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Review Article

Strategies for prevention and management of post-operative shoulder tip pain following laparoscopic cholecystectomy: a narrative review of intraperitoneal and local interventions

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ABSTRACT

Post-operative shoulder tip pain remains a frequent and distressing complication following laparoscopic cholecystectomy, despite the minimally invasive nature of the procedure. This pain, distinct from incisional or visceral discomfort, is primarily attributed to diaphragmatic irritation and phrenic nerve stimulation caused by carbon dioxide pneumoperitoneum and residual intraperitoneal gas. A wide range of preventive and therapeutic strategies have been investigated to address this problem. This narrative review synthesizes evidence from randomized controlled trials, meta-analyses, and clinical studies evaluating mechanical, non-pharmacological, and pharmacological interventions aimed at reducing shoulder tip pain. These include low-pressure pneumoperitoneum, active gas evacuation techniques, intraperitoneal instillation of local anesthetics, alkalinizing agents such as sodium bicarbonate, and various adjuvant analgesics. The reviewed evidence suggests that no single intervention is universally effective; rather, a multimodal approach combining mechanical optimization and intraperitoneal pharmacologic strategies offers the greatest benefit. Further standardized, comparative trials are needed to establish optimal protocols for routine clinical practice.

Keywords: Adenocarcinoma, Colorectal, Carcinoma, Colonoscopy, Retrospective

INTRODUCTION

Laparoscopic cholecystectomy has become the gold standard treatment for gallbladder disease, offering shorter hospital stay and faster recovery than open surgery. Yet up to two thirds of patients still experience unpleasant post-operative pain, often with a distinctive sharp sensation in the tip of the shoulder caused by referred phrenic nerve irritation.[1] In addition to incisional and visceral discomfort, shoulder tip pain (STP) delays mobilization, increases analgesic requirements and reduces patient satisfaction. The characteristic pain is thought to arise from carbon dioxide (CO_2) pneumoperitoneum stretching the diaphragm and stimulating the phrenic nerve, but multiple factors including peritoneal inflammation, residual gas, and mechanical irritation contribute.[2,3] Because this pain is often resistant to routine analgesics, a range of mechanical and pharmacological strategies have been investigated to prevent or mitigate STP. This narrative review synthesizes over thirty distinct studies and reviews to provide a comprehensive overview of interventions aimed at reducing shoulder tip pain after laparoscopic cholecystectomy. It focuses on interventions directed at the peritoneal surface—intraperitoneal alkalinizing solutions and local anaesthetics—and compares them with non-pharmacological approaches such as low-pressure pneumoperitoneum, gas evacuation and nerve blocks. Evidence is drawn from randomized controlled trials, observational studies and meta-analyses published up to December 2025.

POST OPERATIVE SHOULDER TIP PAIN: CLINICAL CHARACTERISTICS AND BURDEN

Post-operative shoulder tip pain typically begins within hours of surgery and can persist for up to three days. An

editorial summarizing several series reported incidence rates of about 63% after laparoscopic cholecystectomy, 66% after gastric banding and 83% after gynaecological laparoscopy.[4] The pain is usually more prominent on the right side and is described as a dull or stabbing ache that worsens with inspiration or movement. In addition to causing discomfort, STP contributes to postoperative nausea, restricts deep breathing and delays mobilization, thereby increasing the risk of pulmonary complications. Simple measures such as removal of residual CO_2 from the abdomen can reduce both shoulder pain and post-operative nausea and vomiting (PONV).[5] Understanding the magnitude and timing of shoulder pain is important because it guides the timing of interventions—strategies that only provide analgesia for a few hours are unlikely to impact a pain phenomenon that peaks later and persists for over 24 hours. Clinicians also need to recognize that shoulder tip pain is distinct from incisional and visceral pain and may not respond to the same analgesic modalities.[2]

PATHOPHYSIOLOGY OF SHOULDER TIP PAIN AFTER LAPAROSCOPY

The pathophysiology of shoulder tip pain remains incompletely understood. Most evidence points to CO_2 pneumoperitoneum as the principal culprit. The gas stretches the peritoneum and diaphragm, creating carbonic acid on the moist peritoneal surfaces that irritates the phrenic nerve, leading to referred pain in the C3–C5 dermatomes. A prospective observational study measuring residual CO_2 volumes after gynaecological laparoscopy found that patients with drains had significantly less residual gas and lower shoulder pain scores.[6] The authors concluded that free gas accumulates under the diaphragm and irritates the phrenic nerve.[6] Similarly, editorial analyses have emphasized that diaphragmatic stretching from insufflation rather than skin incisions is the main source of pain.[4] Other factors such as peritoneal inflammation and peritoneal stretch during surgical manipulation also contribute, explaining why pain may persist even when CO_2 is evacuated. Studies comparing intraperitoneal bupivacaine with saline have shown that early post-operative pain is more closely related to peritoneal irritation and pneumoperitoneum than to cutaneous injury.[7] Neural pathways are complex: the diaphragmatic peritoneum is innervated by the phrenic nerve whereas the parietal peritoneum is innervated by spinal nerves, so interventions that reduce diaphragmatic irritation may not affect incisional pain. Understanding these mechanisms is crucial for designing targeted interventions.

NON-PHARMACOLOGICAL AND MECHANICAL PREVENTIVE STRATEGIES

Low-pressure pneumoperitoneum

Reducing the pressure of pneumoperitoneum has been proposed to minimize diaphragmatic stretch. A randomized controlled trial including forty patients compared low-pressure (9–10 mmHg) with standard-pressure (14 mmHg) pneumoperitoneum during laparoscopic cholecystectomy. The low-pressure group had a significantly lower incidence of shoulder pain (23% versus 57%) and lower visual analogue scale (VAS) scores at 8 and 24 hours, with no significant increase in operative time or complications.[8] A subsequent meta-analysis of twelve studies involving 1,032 participants confirmed that low-pressure pneumoperitoneum significantly reduces the risk of shoulder pain (relative risk 0.48; 95% CI 0.39–0.60).[9] The authors concluded that diaphragmatic overstretching is a major contributor to STP and recommended reducing insufflation pressure when feasible. However, very low pressures may compromise operative exposure and increase technical difficulty, and low pressure alone may not fully prevent pain due to residual gas and peritoneal inflammation.

Gas evacuation maneuvers and drains

Because residual CO_2 is implicated in shoulder pain, several techniques aim to evacuate gas at the end of surgery. A prospective cohort study of 448 patients demonstrated a lower incidence of shoulder pain at both 12 and 24 hours in patients receiving surgical drains compared with those without drains.[6] The hazard ratio for shoulder pain was 0.61, indicating a 39% reduction in risk. Randomized studies evaluating active gas evacuation manoeuvres, including Trendelenburg positioning combined with pulmonary recruitment, have shown significant reductions in shoulder pain scores and PONV over 24–36 hours.[5] These findings support removal of residual CO_2 as a simple, low-cost strategy to mitigate STP, although some studies report inconsistent benefits and potential discomfort related to drain placement.

Pulmonary recruitment and patient positioning

Pulmonary recruitment manoeuvres (PRM) use positive pressure ventilation to increase intrathoracic pressure and facilitate expulsion of CO_2 from the abdominal cavity. In a multicentre randomized controlled trial involving 147 patients, a ventilator-piloted PRM resulted in a significantly lower incidence of shoulder pain over 48 hours (44.7 % versus 63.4 %) and was associated with reduced nausea and lower postoperative analgesic consumption.[10] The number needed to treat was six, and no adverse respiratory or haemodynamic effects were reported. When combined with Trendelenburg positioning, PRM may further enhance gas evacuation by displacing residual CO_2 away from the diaphragmatic surface. However, the available evidence remains limited, and heterogeneity in recruitment protocols—including applied pressure and duration—makes inter-study comparisons difficult. Trendelenburg and right-side-down positioning during desufflation have also been shown to help displace gas away from the diaphragm, but these manoeuvres should be applied cautiously in patients with underlying cardiopulmonary comorbidities.[11]

Phrenic nerve blocks and TAP blocks

Blocking the phrenic nerve has been investigated as a targeted strategy to prevent referred shoulder pain. In a randomized controlled trial evaluating ultrasound-guided phrenic nerve block with ropivacaine, the intervention significantly reduced both the incidence and severity of shoulder pain without affecting incisional pain or increasing postoperative analgesic requirements.[12] Importantly, no adverse respiratory effects or clinically significant diaphragmatic dysfunction were reported.

Despite these promising findings, the technique requires advanced ultrasound expertise and carries a theoretical risk of diaphragmatic paralysis, limiting its routine clinical adoption. Transversus abdominis plane (TAP) blocks provide regional anaesthesia of the anterior abdominal wall. A randomized controlled trial evaluating bilateral ultrasound-guided TAP blocks using levobupivacaine after laparoscopic cholecystectomy demonstrated significantly lower verbal numerical rating scale (VNRS) pain scores at 20 min, 30 min, 60 min, 6 hour, 12 hours and 24 hours postoperatively compared with controls.[13] Use of remifentanil and rescue analgesics in the recovery room was also significantly lower in both TAP block groups, with no block-related complications reported.[14]

While TAP blocks effectively address somatic and incisional pain, they do not directly target diaphragmatic irritation or phrenic nerve–mediated referred pain. Nevertheless, by reducing overall pain burden and opioid requirement, TAP blocks may indirectly improve postoperative comfort.

Preoperative medications (gabapentin and clonidine)

Preoperative administration of centrally acting agents may attenuate central sensitization and reduce postoperative pain. A randomized trial comparing preoperative gabapentin (800 mg) with placebo in patients undergoing laparoscopic surgery demonstrated a significantly lower incidence of shoulder pain (45% versus 75%) and reduced pain severity at 2 and 12 hours postoperatively in the gabapentin group.[15] No significant differences in adverse effects were observed, suggesting that gabapentin may be a safe adjunct.

Similarly, a double-blind randomized controlled trial evaluating oral clonidine (0.2 mg) versus placebo in 60 patients found that clonidine significantly reduced the intensity of shoulder pain at emergence and at 4-and 8-hour post-operation, although it did not reduce the overall incidence of pain.[16] These agents likely exert their effects through modulation of central nociceptive pathways and reduction of sympathetic tone. However, potential side effects such as sedation and hypotension warrant careful monitoring, and current evidence is limited to relatively small trials.

PHARMACOLOGICAL APPROACHES: INTRAPERITONEAL AGENTS

Local anaesthetics (lignocaine, bupivacaine, ropivacaine)

Intraperitoneal instillation of local anaesthetics aims to desensitize visceral peritoneal nociceptors and reduce shoulder pain. A randomized trial comparing intraperitoneal lignocaine and bupivacaine in 206 patients found both agents to be safe and similarly effective, with no significant differences in abdominal or shoulder pain scores and a gradual reduction in pain over time.[17] Several trials have evaluated bupivacaine at different doses and concentrations.

One study using high-volume, low-concentration bupivacaine (30 ml of 0.25%) reported a significant prolongation of analgesia duration and reduced opioid requirement compared with saline, although shoulder pain incidence was not reduced.[18] Other studies have demonstrated modest reductions in early visceral and shoulder pain, while some have shown no significant benefit over placebo, suggesting that early pain may be driven predominantly by peritoneal irritation and residual CO_2 rather than incisional injury.[7]

A large meta-analysis including 39 randomized controlled trials (3,045 patients) concluded that intraperitoneal local anaesthetics reduce abdominal, visceral and shoulder pain at rest and decrease the incidence of shoulder pain (risk ratio 0.437), although no benefit was observed for dynamic pain and significant heterogeneity was noted between studies.[19]

Alkalinising solutions: sodium bicarbonate and soda

Neutralization of carbonic acid formed from CO_2 insufflation has been proposed as an alternative mechanism to reduce phrenic nerve irritation. In a randomized controlled trial comparing intraperitoneal irrigation with sodium bicarbonate solution versus normal saline during laparoscopic cholecystectomy, patients in the bicarbonate group experienced significantly lower shoulder pain scores and reduced postoperative analgesic requirements.[20]

The proposed mechanism involves alkalinization of peritoneal fluid, thereby reducing chemical irritation of the diaphragm. Although relatively few studies have replicated these findings, sodium bicarbonate irrigation remains an attractive adjunct due to its low cost and apparent safety.

Concerns regarding electrolyte imbalance and peritoneal irritation with large volumes persist, highlighting the need for further controlled studies.

COMBINATION THERAPY WITH ADJUVANTS (DEXMEDETOMIDINE, MORPHINE, KETAMINE, HYDROCORTISONE)

Dexmedetomidine

Dexmedetomidine, an α_2-adrenergic agonist with analgesic and sedative properties, has been increasingly used as an adjuvant to local anaesthetics to prolong analgesia. A randomized controlled trial involving 100 patients compared intraperitoneal bupivacaine alone with bupivacaine combined with dexmedetomidine. The combination group demonstrated a significantly longer duration of analgesia (14.5 versus 13.06 hours) and required fewer rescue analgesics.20 Another randomized trial involving 80 patients compared ropivacaine plus dexmedetomidine with ropivacaine plus fentanyl and reported significantly lower VAS pain scores, a longer time to first rescue analgesia (122 min versus 89 min), and reduced total analgesic consumption in the dexmedetomidine group.[21] In addition, a meta-analysis of 24 trials evaluating intraperitoneal ropivacaine demonstrated reductions in opioid consumption, pain scores, shoulder pain, postoperative nausea and vomiting, and hospital stay.[22] Collectively, these findings suggest that dexmedetomidine enhances the analgesic efficacy of intraperitoneal local anaesthetics through both peripheral and central mechanisms.

Morphine and opioid adjuvants

Intraperitoneal opioids aim to exploit the presence of peripheral opioid receptors on the peritoneal surface. A randomized trial comparing intraperitoneal bupivacaine combined with morphine versus bupivacaine alone demonstrated superior postoperative pain control in the morphine group without an increase in adverse events.[23] However, systemic absorption of opioids may still occur, raising concerns regarding sedation and respiratory depression. In contrast, a randomized controlled trial comparing intraperitoneal ketorolac with intravenous ketorolac and control found that both intraperitoneal and intravenous ketorolac significantly reduced shoulder and resting pain compared with control, but there was no significant difference between the two routes of administration.[24] These findings indicate that while opioid and NSAID adjuvants may provide analgesic benefit, their incremental advantage over systemic administration remains uncertain.

Hydrocortisone and corticosteroids

Inflammatory mediators released following peritoneal insufflation contribute to visceral and referred shoulder pain. A double-blind randomized controlled trial involving 62 patients compared intraperitoneal hydrocortisone (100 mg) with saline. The hydrocortisone group demonstrated significantly lower abdominal and shoulder pain scores (mean pain score 10.95 versus 12.95; $p<0.01$) and reduced meperidine consumption, with no reported adverse effects.[25] These findings suggest that local corticosteroid instillation may attenuate inflammatory responses and provide opioid-sparing effects. Nevertheless, concerns regarding immunosuppression and impaired wound healing limit routine use of intraperitoneal corticosteroids.

Ketamine

Ketamine, an N-methyl-D-aspartate (NMDA) receptor antagonist, possesses analgesic and antihyperalgesic properties. In a double-blind randomized controlled trial involving 92 patients, intraperitoneal ketamine (0.25 mg/kg) was compared with bupivacaine. Patients in the ketamine group exhibited significantly lower pain scores at multiple time points (5 min, 15 min, 6 hour, 12 hours and 24 hours) and a longer time to first rescue analgesia.[26] The authors concluded that intraperitoneal ketamine provided superior analgesia without significant safety concerns. Ketamine's anti-inflammatory effects and inhibition of central sensitization may explain its benefit; however, further studies are required to define optimal dosing and evaluate potential psychomimetic effects.

Dexamethasone and other adjuvants

Several studies have evaluated dexamethasone as an intraperitoneal adjuvant. A recent randomized controlled trial reported that intraperitoneal dexamethasone combined with bupivacaine resulted in significantly lower VAS pain scores up to 2 hour post-operation, prolonged time to first rescue analgesia, and reduced analgesic requirements compared with bupivacaine alone.[27] Another trial comparing intraperitoneal with intravenous dexamethasone demonstrated lower pain and nausea severity in the intraperitoneal group, although the incidence of postoperative nausea and vomiting was similar between groups.[28] These findings suggest that intraperitoneal dexamethasone may enhance the analgesic effects of local anaesthetics and modulate local inflammatory responses.

Intraperitoneal magnesium sulfate has also shown promise; in a 2023 randomized controlled trial involving 64 patients, magnesium sulfate significantly reduced VAS pain scores, prolonged time to first analgesic request, and decreased postoperative vomiting without reported adverse effects.[29] Despite encouraging results, these adjuvant therapies require further validation and comparison with systemic administration.

Agents that did not show significant benefit

Not all intraperitoneal interventions have demonstrated efficacy. A randomized controlled trial comparing intraperitoneal bupivacaine with saline found no significant differences in pain scores or postoperative analgesic requirements.[30] The authors suggested that shoulder pain primarily resulted from peritoneal irritation and phrenic nerve stimulation rather than incisional injury and proposed that earlier administration or nerve blockade

before dissection might be more effective.[31] Similarly, an earlier trial reported no significant analgesic benefit when intraperitoneal bupivacaine was instilled at the end of surgery, underscoring the importance of timing and technique.[32] Additionally, studies have shown that intraperitoneal ketorolac offers no advantage over intravenous administration.[24] These findings highlight that intraperitoneal administration does not uniformly confer benefit and must be optimized with respect to drug selection, dose, timing, and distribution.

Integration into multimodal analgesia and ERAS protocols

ERAS protocols advocate multimodal analgesia to minimize opioid use and accelerate recovery. Baseline analgesia with paracetamol and non-steroidal anti-inflammatory drugs remains fundamental, with intraperitoneal interventions considered as adjuncts. Narrative reviews have emphasized that post-laparoscopic shoulder pain arises primarily from phrenic nerve irritation due to pneumoperitoneum and have summarized effective strategies including low-pressure pneumoperitoneum, gas evacuation, pulmonary recruitment manoeuvres, Trendelenburg positioning, and selective nerve blocks.[22] Given the heterogeneity of existing studies, a combination of mechanical optimization and targeted pharmacological strategies within ERAS pathways is likely to provide the greatest clinical benefit.

LIMITATIONS OF THE EVIDENCE AND RESEARCH GAPS

Despite numerous RCTs and meta-analyses, the quality of evidence on shoulder tip pain interventions is variable. Many studies have small sample sizes, single centre designs and heterogeneous protocols (varying drug concentrations, volumes, timing, and outcome measures). Pain assessments often use different scales and time points, complicating comparison. Few studies provide long term follow up beyond 24 hours, leaving the effect on delayed pain unclear.

Many trials do not account for confounding factors such as intraoperative analgesic use, surgeon experience or operative duration. Furthermore, although some RCTs show statistically significant reductions in pain scores, the clinical relevance of small numeric differences remains debatable. The high heterogeneity observed in meta-analyses suggests publication bias and underscores the need for standardized methodology.

Future research should involve adequately powered, multicentre trials comparing head-to-head interventions (e.g., bicarbonate versus local anaesthetic versus dexmedetomidine combination) and evaluating patient centred outcomes such as quality of recovery, opioid consumption and return to normal activities.

FUTURE DIRECTIONS AND CLINICAL IMPLICATIONS

Emerging techniques such as quadratus lumborum blocks, erector spinae plane blocks and laparoscopic assisted transversus abdominis plane blocks show promise for abdominal surgery analgesia but have yet to be specifically evaluated for STP. Advanced gas scavenging devices may further reduce residual CO_2 without compromising operative view. Pharmacological research is exploring novel adjuvants (e.g., neostigmine, lidocaine–ketamine combinations) that may enhance peritoneal analgesia. Personalized analgesia based on patient factors (age, comorbidities, pain thresholds) may allow tailoring of interventions. Clinically, surgeons and anaesthetists should adopt a multimodal approach: maintain low insufflation pressure when feasible, employ manoeuvres to remove residual gas, consider intraperitoneal instillation of a local anaesthetic with an adjuvant (e.g., ropivacaine plus dexmedetomidine or ketamine), and ensure adequate systemic analgesia. Preoperative gabapentin or clonidine may be used selectively in patients at high risk for severe pain. As patient experience becomes a key quality indicator, addressing shoulder tip pain should be integrated into perioperative planning. Importantly, interventions should be chosen based on evidence of efficacy, safety and practicality, rather than adopting novel techniques without robust data.

CONCLUSION

Shoulder tip pain remains a common source of discomfort after laparoscopic cholecystectomy despite advances in surgical technique. The pain results mainly from diaphragmatic irritation due to CO_2 pneumoperitoneum, with residual gas and peritoneal inflammation playing contributory roles. A range of interventions have been investigated. Non pharmacological strategies such as low-pressure pneumoperitoneum, gas evacuation manoeuvres and pulmonary recruitment reduce shoulder pain by minimizing diaphragmatic stretch and removing residual CO_2. Regional techniques like phrenic nerve blocks and TAP blocks can decrease pain and opioid use, though they target somatic rather than referred pain. Intraperitoneal instillation of local anaesthetics and alkalinizing solutions provides modest benefit, with combinations of local anaesthetic and adjuvants such as dexmedetomidine, morphine, ketamine or dexamethasone offering enhanced analgesia.

While some trials report no significant benefit for certain agents, meta-analyses generally support the use of intraperitoneal local anaesthetics. Preoperative medications like gabapentin and clonidine may reduce pain intensity but require further study. Overall, a multimodal strategy combining mechanical and pharmacological interventions appears most effective. Future research should standardize protocols and examine combinations of interventions to develop evidence-based guidelines for preventing shoulder tip pain.

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