Pulmonary Recruitment Maneuver Effects on Laparoscopic Complications: An Evidence Based Practice Analysis

Keywords: laparoscopy, pain, shoulder pain, pneumoperitoneum, PONV, analgesia, surgery, pulmonary maneuver, anesthesia

Introduction

Postoperative shoulder pain is a common complication following laparoscopic surgery with an incidence as high as 80%.[1] The etiology of the shoulder pain is thought to be due to residual carbon dioxide in the abdominal cavity, however the exact mechanism has not been fully elucidated.[2] Anesthesia providers are challenged with providing effective postoperative pain relief while minimizing complications. Evidence in the literature suggests laparoscopic related complications such as pain and postoperative nausea and vomiting (PONV) can be reduced by implementing a pulmonary recruitment maneuver in Trendelenburg position (30°) at the end of surgery.[3] The maneuver may also have an affect on postoperative analgesic requirements.[4,5] The purpose of this evidence-based-analysis is to investigate the effects of a pulmonary recruitment maneuver at the end of laparoscopic surgery on postoperative pain, analgesic requirements, and PONV.

Methodology

A population, intervention, comparison, and outcome (PICO) question was used to provide the clinical framework, "What are the effects of a pulmonary recruitment maneuver (I) in adult laparoscopic surgical patients (P) on postoperative pain, analgesic requirements, and PONV (O) compared to patients who do not receive a pulmonary recruitment maneuver (C)?"

A literature review was performed by searching the electronic databases *CINAHL* and *PubMed.* Keywords used for the search included: *shoulder pain, surgery, pulmonary maneuver, laparoscopy, pain, pneumoperitoneum, PONV, analgesia.* The author found one meta-analysis that examined the effects of a pulmonary recruitment maneuver on postoperative pain, which was determined to be level I evidence according to the Joanna Briggs Institute Levels of Evidence. The author also found six RCTs (Table 1), level II evidence, with similar methodologies that were used for this review. In each RCT, independent variables for removal of CO2 from the abdomen included either a pulmonary recruitment maneuver or passive exsufflation.

Literature Review

In this literature review the "treatment group" refers to a group of subjects receiving a pulmonary recruitment maneuver. "Control group" refers to a group of subjects that did not receive a pulmonary recruitment maneuver.

Postoperative Pain. The pathophysiology of shoulder pain following pneumoperitoneum is poorly understood. It is thought to be caused by retained CO2 in the abdomen, which leads to diaphragmatic irritation and peritoneal stretching.[1,4] However similar pain can be present with

gasless laparoscopy.[6] The incidence of shoulder pain usually peaks 24-48 hours postoperatively[4] and affects the right shoulder more than the left.[7]

A pulmonary recruitment maneuver at the end of surgery can reduce the incidence of shoulder pain.[1,3-5] The extent to which incidence was decreased varied among studies. Incidence of shoulder pain was significantly less in the treatment group compared to control at 12, 24, and 36 hours postoperatively;[3] 4, 12, 24, and 48 hours postoperatively;[4] 12, 24, and 48 hours postoperatively;[1] and a decreased overall incidence.[5] One consistent finding across studies was that the pulmonary recruitment maneuver intervention significantly reduced the incidence of shoulder pain between 12 and 48 hours postoperatively compared to passive exsufflation.

Results from four studies showed a pulmonary recruitment maneuver at the end of surgery reduced the severity of shoulder pain.[1,3,4,8] The severity of shoulder pain was significantly less in the treatment group compared to control at 12, 24, and 36 hours postoperatively.[3] However, there was no significant difference in shoulder pain between groups at discharge.[3] A weakness in this study is that pain scores were self-reported and subjects were instructed to only report shoulder pain, not surgical pain. Subjects in this study may have reported surgical pain instead of shoulder pain, which may cause the results to be misrepresented.

Sharami et al. found the severity of shoulder pain was significantly lower in the treatment group compared to control at 4, 12, 24, and 48 hours postoperatively. Additionally, the mean duration of surgery was significantly lower in the control group.[4] Khanna et al. found pain severity was less in the treatment group compared to control at 12 and 24 hours postoperatively.[8] However, a weakness was that their working definition of pain was broad and included "both abdominal and shoulder tip pain"[8] (1291). Tsai et al. found shoulder pain severity was less in the treatment group compared to control at 12, 24, and 48 hours postoperatively.[1] It is important to note the treatment group received both an intraperitoneal infusion of normal saline and a pulmonary recruitment maneuver to aid in exsufflation of the abdomen in the aforementioned study[1]. In two studies, there was no significant difference between groups with respect to shoulder pain severity.[5,9]

A pulmonary recruitment maneuver can significantly reduce the severity of postoperative abdominal pain.[1,5,8,9] Definitions of abdominal pain varied somewhat among studies. Liu et al.[5] examined pain during movement and at rest. Dynamic pain, defined as pain while standing or coughing, was significantly lower in the treatment group compared to control at 0, 4, and 24 hours postoperatively.[5] Static pain, defined as pain at rest, was significantly lower in the treatment group compared to control at 0, 2, and 24 hours postoperatively.[5] Tsai et al. collected data on both upper abdominal pain and surgical pain.[1] Upper abdominal pain was significantly lower in the treatment group compared to control at 12 and 24 hours postoperatively. Tsai et al. found no significant difference in the incidence or severity of surgical wound pain between groups.[1] Tsai et al. collected data on upper abdominal pain and lower abdominal pain.[9] They found no significant difference in lower abdominal pain severity or incidence between treatment and control groups. Upper abdominal pain severity was significantly less in the treatment group compared to control at 12 and 24 hours postoperatively.[9] A weakness in the study design was that the investigators collecting postoperative data were not blinded to subject allocation.[9] Two of the studies did not collect data on abdominal pain.[3,4]

Postoperative Nausea and Vomiting. Laparoscopic surgery may be implicated in PONV. The pneumoperitoneum decreases intestinal blood flow, which can lead to gastrointestinal ischemia. Serotonin, a highly emetogenic substance, is released in response to ischemia which may lead to PONV.[10] Complications associated with PONV can lead to prolonged hospital stay and increased costs.[11] A pulmonary recruitment maneuver following laparoscopic surgery has been shown to decrease PONV.[3]

Four of the six studies collected data regarding the incidence of PONV. Three studies found no significant difference in the incidence of PONV between groups.[1,5,9] However neither study by Tsai et al.[1,9] collected data on intraoperative opioid consumption. Intraoperative opioids increase the risk for PONV. The amount of intraoperative opioids subjects received in these two studies may have affected the incidence of PONV. In contrast, Cakmakkaya et al. found the incidence of PONV was significantly lower in the treatment group compared to control.[3] There was no difference in the amount of postoperative opioids administered between the groups. Sharami et al. noted that NSAIDS were routinely used at their facility and the incidence of PONV was low[4].

Analgesic Requirements. The American Pain Society recommends multimodal analgesia for postoperative pain management utilizing a variety of both pharmacological and nonpharmacological interventions.[12] A pulmonary recruitment maneuver could be a potential nonpharmacological intervention to help decrease postoperative pain and reduce analgesic requirements.

Postoperative analgesia regimens varied among studies and included: IV meperidine, diclofenac suppository, and IV tramadol. Postoperative analgesic consumption data was reported in five of the studies. There was no significant difference in analgesic requirements between groups in three of the studies.[3,5,9] However, the authors in two of the aforementioned studies did not discuss the use of analgesics intraoperatively, which may have affected postoperative analgesic requirements.

Analgesic requirements were significantly lower in the treatment group compared to control in two of the studies.[4,5] Sharami et al. utilized a diclofenac suppository for postoperative analgesia followed by IV meperidine if the diclofenac was ineffective[4]. A weakness in the study is they collected data regarding diclofenac consumption, but not meperidine consumption. Furthermore, the external validity may be somewhat limited because NSAIDS were used as first line treatment for postoperative pain, which may vary across practice settings. Liu et al. found IV tramadol use was lower in the treatment group compared to control[5]. Again, external validity may be limited because IV tramadol for postoperative analgesia may not reflect common practice. Regardless of the type of postoperative analgesic regimen, postoperative analgesic consumption was decreased when a pulmonary recruitment maneuver was implemented at the end of surgery in two studies[4,5].

Strengths/Limitations. There are strengths and limitations of the studies reviewed that impact the quality of this evidence based practice analysis. General endotracheal anesthesia was the anesthesia technique utilized in each study. Regarding the number of manual pulmonary inflations, five of the six studies implemented five manual pulmonary inflations, while one study

implemented two manual pulmonary inflations each held for 5 seconds. This is a strength as the intervention was similar across studies. Pressure of pulmonary inflation varied slightly among studies—four studies used a pressure of 60 cmH2O while two studies used 40 cmH2O. Five studies held the last pulmonary inflation for 5 seconds. In both control and treatment groups, the trocar sleeves were fully open to allow CO2 to escape. Timing of the intervention was consistent and performed at the end of surgery. The degree of Trendelenburg (30°) was the same in each study. Intraabdominal pressure varied only slightly from 12-15 mmHg among studies and intraabdominal gas flow rates were 1-2 L/min. Five of the six studies utilized a visual analogue scale to measure pain. One study used a numeric rating scale to measure pain. Pain scores were self-reported in one of the six studies.

Induction, maintenance, and emergence varied among studies. Three of the studies did not define the specific anesthetics administered, only that the anesthesia technique was standard and did not vary.[1,8,9] Furthermore, these studies did not report the amount of intraoperative analgesics subjects received. This is a significant weakness because intraoperative analgesics have an affect on postoperative pain. Three studies described the anesthetic technique and included induction with a hypnotic, fentanyl, and a nondepolarizing neuromuscular blocking agent.[3-5] In one study, fentanyl boluses were repeated "according to clinical needs"[3] but the authors did not report the total amount of intraoperative fentanyl administered. In the remaining two studies, anesthesia providers gave a single dose of fentanyl during induction to all subjects.[4,5] TIVA with propofol and remifentanil was utilized in one study and there was no significant difference in cumulative remifentanil doses between groups.[5]

A significant selection bias was present in the articles reviewed, both in demographics and surgical specialty. A total of 571 subjects were included in the studies, of which 534 were female. Furthermore,-the majority of subjects (n=495) underwent laparoscopic gynecological procedures. The remaining procedures were laparoscopic cholecystectomy (n=47) and laparoscopic inguinal hernia repair (n=29). All subjects were relatively healthy according to their ASA physical status of I or II with the exception of one study that included 5 subjects with an ASA physical status of III. Thus, external validity is somewhat limited to a specific population because of the relatively homogenous sample, healthy females undergoing laparoscopic gynecological surgery. This could be perceived as a potential strength or weakness.

Tsai et al.[1] and Tsai et al.[9] examined the effects of an intraperitoneal normal saline infusion combined with a pulmonary recruitment maneuver, which limits comparison of literature. Tsai et al. compared a group receiving an infusion of normal saline (15-20 mL/kg) in the upper abdominal cavity combined with a pulmonary maneuver to a control group.[1] Tsai et al. also compared a group receiving intraperitoneal normal saline combined with a pulmonary maneuver, however, they included a group that received only a pulmonary recruitment maneuver.[9] This review does not include data from the group that received intraperitoneal normal saline and a pulmonary maneuver in the Tsai et al.[9] study. Incisional infiltration of local anesthesia was utilized in one study in both control and treatment groups.

Table 1
Pulmonary Recruitment Maneuver Evidence Matrix

Author	Sample (n) & Population	Variables	Results
Cakmakkaya et al.[3], 2008	n=100 n=46 control n=54 treatment Elective gynecologic laparoscopic surgery	Dependent Shoulder pain incidence Shoulder pain severity PONV Meperidine consumption Independent 5 manual pulmonary inflations at a pressure of 60cmH2O, 5th held for 5s	• Shoulder pain incidence less in treatment group at 12, 24, 36h • Shoulder pain severity less in treatment group at 12, 24, 36h • PONV lower in treatment group • No difference in postoperative analgesic requirements between groups • No difference in pain at discharge between groups
Sharami et al.[4], 2010	n=131 n=64 control n=67 treatment Minor gynecological laparoscopy	Dependent Shoulder pain incidence Shoulder pain intensity Diclofenac consumption Independent 5 manual pulmonary inflations at a pressure of 40cmH2O, 5th held for 5s	• Shoulder pain incidence and intensity less in treatment group at 4, 12, 24, 48h • Greater postoperative use of diclofenac in control group • No difference in pain within first 4h between groups
Tsai et al.[9], 2011	n=104 n=51 control n=53 treatment Laparoscopic surgery for benign gynecologic lesions	Dependent Shoulder pain incidence Shoulder pain severity Upper abdominal pain Lower abdominal pain PONV Meperidine consumption Independent 5 manual pulmonary inflations at a pressure of 60cmH2O, 5th held for 5s	• No difference in shoulder pain incidence or severity between groups • Upper abdominal pain severity and incidence less in treatment group at 12 and 24h • No difference in lower abdominal pain incidence or severity between groups • No difference in PONV or postoperative meperidine consumption between groups

Author	Sample (n) & Population	Variables	Results
Tsai et al.[1], 2013	n=100 n=50 control n=50 treatment Laparoscopic surgery for benign gynecologic lesions	Dependent Shoulder pain incidence Shoulder pain severity Upper abdominal pain Surgical pain PONV Meperidine consumption Independent Normal saline (15-20mL/kg) instilled in upper abdominal cavity followed by 5 manual pulmonary inflations at a pressure of 60cmH2O	• Shoulder pain incidence and severity lower in treatment group at 12, 24, 48h • Upper abdominal pain incidence lower in treatment group at 12, 24, 48h • Upper abdominal pain severity lower in treatment group at 12, 24h • No difference in surgical pain incidence or severity between groups • No difference in PONV between groups • No difference in meperidine consumption between groups
Khanna et al.[8], 2013	n=76 n=39 control n=37 treatment Laparoscopic cholecystectomy or transabdominal preperitoneal inguinal hernia repair	Dependent Postoperative pain, includes abdominal and shoulder tip Independent 2 manual pulmonary inflations at a pressure of 60cmH2O, each inflation held for 5s	• Pain severity less in treatment group at 12 and 24h
Liu et al.[5], 2014	n=60 n=30 control n=30 treatment Diagnostic hysteroscopy and laparoscopy	Dependent Shoulder pain incidence Shoulder pain severity Dynamic pain Static pain PONV Tramadol consumption Independent 5 manual pulmonary inflations at a pressure of 40cmH2O, 5th inflation held for 5s	• Lower overall incidence of shoulder pain in treatment group • No difference in R or L shoulder pain between groups • No difference in shoulder pain severity between groups • Dynamic pain decreased in treatment group at 0, 4, 24h • Static pain decreased in treatment group at 0, 2, 24h • No difference in PONV between groups • Tramadol use less in treatment group

Note. All results are statistically significant at $p<0.05$. Treatment groups received pulmonary recruitment maneuvers for all studies. Control groups did not receive a pulmonary recruitment maneuver.

Conclusions

The reviewed studies shared similar methodologies with minor variations in the pulmonary recruitment maneuver technique and the quantity of data collected. Pulmonary recruitment maneuvers expose patients to a low risk of pneumothorax because of the increased intrapulmonary pressure. However, coughing and sneezing can increase intrapulmonary pressures to 80-130 $cmH2O^3$ so it is unlikely manual pulmonary inflations with a pressure of 60 cmH2O would cause a pneumothorax in the absence of underlying pulmonary disease. Pulmonary recruitment maneuvers may be contraindicated if a pneumothorax is suspected or the patient has risk factors for pneumothorax.

The pulmonary recruitment maneuver may decrease cardiac output secondary to decreased venous return caused by increased intrathoracic pressure. However, the Trendelenburg position may offset the decrease in venous return. It may be prudent to avoid this maneuver if the patient has cardiovascular disease and does not tolerate a decrease in venous return. Furthermore, use good clinical judgement and proceed with caution in the hypotensive patient as this maneuver can potentiate hypotension. None of the study subjects in this literature review suffered complications related to the pulmonary recruitment maneuver.

A key limitation in this review is the relative homogeneity of the population examined. The results may only be generalized to females with an ASA physical status of I or II undergoing laparoscopic gynecologic procedures. A pulmonary recruitment maneuver in Trendelenburg position (30°) at the end of laparoscopic surgery appears to be a safe, effective technique that may reduce PONV, postoperative pain, and postoperative analgesic consumption in healthy females undergoing gynecological surgery. Patients who qualify for pulmonary recruitment are healthy patients undergoing laparoscopic surgery without coexisting cardiopulmonary disease. Despite the homogenous sample of females, the intervention may have an affect on the general surgical population. The proposed explanation of exsufflation of the abdomen is independent of gender. Further research is necessary to support the findings in other patient populations.

Surgeon compliance is required for implementation of the intervention. Anesthesia providers are recommended to utilize a multimodal approach to postoperative pain. A pulmonary recruitment maneuver at the end of laparoscopic surgery in healthy patients seems to be a low risk nonpharmacological intervention that may reduce PONV, postoperative pain, and postoperative analgesic requirements.

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