhat or very likely to recommend the use of PRMs. However, there was no increase in knowledge on the proposed etiologies of PLSP, indicating a potential deficiency in how that information was taught in the education module. The average pre-test score was 5.25 points out of 10 scored questions (52.5%). The pre-test and post-test had an additional two questions (for a total of 12 questions) that were Likert-style questions, and these were not scored in the paired T-test. The average post-test score was 6.25 points out of 10 scored questions (62.5%). These scores indicate that the overall knowledge increase was 1 point or 10%. However, this knowledge increase was not statistically significant as identified by the paired T-test analysis (p=0.423).

**Limitations**

One major limitation of this study is that the knowledge increase demonstrated by the increase in average score between the pre-test and post-test was not statistically significant, meaning that the results for the sample do not apply to the whole population of Anesco employees. Many factors could have caused this lack of statistical significance. The first reason is that the sample size was very small at n=4. As a result, one participant could increase or decrease a score on a question by 25% with only one correct or incorrect answer. Therefore, this small sample size could have significantly skewed the results. In addition, participant four scored lower on the post-test than the pre-test (50% versus 70%) and took only one minute and 15 seconds to complete all ten post-test questions (see Graph 5). A total time of one minute and 15 seconds means that the participant only took about 7.5 seconds per question. While there is no way to know definitively why the participant scored lower on the post-test, the short time spent on each question and the fact that the participant scored worse on the post-test while all of the other participants had an improvement in their score (visually represented in Graph 5) indicates that
they likely just clicked through the questions and, therefore, did not answer based on any knowledge that may have been gained from the education module. This participant, in combination with the small sample size, could have significantly skewed the results. A larger sample size would provide greater statistical significance and reduce the sample bias created by only four CRNAs voluntarily participating in this survey and education module.

One cause of the small sample size was the population studied. The population surveyed was Anesco, a small anesthesia company, so the number of people that could have been surveyed was limited. In addition, the email list provided by Anesco only contained 63 emails, which included both personal and work emails for some anesthesia providers (5 providers had multiple emails listed on the list). Also, nine emails got sent back because those emails no longer existed (i.e., the emails belonged to anesthesia providers that no longer work for Anesco). That means that the education module was sent to only 49 anesthesia providers, which is only a fraction of the anesthesia providers that Anesco employs. In other words, the population sampled was small to begin with, and the education module was only sent to a fraction of that population due to the limited list that Anesco provided. Therefore, being provided with a better, more comprehensive email list with recent hire emails and up-to-date emails that CRNAs check may have helped obtain a larger sample size of CRNAs willing to participate. A better email list may have also prevented the sampling bias that occurred when some CRNAs were excluded from receiving the education module because their email was not provided.20

Another reason for the small sample size was likely the CRNAs’ lack of willingness to participate. One reason for this could have been that they did not want to take the time to complete the surveys and the education module. The pre-test and post-test surveys take about 5 minutes each to complete, and the PowerPoint voiceover video is 10 minutes long. That means that the total time to complete the education module is about 20 minutes, and this length of time was mentioned in the email to Anesco employees. Some CRNAs might have thought 20 minutes was too long and decided to opt out of the education module as a result. Therefore, offering an
incentive and making the pre-test, post-test, and video shorter may have increased participation and reduced non-response bias.20,21

In addition to the small sample size, the fact that the overall scores did not increase by much could have helped contribute to the lack of statistical significance. The average overall increase in scores was one point. This slight increase could indicate the teaching in the education module was not that effective. Many factors could have contributed to ineffective teaching, including having too many words on each slide, not explaining the information well, and not appropriately emphasizing important information. The education module could be improved by making the slides and voice-over less wordy or providing the education in a different format.

On the other hand, this slight increase in overall average scores could have been partly due to a higher overall initial score on the pre-test. The overall average pre-test score was 5.25, which is relatively high. There were three questions that every participant answered correctly on the pre-test. These scores could indicate that the baseline knowledge of these participants on the topic was already high. The goal of the project was to increase the knowledge of CRNAs, but knowledge cannot be increased on information that a CRNA already knows. Also, how the questions were asked and the answer choices provided could have affected how the participants answered. For example, the last question on the pre- and post-test asks which pressure is the lowest pressure at which PRMs have shown to decrease PLSP effectively. Three participants chose 15 cmH2O on the pre-test. This was the lowest answer choice, so it would make sense to choose this answer. In other words, participants could have guessed this correct answer. In addition, three questions contained the word, not, in the question stem. Sometimes it is easy to deduce the correct answer from the other answer choices on these questions. It is also easy to miss the word not when reading the question and then choose an incorrect answer. The participant who changed their answer from a correct answer on the pre-test to an incorrect answer on the post-test could have misread the question that asked about which of the following is not true about PLSP. This decrease in score could then potentially be attributed to the participant missing
the word, not, in the question stem. Therefore, the questions could be changed to exclude not in the question stem and change the answer choices to make it more difficult to deduce the answer from the way the question is asked and the answer choices. These actions could help make the pre-test scores more representative of the participants’ baseline knowledge.

This study relied on CRNAs deciding to participate in the education module once they received the email. This method of survey administration results in self-selection bias, which means that the survey sample was not random, and the principles of probability sampling were not followed. Without a completely random sample, it is impossible to construct unbiased estimates based on the results of the surveys. In such cases, it is impossible to state unambiguously that an increase in score from the pre-test to the post-test was due to the education module and not to the preexisting characteristics of those individuals who chose to complete the education module. A CRNA who is driven to learn is probably more likely to participate in an education module. This person might have a higher baseline knowledge due to their affinity for continuing education and be more motivated to learn during the education module, resulting in higher pre-test and post-test scores. This type of bias could have had a major effect on the results.

Another limitation of this study was the format in which the education module and questions were sent out. Although all Anesco employees have emails, not all employees check their email or check it regularly. As a result, there may have been some providers who did not realize an education module had been sent to them via email. There may also have been some providers who saw the education module but were not as technologically savvy and could not figure out how to navigate the Qualtrics survey. These CRNAs were consequently not adequately represented in the sample, illustrating undercoverage bias. This type of bias may have been prevented by administering the education module and questions in person.
Future Implications to Advanced Practice Nursing

The outcomes of the education module demonstrate the need for continuing education to expand providers’ knowledge bases and empower providers to utilize evidence-based practices. Opioids have been used as a method to attempt to treat PLSP postoperatively. However, research demonstrates that this is not an effective method for treating this type of pain and that prevention is the most effective method for treatment. Unfortunately, providers are slow to adopt new evidence-based research into their current practices to better treat and care for patients. Although the reluctance to change and evolve is common, implementing education modules to equip anesthesia providers with the most up-to-date research and show them how beneficial this change can be for their patients can help overcome this reluctance. Therefore, continuing education remains an essential aspect of CRNA practice. The CRNAs who participated were more likely to recommend the use of PRMs after viewing the education module, meaning that the education was effective in convincing CRNAs of the benefits of PRMs in reducing PLSP. The CRNAs who participated in the education module also showed an overall average increase in knowledge on the incidence of PLSP and the treatment and prevention of
PLSP. Although this increase was not statistically significant, the overall average score increase still indicates this topic is worthy of further research as there is a potential to increase the knowledge of CRNAs on this topic through an education module. However, a major issue with this study is that the results did lack statistical significance, and this can be attributed at least in part to the small sample size of CRNAs who chose to participate. A study by Yu et al. showed a 30% increase in survey participation with a $10 incentive, and a study by Brick et al. showed a 22.7% increase in survey participation with a $5 incentive. Therefore, creating an incentive, like offering a $5 Amazon gift card for participating in the education module, may help boost participation, thereby reducing non-response bias and self-selection bias and potentially increasing the statistical significance of the results. The results might then be more indicative of the value of an education module.

CONCLUSION

Ten RCTs and one meta-analysis were selected and reviewed to evaluate PRMs at various pressures and in different positions to decrease the incidence or reduce the severity of PLSP. Collectively, these studies demonstrated that PRMs at 15 cmH2O, 30 cmH2O, 40 cmH2O, and 60 cmH2O decreased PLSP scores compared to passive exsufflation. Additionally, one RCT demonstrated that receiving PRMs significantly reduced PLSP and the volume of subdiaphragmatic CO2 compared to intraperitoneal ropivacaine administration, indicating that PRMs may be a superior alternative pain management technique. In another study, PLSP scores were compared between subjects receiving PRMs in the neutral position and subjects receiving PRMs in the semi-fowler’s position, and it showed that the semi-fowler’s position was associated with lower pain scores. In addition, the efficacy of PRMs at 40 cmH2O and 60 cmH2O and the efficacy of PRMs at 30 cmH2O and 15 cmH2O were compared. There was no significant difference in the PLSP scores between the different pressures. Therefore, PRMs can be used at a pressure of as low as 15 cmH2O and in the semi-fowler’s position to reduce the severity and incidence of PLSP significantly.
An educational module was created and implemented based on evidence-based research. The education module then received IRB exemption status before being emailed to CRNAs employed by Anesco. These CRNAs were asked to participate on an entirely voluntary and anonymous basis. Each participant took a pre-test, viewed the education module, and then completed a post-test. Qualtrics was used to create and provide the surveys and education module, while SPSS was utilized to conduct statistical analysis of the survey results. The pre-test results provided evidence that the CRNAs’ knowledge of the incidence and etiology of PLSP and methods to treat PLSP was somewhat lacking. The results also indicated that the CRNAs were more likely to recommend PRMs after viewing the education module. However, the results did not demonstrate a statistically significant improvement in the scores between the pre-test and post-test. The results did not show that CRNAs gained a significant increase in knowledge from the education module. As a result, further research is needed to solidify the benefits of the education module by increasing the sample size and improving the pre- and post-test questions and the slides and voice-over of the education module.
REFERENCES


Appendix A: PRISMA Flow Diagram

Records identified through database searching (n = 73)

Additional records identified through other sources (n = 0)

Records after duplicates removed (n = 37)

Records screened (n = 34)

Records excluded (n = 6)

Articles assessed for eligibility (n = 28)

Full-text articles excluded with reasons (n = 17)

6 Wrong Intervention
6 Wrong Study Design
5 No full text available

Studies included in qualitative synthesis (n = 11)
Appendix B: Florida International University IRB Exemption Letter

MEMORANDUM

To: Dr. Vicente Gonzalez
CC: Sarah Cole
From: Elizabeth Juhasz, Ph.D., IRB Coordinator
Date: June 1, 2021

Protocol Title: "Effects of Pulmonary Recruitment Maneuver Techniques During Trocar Removal on Patient Post-Laparoscopic Shoulder Pain: An Evidence Based Educational Module"

The Florida International University Office of Research Integrity has reviewed your research study for the use of human subjects and deemed it Exempt via the Exempt Review process.

IRB Protocol Exemption #: IRB-21-0199    IRB Exemption Date: 06/01/21
TOPAZ Reference #: 110228

As a requirement of IRB Exemption you are required to:

1) Submit an IRB Exempt Amendment Form for all proposed additions or changes in the procedures involving human subjects. All additions and changes must be reviewed and approved prior to implementation.
2) Promptly submit an IRB Exempt Event Report Form for every serious or unusual or unanticipated adverse event, problems with the rights or welfare of the human subjects, and/or deviations from the approved protocol.
3) Submit an IRB Exempt Project Completion Report Form when the study is finished or discontinued.

Special Conditions: N/A

For further information, you may visit the IRB website at http://research.fiu.edu/irb.

EJ
Appendix C: Broward Health IRB Exemption Letter

DATE: 06/21/2021

TO: Sarah Cole, BSN

FROM: Broward Health Institutional Review Board

RECORD NUMBER: 2021-074

STUDY TITLE: Effects of Pulmonary Recruitment Maneuver Techniques During Trocar Removal on Patient Post-Laparoscopic Shoulder Pain: An Evidence Based Educational Module

RE: NOT HUMAN SUBJECT RESEARCH DETERMINATION

Dear Sarah Cole, BSN:

This is to advise you that your project, “Effects of Pulmonary Recruitment Maneuver Techniques During Trocar Removal on Patient Post-Laparoscopic Shoulder Pain: An Evidence Based Educational Module” was reviewed on behalf of the Broward Health Institutional Review Board and was declared “not research involving human subjects” based on the definitions provided in the U.S. Department of Health and Human Services Code of Federal Regulations found at 45 CFR 46.102.

Please note, this determination does not absolve the Principal Investigator from complying with other federal, state, or local laws or institutional policies and procedures that may be applicable in the conduct of this project. This determination applies to your project in the form and content as submitted to the IRB for review. Any variations or modifications to this project involving the participation of human subjects must be approved by the IRB prior to implementing such changes. Please maintain a copy of this determination for your records.

Thank you for submitting your project to the IRB for consideration.

The Broward Health Institutional Review Board – FWA00001248 operates in accordance with the Office of Human Research Protections and U.S. Food and Drug Administration (FDA) regulations. The Broward Health Institutional Review Board complies with the ICH guidelines on Good Clinical Practice (GCP) where they are compatible with the FDA and HHS regulations.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within Broward Health IRB’s records.
Appendix D: Anesco Support Letter

March 3, 2021

Fernando C Alfonso, DNP, CRNA, APRN
Clinical Assistant Professor
Department of Nurse Anesthetist Practice
Florida International University

Dr. Alfonso,

Thank you for inviting Broward Health to participate in Doctor of Nursing Practice (DNF) project conducted by Sarah Cole entitled “Effects of Pulmonary Recruitment Maneuver Techniques During Tissue Removal on Patient Post-Laparoscopic Shoulder Pain: An Evidence Based Educational Module” in the Nicole Wertheim College of Nursing and Health Sciences, Department of Nurse Anesthetist Practice at Florida International University. I have granted the student permission to conduct the project using our providers.

Evidence-based practice's primary aim is to yield the best outcomes for patients by selecting interventions supported by the evidence. This proposed quality improvement project seeks to investigate and synthesize the latest evidence.

We understand that participation in the study is voluntary and carries no overt risk. All Anesthesiology providers are free to participate or withdraw from the study at any time. The educational intervention will be conveyed by a 15-minute virtual PowerPoint presentation, with a pretest and posttest questionnaire delivered by a URL link electronically via Qualtrics, an online survey product. Responses to pretest and posttest surveys are not linked to any participant. The collected information is reported as an aggregate, and there is no monetary compensation for participation. All collected material will be kept confidential, stored in a password-encrypted digital cloud, and only be accessible to the investigators of this study: Sarah Cole and Dr. Fernando Alfonso.

Once the Institutional Review Board's approval is achieved, this scholarly project's execution will occur over two weeks. Sarah Cole will behave professionally, follow standards of care, and not impede hospital performance. We support the participation of our Anesthesiology providers in this project and look forward to working with you.

Edward Punzalan, DNP, CRNA, APRN
Administrative Director of Nurse Anesthesia
Healthcare Performance Anesco
Broward Health

March 1, 2021
Appendix E: Recruitment Letter

Effects of Pulmonary Recruitment Maneuver Techniques During Trocar Removal on Patient Post-Laparoscopic Shoulder Pain: An Evidence Based Educational Module

Dear Broward Health Anesco Anesthesia Provider:

My name is Sarah Cole and I am a student from the Anesthesiology Nursing Program Department of Nurse Anesthetist Practice at Florida International University. I am writing to invite you to participate in my quality improvement project. The goal of this project is to improve health care provider knowledge on the effects of pulmonary recruitment maneuver techniques during trocar removal on patient post-laparoscopic shoulder pain. You are eligible to take part in this project because you are a member of the Anesthesia Department for Anesco at Broward General.

If you decide to participate in this project, you will be asked to complete and sign a consent form for participation. Next, you will complete a pre-test questionnaire, which is expected to take approximately 5 minutes. You will then be asked to view an approximately 15 minute long educational presentation online. After watching the video, you will be asked to complete the post-test questionnaire, which is expected to take approximately 5 minutes. No compensation will be provided.

Remember, this is completely voluntary. You can choose to be in the study or not. If you'd like to participate or have any questions about the study, please email or contact me at seedo057@fiu.edu or 386-556-8621.

Thank you very much.

Sincerely,

Sarah Cole, SRNA, BSN
Appendix F: Quality Improvement Project Consent

CONSENT TO PARTICIPATE IN A QUALITY IMPROVEMENT PROJECT
“Effects of Pulmonary Recruitment Maneuver Techniques During Trocar Removal on Patient Post-Laparoscopic Shoulder Pain: An Evidence-Based Educational Module”

PURPOSE OF THE PROJECT
You are being asked to be in a quality improvement project. This project aims to improve health care provider knowledge on the effects of pulmonary recruitment maneuver techniques during trocar removal on patient post-laparoscopic shoulder pain.

DURATION OF THE PROJECT
Your participation will require about 20 minutes of your time.

PROCEDURES
If you agree to be in the project, we will ask you to do the following things:
- Take a 5 minute pre-test on Qualtrics
- View a 10 minute PowerPoint
- Take a 5 minute post-test on Qualtrics

RISKS AND/OR DISCOMFORTS
Minimal physical, psychological, social, legal, and economic risks that are not greater than if participant was engaged in a similar activity. The main risk or discomfort from this research is minimal. There will be minimal risks involved with this project, as would be expected in any type of educational intervention, which may include mild emotional stress or mild physical discomfort from sitting on a chair for an extended period of time, for instance.

BENEFITS
The following benefits may be associated with your participation in this project: An increase in cholesterol management knowledge, which will help you to better assess medication adherence and guidelines implementations to reduce the risk of cardiovascular events. The overall objective of the program is to increase the quality of healthcare delivery, improving the health indicator of our patients, and increase patient engagement.

ALTERNATIVES
There are no known alternatives available to you other than not taking part in this project. However, if you like to receive the educational material given to the
participants in this project, it will be provided to you at no cost.

CONFIDENTIALITY
The records of this project will be kept private and will be protected to the fullest extent provided by law. If, in any sort of report, we might publish, we will not include any information that will make it possible to identify you as a participant. Records will be stored securely, and only the project team will have access to the records. All data regarding participant knowledge, perceptions, and practices regarding pulmonary recruitment maneuvers in decreasing patient post-laparoscopic pain will be collected anonymously. Only investigators will have access to the information collected.

COMPENSATION & COSTS
There is no cost or payment to you for receiving the health education and/or participating in this project.

RIGHT TO DECLINE OR WITHDRAW
Your participation in this project is voluntary. You are free to participate in the project or withdraw your consent at any time during the project. Your withdrawal or lack of participation will not affect any benefits to which you are otherwise entitled. The investigator reserves the right to remove you without your consent at such time that they feel it is in the best interest.

RESEARCHER CONTACT INFORMATION
If you have any questions about the purpose, procedures, or any other issues relating to this research project, you may contact Sarah Cole at 386-956-8621, scole057@fiu.edu or Dr. Alfonso at falfonso@fiu.edu.

IRB CONTACT INFORMATION
If you would like to talk with someone about your rights of being a subject in this project or about ethical issues with this project, you may contact the FIU Office of Research Integrity by phone at 305-348-2494 or by email at ori@fiu.edu.

PARTICIPANT AGREEMENT
I consent by participating in the survey. I have read the information in this consent form and agree to participate in this project.
Appendix G: Quality Improvement Project Survey

FLORIDA INTERNATIONAL UNIVERSITY

Pretest and Posttest Questionnaire:

Pulmonary Recruitment Maneuvers to Decrease Post-laparoscopic Shoulder Pain

INTRODUCTION

The primary aim of this QI project is to improve the knowledge of CRNAs pertaining to pulmonary recruitment maneuvers in adults undergoing laparoscopic surgery in order to improve patient outcomes in this population.

Please answer the question below to the best of your ability. The questions are in multiple choice format and are meant to measure knowledge and perceptions on pulmonary recruitment maneuvers.

PERSONAL INFORMATION

1. Gender: Male    Female    Other_______
2. Age: ______
3. Ethnicity:

Hispanic    Caucasian    African American    Asian    Other______________

4. Position/Title: ________________________

5. Level of Education: Associates    Bachelors    Masters    Doctorate    Other    _________

6. How many years have you been an anesthesia provider?

Over 10    5-10 years    2-5 years    1-2 years
QUESTIONNAIRE

1. Depending on patient risk factors, the incidence of shoulder pain after laparoscopic surgery can be as high as:
   a. 20%
   b. 40%
   c. 60%
   d. 80%

2. Which of the following is NOT a proposed etiology for post-laparoscopic pain?
   a. The residual carbon dioxide in the abdomen puts pressure on the diaphragm and peritoneum
   b. The carbonic acid that forms from the carbon dioxide used for insufflation irritates the peritoneum, diaphragm, and phrenic nerve
   c. Retained pockets of carbon dioxide cause loss of negative pressure in the peritoneal cavity, resulting in traction on the ligaments of the liver
   d. Stretching and tearing of the peritoneum, diaphragm, nerves, and blood vessels from the carbon dioxide results in release of inflammatory mediators

3. Which of the following is NOT true about post-laparoscopic shoulder pain?
   a. Carbon dioxide plays a role in causing this type of pain
   b. It responds better to analgesics than wound pain
   c. This pain has been shown to be positively correlated with residual pneumoperitoneum
   d. The best method of treatment is prevention

4. Uncontrolled pain can cause:
a. Atelectasis
b. Increased blood pressure
c. Hypoventilation
d. Increased cardiac workload
e. All the above

5. What are some proposed methods for reducing post-laparoscopic and/or reducing residual pneumoperitoneum? Select 3
   a. Local intraperitoneal anesthesia
   b. Intraoperative morphine administration
   c. Intraperitoneal saline administration
   d. Pulmonary recruitment maneuvers
   e. Premedication with gabapentin
   f. TAP block

6. Which of the following pressures used for pulmonary recruitment maneuvers has NOT been studied or supported by the research?
   a. 40 cmH2O
   b. 60 cmH2O
   c. 15 cmH2O
   d. 30 cmH2O
   e. 10 cmH2O

7. The pulmonary recruitment maneuver administered in what position was shown to have a greater effect on post-laparoscopic pain than the pulmonary recruitment maneuver administered in the neutral position?
8. Pulmonary recruitment maneuvers at 15 cmH₂O are ________ in their reduction of post-laparoscopic shoulder pain compared to higher pressures:
   a. As effective
   b. More effective
   c. Less effective

9. Some other possible benefits of pulmonary recruitment maneuvers in addition to post-laparoscopic pain reduction are:
   a. Reduce the incidence of subdiaphragmatic CO₂
   b. Decreased upper abdomen pain
   c. Reduce the volume of subdiaphragmatic CO₂
   d. Decreased postoperative nausea and vomiting
   e. All of the above

10. What is the lowest pressure used in a pulmonary recruitment maneuver that has been shown to reduce post-laparoscopic shoulder pain?
    a. 30 cmH₂O
    b. 15 cmH₂O
    c. 40 cmH₂O
    d. 60 cmH₂O
11. How likely are you to use alternative methods to decrease post-laparoscopic shoulder pain?
   a. Most likely
   b. Somewhat likely
   c. Somewhat unlikely
   d. Most unlikely

12. How likely are you to recommend the use of pulmonary recruitment maneuvers?
   a. Most likely
   b. Somewhat likely
   c. Somewhat unlikely
   d. Most unlikely
Appendix H: Education Module

Effects of Pulmonary Recruitment Maneuver Techniques During Trocar Removal on Patient Post-Laparoscopic Shoulder Pain: An Evidence-Based Education Module

Presented by Sarah Cole MSN, RN
Supervised by Fernando Alfonso DNP, CRNA, ARNP

Learning Goals

- **Learn about** Learn about the significance of post-laparoscopic shoulder pain (PLSP)
- **Understand** Understand the etiologies of PLSP
- **Learn about** Learn about the methods that have been proposed to decrease PLSP
- **Define** Define pulmonary recruitment maneuvers
- **Learn about** Learn about the benefits of pulmonary recruitment maneuvers in reducing PLSP
- **Describe** Describe the proposed evidence-based pulmonary recruitment maneuver technique
Background of the Problem

Laparoscopy advantages: reduction in surgical incision wound size, less wound-related pain, minimal trauma and injury, smaller scars, rapid recovery time, a shorter hospital stay, and an earlier return to daily activities and work compared with conventional exploratory laparotomy.

Up to 80% of patients still have severe pain after laparoscopic surgery and require pain relief.

Pain increases analgesia use and causes extended hospital stays, slower recovery, and many complications.

A type of pain specific to laparoscopic surgery is post-laparoscopic shoulder pain (PLSP).

Post-laparoscopic shoulder pain is not entirely understood.

- 3 theories proposed for its etiology:
  - The carbonic acid that forms from the carbon dioxide used for insufflation irritates the peritoneum, diaphragm, and phrenic nerve.
  - Retained pockets of carbon dioxide cause loss of negative pressure in the peritoneal cavity, resulting in traction on the ligaments of the liver.
  - Stretching and tearing of the peritoneum, diaphragm, nerves, and blood vessels from the carbon dioxide, which results in the release of inflammatory mediators.
  - Commonality among the 3 theories: carbon dioxide is the cause.
Significance of the Problem

- PLSP occurs in up to 80% of patients undergoing laparoscopic surgery.
- Studies have shown that PLSP is less responsive to analgesics when compared to wound pain.
- Prevention is vital to treating this type of pain.
- It is thought that facilitating the removal of CO2 decreases PLSP.
- The volume of abdominal CO2 is positively correlated with intensity of shoulder pain reported by patients.

Methods to decrease PLSP

Several methods have been proposed to decrease PLSP and aid in the removal of CO2:

- use of an alternative insufflating gas
- the use of a low-pressure pneumoperitoneum
- gasless laparoscopy
- the use of warm and humidified carbon dioxide
- local intraperitoneal anesthesia
- intraperitoneal drainage
- intraperitoneal saline instillation
- pulmonary recruitment maneuvers
Pulmonary Recruitment Maneuvers (PRMs)

Benefits of PRMs

At 6, 12, and 24 hours postoperatively, the lowest PLSP scores were recorded in patients who received the PRM in the semi-Fowler position (head of bed elevated 30 degrees) compared to those receiving the PRM in the neutral position and passive extubation.

Studies have shown decreased PLSP scores relative to passive extubation in patients receiving PRMs at:

- 5 manual pulmonary inflations at 60cmH2O for 5 seconds
- 5 manual pulmonary inflations at 50cmH2O for 5 seconds
- 5 manual pulmonary inflations at 40cmH2O for 5 seconds
- 5 manual pulmonary inflations at 30cmH2O for 5 seconds

No significant differences in wound pain score, PLSP, number of rescue analgesics used, IV analgesics used, total analgesic dosages used, ambulation time, length of hospital stay, and height of the pleuropertitoneum measured on chest x-ray between administering PRM at 15 cmH2O and 30 cmH2O.

PLSP at 24 h and 48 h after surgery were not significantly different between PRM at 40cmH2O and 60cmH2O.
Proposed Application to Practice

5 manual pulmonary inflations at a pressure of 15cmH2O that are held for 5 seconds each and completed with the head of the bed elevated to 30 degrees once the trocars are removed.

Summary

A Troublesome Pain Associated with Laparoscopic Surgery is PLEP

Uncontrolled pain has many complications.

PLEP can only be treated by prevention as it is not responsive to analgesics.

Carbon dioxide is theorized to cause PLEP.

PrMs are a technique that has been proposed to aid in the removal of CO2, thereby decreasing PLEP.

Studies have shown that PrMs are efficacious in reducing PLEP at various pressures and positions.

Proposed evidence-based practice: administer 3 PrMs at 15cmH2O for 5 seconds in the semi-Fowler’s position.
References


References


Appendix I: Supervisor CITI Training Certificate

This is to certify that:

Fernando Alfonso

Has completed the following CITI Program course:

Basic/Refresher Course - Human Subjects Research
Social/Behavioral Human Research Course
1 - Basic Course

Under requirements set by:

Florida International University

Completion Date 08-Jan-2020
Expiration Date 07-Jan-2023
Record ID 34614144

Not valid for renewal of certification through CME. Do not use for TransCelerate mutual recognition. (see Completion Report).

Verify at www.citiprogram.org/verify/?wf3263f28-ad0d-435e-b098-674574619cd6-34614144
Appendix J: Investigator CITI Training Certificate

This is to certify that:

Sarah Cole

Has completed the following CITI Program course:

**Basic/Refresher Course - Human Subjects Research**
(Contract Group)

**Social/Behavioral Human Research Course**
(Course Learner Group)
1. Basic Course
   (Stage)

Under requirements set by:

Florida International University

Verify at www.citiprogram.org/verify/?w4babe6b0-6bba-4c06-a36a-002f26c8bb59-38897333
# Appendix K: Paired T-Test

## T-Test

### Paired Samples Statistics

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### Paired Samples Correlations

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### Paired Samples Test

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<td>Measurement And Data Analysis</td>
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<tr>
<td>Garezo-Martinez D, Rodriguez-Avala E, Weiner-Sanchez A, Bravo-Torrellan C, Carbó-Romano R.</td>
<td>Blind randomized control trial (RCT) of 82 total patients (ASA I and ASA II): 41 in the experimental group, who received pulmonary recruitment maneuver (PRM) (consisted of placing the patient in Trendelenburg position and applying 5 cm H2O pressure); 41 in the control group who received intraperitoneal anesthetic instillation.</td>
<td>82 total patients (ASA I and ASA II) of either sex n=41 experimental group; n=41 control group; 18 years or older, undergoing laparoscopic cholecystectomy, appendectomy, or inguinal hernioplasty in a tertiary care center in Mexico City</td>
<td>Independent variable: IV1 is PRM vs. intraperitoneal anesthetic instillation.</td>
<td>At 6 hours postoperatively, all patients were asked to fill out a 10-point visual analog pain scale. Also, a CXR was performed. Both presence and volume of subdiaphragmatic CO2 were recorded.</td>
<td>- No statistical difference was found for mean age, gender distribution, body mass index or pneumoperitoneum pressure, volume, and flow. - A slight but significant (p = 0.03) difference was found in the duration of surgery between the two groups. - Patients who were subject to the PRM were found to have a lower incidence of subdiaphragmatic pneumoperitoneum present in the CXR (20% vs 55%, respectively), p = 0.01, and were half as likely to present shoulder pain (24%), than those in the anesthetic instillation group (50%), p = 0.01. - Patients in the PRM group showed less pain intensity.</td>
<td>PRM decreases the incidence of subdiaphragmatic pneumoperitoneum and shoulder pain relative to the anesthetic instillation group. PRM also decreases shoulder pain intensity. The quality of subdiaphragmatic CO2 volume was positively correlated with the intensity of shoulder pain, indicating that PRM’s benefit on shoulder-tip pain may be due to its ability to decrease residual CO2.</td>
<td>Pulmonary recruitment maneuver significantly reduces the incidence and intensity of postoperative shoulder tip pain, when compared to the intraperitoneal anesthetic instillation technique, in conventional general laparoscopic surgery cases. This maneuver also has a significant effect on decreasing the presence and volume of residual subdiaphragmatic CO.</td>
</tr>
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<td>contd. on instilling 20 ccs of 7.5% ropivacaine into the abdomen, through one of the trocars, before passively evacuating the pneumoperitoneum.</td>
<td>- P values of &lt; 0.05 are statistically significant</td>
<td>(p = 0.000) and less volume of subdiaphragmatic CO2 (p = 0.02)</td>
<td>- Both groups showed significantly more shoulder pain when residual gas was present. The PRM group had a relative risk (RR) of 11.1, p = 0.0001 and the LRI group an RR of 8.3, p = 0.000. - The quantity of subdiaphragmatic CO2 volume was positively correlated with the intensity of shoulder pain reported by the patients, with a Pearson’s coefficient of r = 0.54, p = 0.000</td>
<td>scores were affected by analgesic use. <strong>Feasibility:</strong> PRM can easily be implemented with the use of an anesthesia machine and all ORs in the US have anesthesia machines.</td>
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<td>Group</td>
<td>Procedure</td>
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<td>Method</td>
<td>Findings</td>
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| Blinded RCT of 113 total patients (ASA I-III): 57 in the experimental group, who received PRM in the Trendelenburg position (30°) and the PRM, consisted of 2 manual inflations to a maximum pressure of 40 cm, holding each for 5 seconds; 56 in the control group where residual gas pneumoperitoneum was evacuated passively at the end of the procedure by opening the operative ports to allow the abdomen to discharge. | Pain scores were determined at 12, 24, and 48 hours using a 10-point visual analog scale. | Kolmogorov-Smirnov test and the chi-squared test were used for categorical variables. The Student's t-test was used to detect differences in normally distributed continuous variables, and the Mann-Whitney U test was used for abnormally distributed variables. | Postoperative shoulder pain scores were significantly lower in the maneuver group than in the control group at 12 hours (2.1±0.5 vs. 4.9±0.9; p=0.001) and 24 hours (2.0±0.4 vs. 3.9±0.4; p=0.001) after the operation. No significant difference was observed between the groups at 48 hours (1.7±0.5 and 1.9±0.4; p=0.115). Upper abdominal pain scores were significantly lower in the maneuver group than in the control group at 12 hours (3.1±0.4 vs. 2.9±0.3; p=0.001) and 24 hours (2.9±0.4 vs. 4.9±0.5; p=0.001) after the operation, but did not differ at 48 hours (2.7±0.5 and 2.9±0.4; p=0.120). Lower abdominal (wound) pain scores did not differ between the 2 groups at 12, 24, or 48 hours. | PRM can help reduce shoulder and abdominal pain from 12 to 24 hours postoperatively without postoperative nausea and vomiting after laparoscopic gynecological oncologic surgery. | Level I A

**Strengths:**
- Adequate sample size according to the power analysis and adequate control with blinding.

**Limitations:**
- Different surgical types and durations (could interfere with the pain evaluation, although there was no difference in the surgical type between the groups).
- Risk or harm: No case was complicated by cardiovascular, pulmonary, or respiratory problems.
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<td><strong>Blind RCT of 84 total patients (ASA I and ASA II): 42 in the experimental group, who received PRM that consisted of placing the patient in Trendelenburg position and applying 5 pulmonary inflations for 5 seconds with a pressure of 30cm H2O; 42 in the control group (passive eoxsufflation).</strong></td>
<td><strong>Independent variable:</strong> PRM vs. passive eoxsufflation. <strong>Dependent variable:</strong> DV1 is shoulder pain intensity; DV2 is low abdominal surgical pain intensity; DV3 is postoperative nausea and vomiting incidence, DV4 is additional administered analgesics.</td>
<td><strong>Pain scores were determined at 24 and 48 hours using a 10-point visual analog scale.</strong> - Mann-Whitney U test for the VAS. - Independent t-test for other continuous data and the x2 or Fisher exact test for categorical data between the 2 groups. - PRM reduced median VAS scores of shoulder pain from 1.5 to 0 at 24 hours postop (P&lt;0.001).</td>
<td><strong>The VAS score of shoulder pain was significantly lower in the PRM group than in the control group (P&lt;0.001).</strong> and the VAS scores of surgical pain were similar between the 2 groups. - Low-pressure PRM using 30 cm H2O reduced postlaparoscopic shoulder pain (PLSP) significantly in patients who underwent laparoscopic gynecologic surgery.</td>
<td><strong>PRM with 30cm H2O of pressure is enough to reduce PLSP effectively.</strong></td>
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<td><strong>Strengths:</strong> adequate sample size according to power analysis and patient analysis. Use was monitored during the study, which helped explain the lower pain scores and indicated the need to look at the difference between the control and experimental groups. <strong>Limitations:</strong> control group was not placed in Trendelenburg position like the PRM group was and longer duration surgeries were not included in the study (longer time of pneumoperitoneum may cause more PLSP).</td>
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Blind RCT of 90 total patients (ASA I and ASA II): 30 in experimental group 1, who received PRM at 40 cm H2O (consisted of placing the patient in Trendelenburg position and applying 5 pulmonary inflations for 5 seconds with a pressure of 40 cm H2O); 30 in experimental group 2 who received PRM at 60 cm H2O (consisted of placing the patient in Trendelenburg position and applying 5 pulmonary inflations for 5 seconds with a pressure of 60 cm H2O); 30 in the control group (passive euvatilation).

90 total patients (ASA I and ASA II) of the female sex: n=30 PRM 40 cm H2O group; n=30 60 cm H2O group; n=30 control group; ages 19-65 years; undergoing elective bariatric gynecologic laparoscopy at the Kangbuk Samsung Hospital.

Independent variable: PRM 40 cm H2O vs. 60 cm H2O vs. passive euvatilation

Dependent variable: DV1 is shoulder pain intensity; DV2 is low abdominal surgical pain intensity; DV3 is the height of postoperative residual pneumoperitoneum (perpendicular length of the free air collected between the right hemidiaphragm and the liver on CXR); DV4 is pulmonary complications (i.e. atelectasis, pleural effusion, and pneumothorax).

- Pain scores were determined at 24 and 48 hours using a 10-point visual analog scale.
- Study outcomes were compared using the chi-squared test or Fisher’s exact test (categorical variables).
- ANOVA, or Kruskal-Wallis test (continuous variables).
- P-values < 0.05 are statistically significant.

- PLSP scores in the 2 interventions groups were significantly lower in the control group (P=0.006 and P=0.001 respectively).
- Postoperative wound scores were not different between the 3 groups (P=0.988 48 hours and P=0.812 48 hours).
- PLSP at 24 and 48 hours were not significantly different between the 2 PRM groups (P=0.231).
- Height of postop residual pneumoperitoneum in the 40 cm H2O and 60 cm H2O groups was significantly lower than the control group (P=0.001 and P=0.003 respectively).
- Atelectasis developed in 5 patients and pleural effusion in 2 patients with no significant difference between the 3 groups (P=0.318 and P=0.999 respectively).

- No significant difference in PLSP intensity between 40 cmH2O PRM and 60 cmH2O PRM.
- PRM did not affect wound pain.
- PRM did not cause pulmonary complications.
- PRM at both pressures significantly decreased residual pneumoperitoneum.

- A maximum inspiratory pressure of 40 cmH2O is sufficient to reduce PLSP in patients undergoing laparoscopic surgery.
- PRM markedly reduced PLSP.
- Reduced residual CO2 gas in the 2 intervention groups resulted in decreased irritation of the phrenic nerve, and a consequent reduction in PLSP.

Level 1A

Strengths: good study design with adequate control, appropriate sample size in the control and PRM 40 cmH2O groups.

Limitations: Power analysis showed that 30 patients were needed per group for a power of 80%. One patient withdrew consent, so the 60 cmH2O PRM group ended up with only 29 patients for analysis, making the sample size of that group too small. The study only followed up with pain scores for 48 hours postop, but shoulder pain has been reported to last for up to 7 days, so this study cannot make a conclusion about the lasting effects of PRM.
<table>
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<tr>
<td><strong>Blind RCT of 76 total patients (ASA I and ASA II).</strong> 37 in the experimental group, who received pulmonary recruitment manoeuvre (PRM) (consisted of placing the patient in Trendelenburg position (30 degrees) and applying 2 pulmonary inflations for 5 seconds with a pressure of 60 cm H2O: 49 in the control group (passive exsufflation).</td>
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<td><strong>Independent variable:</strong> PRM 60 cm H2O vs. passive exsufflation. <strong>Dependent variable:</strong> postoperative pain in general (including both abdominal and STP).</td>
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<td>- Pain scores were determined at 6, 12, 24, and 48 hours using a 10-point visual analog scale.</td>
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<td>- Mann-Whitney U test for non-categorical variables, and Fisher’s exact test or χ2 test for categorical variables.</td>
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<td>- Postoperative pain scores were significantly lower in the PRM group (P&lt;0.001, 2-way repeated measure ANOVA).</td>
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<td>- Bonferroni post-testing: 12 hour (3.1±5) vs. 5.3±6; P&lt;0.01) and 24 hour (3.4±5) vs. 4.5±6; P&lt;0.01).</td>
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<tr>
<td>- Postoperative pain scores were significantly lower in the PRM group (P&lt;0.001, 2-way repeated measure ANOVA).</td>
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<tr>
<td>PRM resulted in less postop pain.</td>
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<tr>
<td>Administration of 2 PRMs in the Trendelenburg position was effective in reducing pain significantly at 12 and 24 hours after surgery.</td>
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<td>Level IA</td>
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<td><strong>Strengths:</strong> good study design with adequate randomization and control. <strong>Limitations:</strong> does not differentiate between the abdominal and shoulder pain in the results, so it is not impossible to tell how the PRM affected each type of pain.</td>
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<tr>
<td>Independent variable:</td>
<td>PRM 60cm H2O vs. passive exsufflation</td>
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<tr>
<td>Dependent variable:</td>
<td>DV1 is PLSP intensity and incidence; DV2 is the occurrence of nausea and vomiting; DV3 is the presence of positional pain</td>
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<tr>
<td>Pain scores were determined at 12, 24, 36, and 48 hours via a questionnaire using a 100-point visual analog scale</td>
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<tr>
<td>Normality was assessed using the Kolmogorov-Smirnov test</td>
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<tr>
<td>Differences between groups were analyzed via unpaired two-tailed t-test for continuous variables and the x2 test for binomial outcomes</td>
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<td>P-values &lt; 0.05 is statistically significant</td>
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-73% of patients reported shoulder pain over the 48-hour assessment period. In the control group, 83% reported pain compared with 63% in the intervention group (P=0.05). 63% of patients in the control group stated their pain was positional; in the intervention group, this number was only 31% (P=0.05). Postoperative pain scores were significantly higher in the control group compared with the intervention group at 12 (30.3±4.5 compared with 15.6±3.0), 24 (25.7±6.7 compared with 10.8±2.4), and 36 (21.7±4.3 compared with 9.1±2.5) hours after discharge (P<0.05). PLSP peaked at 12 hours and an improvement in pain was reported at 48 hours in both groups. The incidence of postoperative nausea and vomiting was significantly higher in the control group compared with the intervention group (P=0.05). PRM reduced the frequency and severity of PLSP after gynecologic laparoscopic surgery.

**Strengths:**
- Adequate sample size as determined by the power analysis (45 patients per group)

**Limitations:**
- The amount of pain medication was not recorded, making the effect of that on the pain levels impossible to assess and the study was limited to a 48-hour follow up, which prevents its use in concluding the lasting effects of PRM.

**Risk or harm:**
- PRM caused no cardiovascular or pulmonary complications.

Blind RCT of 100 total patients (ASA I and ASA II): 54 in the experimental group, who received pulmonary recruitment maneuver (PRM) (consisted of placing the patient in Trendelenburg position (30 degrees) and applying 5 pulmonary inflations for 5 seconds with a pressure of 60cm H2O; 46 in control group (passive exsufflation).
| | | | | vomiting after surgery was significantly lower in the intervention group. 20.4% compared with 56.5% (P<0.001) |


| Yilmaz G, Kiyak H, Akca A, Sahiboglu Z. Low-pressure pulmonary recruitment maneuver: Equal to or worse than moderate-pressure pulmonary recruitment maneuver in preventing postlaparoscopic shoulder pain? A randomized controlled trial of 72 patients. Wskoclrz VG. 2020;15(3):519-525. doi: 10.5114/witm.2019.89831 | Blind RCT of 72 total patients (ASA I and ASA II): group 1 included patients who received the PRM which consisted of five manual pulmonary inflations where each positive pressure inflation was done for 5 s at a maximum pressure of 30 to 40 cm H2O in a semi-Fowler position (30\(^\circ\) head of bed elevation), and group 2 included patients who received the PRM at a maximum pressure of 15 cm H2O in a semi-Fowler position. | 72 total patients (ASA I and ASA II): group 1: n=35 Group 2: n=37 Group 2: ages 18-70 years; undergoing gynecologic laparoscopic surgery for non-malignant conditions in Istanbul Health Sciences University, Kamar Sultan Suleyman Education and Research Hospital. | Independent variable: PRM 30-40 cm H2O vs PRM 15 cm H2O. Dependent variable: DV1 is the difference in PSLP between the two groups; DV2 is the postoperative analgesic requirement; DV3 is postoperative wound pain; DV4 is time to unassisted ambulation; DV5 is pneumoperitoneum height measured on chest X-ray which was taken 24 h postoperatively. | - Pain scores were determined at 6, 12, and 24 hours using a 10-point visual analog scale. - Upright posterior-anterior (PA) chest X-ray imaging was performed in all patients at the postoperative 24th hour. The height of the gas bubble under each hemidiaphragm was measured and their sums were divided into two to estimate the residual gas volume. - The Kolmogorov-Smirnov test was used to determine whether the data were distributed normally. The student’s t-test was employed for group comparisons and the x2 test for comparison of dichotomous variables. - P-values <0.05 is statistically significant. | - There were no significant differences in wound pain score or PSLP score between patients receiving the PRM at 30-40 cm H2O and 15 cm H2O at 6, 12, and 24 hours (P=0.220, 0.298, and 0.218 respectively). - The number of patients receiving rescue analgesics was also not different between the two groups (25% vs. 11%, P=0.318). - The number of subjects receiving intravenous analgesics was similar in the two groups (20% vs. 19%, P=0.81). - There were no significant differences in mean analgesic doses of the two groups (78±38 mg vs. 68±35 mg, P=0.572). - The groups were similar concerning ambulation time (13.9±1.3 h vs. 13.3±1.7 h, P=0.215), length of hospital stay (1.7±0.4 days vs. 1.6±0.5 days, P=0.350) and height of the pneumoperitoneum measured on chest X-ray (3.4±0.7 mm vs. 3.2±0.8 mm, P=0.131). | PRM with 15 cm H2O pressure provides similar efficacy as the PRM with 30 to 40 cm H2O concerning PLSP, wound pain, the height of pneumoperitoneum, time of ambulation, and length of hospital stay. | Low-pressure PRM with a maximal inspiratory pressure of 15 cm H2O pressure provides a similar benefit when compared to a moderate-pressure PRM with a maximal inspiratory pressure of 30-40 cm H2O in patients undergoing gynecologic laparoscopic procedures. The results may not be generalizable to other laparoscopic procedures and there is a lack of data concerning alveolar damage or the hemodynamic response in both groups. | Level IVA Strengths: Adequate sample size based on the power analysis (42 patients needed). Limitations: Only involves patients undergoing gynecologic laparoscopic procedures. The results may not be generalizable to other laparoscopic procedures and there is a lack of data concerning alveolar damage or the hemodynamic response in both groups. |
|---|
| Blind RCT of 106 total patients (ASA I and ASA II). Group 1 consisted of patients receiving PRM in the neutral position (5 manual pulmonary inflations where each positive pressure inflation was done for 5 s at a maximum pressure of 40 cm H2O in the neutral position). Group 2 comprised patients receiving PRM in the semi-Fowler position (30 degrees head of bed elevation). Control group received neither PRM nor additional positioning. 106 total patients (ASA I and ASA II) of the female sex: n=33 Group 1; n=32 Group 2; n=41 control group; ages 18-70 years; gynaecologic LS for non-malignant pathologies (e.g. hysterectomy, myomectomy, sacrocolpopexy, cystectomy, etc.) in Istanbul Health Sciences University, Kanuni Sultan Suleyman Education and Research Hospital. Independent variable: PRM 40 cm H2O in neutral position vs. PRM in semi-Fowler’s position vs. no RPM or additional positioning. Dependent variable: DV1 is PLSP intensity; DV2 is wound pain score; DV3 is the height of the residual pneumoperitoneum at 24 h postoperatively; DV4 is the anaesthetic requirements; DV5 is the time to unassisted ambulation; DV6 is the time of oral intake and the time to return of bowel function. - The PLSP scores in group 1, group 2 and the control group at postoperative 6 h (5.71 ± 0.86, 3.28 ± 0.84 and 6.61 ± 0.91, respectively, p < 0.001), 12 h (4.41 ± 0.38, 4.01 ± 0.82 and 5.32 ± 0.97, respectively, p < 0.001) and 24 h (3.24 ± 0.78, 3.44 ± 0.73 and 4.34 ± 0.85, respectively, p < 0.001) were significantly different among the groups. - The wound pain score at 6 h postoperatively was significantly lower in the controls compared with patients receiving PRM in the semi-Fowler position or the neutral position (6.07 ± 0.95 to 6.94 ± 0.97 and 6.73 ± 0.98, respectively, p < 0.001 for all). - The number of patients receiving rescue analgesics was significantly higher for the control patients compared with patients who. - At all time intervals, the lowest PLSP scores were recorded in patients who received the PRM in the semi-Fowler position compared with those receiving the PRM in the neutral position and the controls. - At the postoperative 12th and 24th hour, wound pain scores were similar across the three groups. - The lowest height of pneumoperitoneum was recorded in patients who received the PRM in the semi-Fowler position. - The time of oral intake, time of the return of bowel function, and duration of hospitalization were similar across the groups. - The number of patients receiving rescue analgesics was significantly higher for the control patients compared with patients who. - When compared with the PRM in the neutral position and no PRM, the PRM in the semi-Fowler position seems to better evacuate the remaining intra-abdominal CO2 and provides a significantly lower PLSP for up to 24 h following laparoscopic gynaecologic procedures. Implementation of semi-Fowler positioning for different types of surgery and in patients with comorbidities would provide more information regarding the efficacy of this intervention. The amount of analgesics administered in the current study was not recorded. The follow-up for pain scoring was only maintained for 24 h. |
| received the PRM in the semi-Fowler position or the neutral position (27 to 11 and 9, respectively, p = 0.024) | The height of the pneumoperitoneum (17.21 ±3.24 mm to 7.97 ±3.06 mm and 3.03 ±1.34 mm respectively, p < 0.001 for all) and time of unassisted ambulation (17.27 ±1.61 h to 15.55 ±1.25 h and 14.43 ±1.43 h, respectively, p < 0.001 for all) were significantly higher in the control group compared with those who received the PRM in the semi-Fowler position or the neutral position | significantly higher in the control group compared with those who received the PRM in the semi-Fowler position or the neutral position |
|---|---|---|---|---|---|---|---|
| **Sample**: 280 patients (70 in each group) Characteristics: 20-65 years with benign gynecologic diseases and ASA class I/II that underwent gynecologic procedures Setting: Referral hospital in Tehran, Iran Surgery type: Laparoscopic gynecologic procedures. | IV1: PRM 60 cm H2O IV2: intraperitoneal NS infusion DV1: pain in the shoulder, DV2: pain at the incision site, DV3: pain in the upper abdomen, DV4: frequency of adverse events such as nausea, vomiting, and diuresis. | Pain scores were determined at 2, 6, 12, and 24 hours using a 10-point visual analog scale. The mean age and operation duration were compared among the intervention groups using the one-way analysis of variance (ANOVA). | No statistically significant difference was observed in the mean duration of operation among the intervention groups (P=0.21). Interaction of time interval and intervention status was statistically significant for shoulder and incision site pain (P ≤ 0.05). The study results showed a potential beneficial effect of PRM on the reduction of postoperative shoulder pain; therefore, compared to other groups, patients receiving PRM had a medium level of shoulder pain 24 hours after surgery (mean=0.4) (P=0.01). The patients in the control group had the lowest incision site pain 24 hours after surgery (mean=0.4) (P=0.01). The current study showed that the PRM technique can be considered as a safe and easy technique to reduce pain in the shoulder and upper abdomen after 24 hours in patients undergoing elective laparoscopic gynecologic surgery; in addition, patients receiving gentle abdominal pressure had lower incision site pain significantly decreased after 24 hours. | The current study showed that the PRM technique can be considered as a safe and easy technique to reduce pain in the shoulder and upper abdomen after 24 hours in patients undergoing elective laparoscopic gynecologic surgery; in addition, patients receiving gentle abdominal pressure had lower incision site pain significantly decreased after 24 hours. | **Level IB** |
| **Strengths**: Good study design and some control. **Limitations**: Does not mention a power analysis, so there is no indication that the sample size is adequate. Does not mention how the pain scores were obtained (i.e. where they were obtained via questionnaire or in the hospital. Who measured these pain scores, if they were measured in the hospital? Were those individuals blinded to interventions that the patients received?) Short follow-up time. Previous studies indicated the maximum benefit of intraperitoneal NS infusion was at 48 hours. Also, it is documented in other studies that the effect of PRM diminished by 48 hours, and PRM... |
### Table 1: Ventilation Methods and Pain Outcomes

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<th>Method</th>
<th>Pain 24 hours after surgery (mean ± SD)</th>
<th>Risk of harm</th>
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<tr>
<td>Maximum pressure of 60 cm H2O PRM was performed mechanically using positive-pressure ventilation to inflate the lungs and lower diaphragm. Subjects in the control group (D) received the routine method by applying gentle abdominal pressure and residual CO2 was removed by passive deflation at the end of surgery. (control group)</td>
<td>mean = 1.10 (P = 0.001)</td>
<td>Not addressed, but did refer to PRM as a &quot;safe&quot; technique. Feasibility: PRM is easy to implement</td>
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**Pain 24 hours after surgery (mean ± SD):**

- PRM group: mean = 1.10 (P = 0.001)

**Risk of harm:**

Not addressed, but did refer to PRM as a "safe" technique. Feasibility: PRM is easy to implement.
- Band RCT of 150 total participants
- Patients undergoing elective laparoscopic bariatric surgery were randomized to receive routine extubation (control group, n=71) or ventilator-piloted pulmonary recruitment maneuver (PRM)→The ventilator mode was changed to pressure-controlled ventilation and the patient received six breaths with a positive inspiratory pressure of 20 cmH2O and a PEEP of 20 cm H2O giving a total pressure of 40 cmH2O. This was completed over one minute.
- Pain and nausea intensities were recorded at 4, 12, 24, 36, and 48 hours after surgery using a numerical rating scale (NRS) with a range of 0-10.
- Differences between groups were compared using the x² test for binomial variables
- 2-sample t-test or Mann-Whitney U test was used to compare continuous variables
- Statistical significance was defined as P<0.05
- Analysis of variance (ANOVA) was used to determine the statistical significance of the differences of the NRS scores at 4, 12, 24, 36, and 48 hours between the control and intervention groups
- NRS pain scores varied significantly during the 48 hour postop period (P<0.001 ANOVA)
- The variation in NRS pain scores over time were significantly lower in the intervention group 4-24 hours postop (P=0.045 ANOVA)
- The NRS pain score was significantly lower in the intervention group at 24 hours (2 vs. 3; P=0.002)
- There was no significant difference in the prevalence of pain in the patients overall (P=0.422 at 24 hours; P=0.873 at 48 hours).
- The control group consumed a significantly higher amount of opioids during their stay in the hospital (P=0.025)
- There was no significant difference between the groups regarding the incidence of constant or PRM significantly reduced overall postoperative pain after laparoscopic bariatric surgery.
- Pain was most intense during the first 24 hours after surgery. However, there was a significant difference between the groups, in favor of the PRM group, in pain development over these two days. While the intensity of pain in the PRM group was fairly constant over the first 36 hours after surgery, a peak with a higher pain score was seen at 24 hours in the control group. Compared
- 1-minute ventilator-piloted PRM significantly reduces pain after laparoscopic upper gastrointestinal surgery and decreases the need for opioids

| Setting: Vinneryd Hospital in Sweden
| Surgery type: laparoscopic Roux-en-Y gastric bypass or laparoscopic sleeve gastrectomy
| IV-ventilator-piloted pulmonary recruitment maneuver (PRM)→The ventilator mode was changed to pressure-controlled ventilation and the patient received six breaths with a positive inspiratory pressure of 20 cmH2O and a PEEP of 20 cm H2O giving a total pressure of 40 cmH2O. This was completed over one minute.
| Pain and nausea intensities were recorded at 4, 12, 24, 36, and 48 hours after surgery using a numerical rating scale (NRS) with a range of 0-10.
| Differences between groups were compared using the x² test for binomial variables
| 2-sample t-test or Mann-Whitney U test was used to compare continuous variables
| Statistical significance was defined as P<0.05
| Analysis of variance (ANOVA) was used to determine the statistical significance of the differences of the NRS scores at 4, 12, 24, 36, and 48 hours between the control and intervention groups
| NRS pain scores varied significantly during the 48 hour postop period (P<0.001 ANOVA)
| The variation in NRS pain scores over time were significantly lower in the intervention group 4-24 hours postop (P=0.045 ANOVA)
| The NRS pain score was significantly lower in the intervention group at 24 hours (2 vs. 3; P=0.002)
| There was no significant difference in the prevalence of pain in the patients overall (P=0.422 at 24 hours; P=0.873 at 48 hours).
| The control group consumed a significantly higher amount of opioids during their stay in the hospital (P=0.025)
| There was no significant difference between the groups regarding the incidence of constant or PRM significantly reduced overall postoperative pain after laparoscopic bariatric surgery.
| Pain was most intense during the first 24 hours after surgery. However, there was a significant difference between the groups, in favor of the PRM group, in pain development over these two days. While the intensity of pain in the PRM group was fairly constant over the first 36 hours after surgery, a peak with a higher pain score was seen at 24 hours in the control group. Compared
| 1-minute ventilator-piloted PRM significantly reduces pain after laparoscopic upper gastrointestinal surgery and decreases the need for opioids

Strengths:
- The sample size required for adequate power was 69 participants per group, using a 2-tailed Wilcoxon Mann-Whitney U test, so the study had an adequate sample size.
- Used the appropriate statistical analysis
- Utilized adequate control (both groups had the pneumoperitoneum released in the supine position, any patient that had anything occur outside of the planned laparoscopic procedure was excluded from analysis, etc.)

Limitations:
- Standardization of the anesthetic management was not provided. However, there was no statistically significant difference between the PRM and control group
| intermittent nausea (P= 0.799 at 4 hours; P=0.937 intermittent episode of nausea, constant nausea P=0.366; P=0.601 had at least one episode of vomiting. | with the control group, 1 minute of ventilator-piloted PRM significantly reduced NRS pain scores 24 hours after surgery. The control group required a significantly higher amount of opioids than the intervention group. There were no differences between the groups regarding the incidence of nausea or nausea NRS score, which indicates that PRM does not affect nausea. | regarding anesthetic regimen. Risk or harm: Because the pulmonary pressure when coughing or sneezing usually rises to 4100 cm H2O, the risk of pneumothorax at 40 cm H2O was considered negligible, at least in persons not suffering from severe lung disease. The technique was easy to monitor, and no adverse effect was observed. Feasibility: inexpensive, easily implemented |
Network meta-analysis of 11 RCTs:
- Irrespective of the language of publication, year of publication, or sample size.
- The population was women who underwent any kind of gynecologic laparoscopy.
- Intervention of interest was PRM at any maximum inflation pressure performed alone or in combination with another intervention.
- Comparisons included abdominal compression aimed at expelling as much residual CO2 as possible, PRM alone with different inflation pressures from that applied in the intervention group, or any combination of PRM with another intervention.

Independent variable: PRM at various pressure vs. abdominal compression vs. PRM with another intervention
Dependent variable: intensity of shoulder pain evaluated at 24 hours following operation, shoulder pain intensity at 48 hours, the incidence of shoulder pain at 24 and 48 hours, postoperative nausea/vomiting, cardiopulmonary complications, and requirement of postoperative analgesia.

Effect measures were presented as pooled mean differences (MD) with corresponding 95% confidence intervals (CIs) for the continuous outcome (i.e., shoulder pain score) and risk ratio (RR) for binary outcomes (i.e., the incidence of shoulder pain).

Participants undergoing PRM at a maximum inspiratory pressure of 60 cm H2O experienced a slightly higher shoulder pain than those who underwent PRM performed with a maximum inspiratory pressure of 40 cm H2O (MD 0.43; 95% CI 0.21 to 0.63).
- Among the available comparisons evaluating the risk of developing shoulder pain at 24 hours after the operation, a combination of PRM and IPS can reduce the risk of shoulder pain with estimated RRs ranging from 0.69 (95% CI 0.51-0.95) to 0.66 (95% CI 0.48-0.93) depending on the maximum inspiratory pressure applied. For the 48-hour time point, only PRM with a pressure of 60 cm H2O was noted to be a marginal significant intervention associated with lower risk of shoulder pain (OR 0.81; 95% CI 0.66-0.99).
- PRM with a maximum inspiratory pressure of 40 cm H2O was most likely to result in the lowest shoulder pain intensity at 24 hours while abdominal compression seemed appreciably less attractive than the various alternatives.
- Significant reduction of pain intensity after the application of PRM alone or PRM combined with IPS was shown across the studies with different complexities of laparoscopic procedures when compared to abdominal compression.

Strengths: analyzed the risk of bias of each study and indicated the studies included had an overall low risk of bias.
Limitations: As it was not feasible to blind the personnel involved in the studies, i.e., surgeon and anesthesiologist, to the intervention received, all included studies were deemed as having a high risk of performance bias. A limited number of included studies precluded the ability to create comparison-adjusted funnel plots to assess the small-study effects.