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Original Article

Impact of Pneumoperitoneum Pressure on Shoulder Pain

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ABSTRACT

Background: Shoulder tip pain is a frequent complication following laparoscopic cholecystectomy and is largely attributed to diaphragmatic irritation caused by carbon dioxide pneumoperitoneum. Low pressure pneumoperitoneum (LPP) has been proposed as a strategy to reduce postoperative pain and improve recovery.
Methods: A randomised controlled study was conducted among 190 patients undergoing elective laparoscopic cholecystectomy. Participants were equally divided into two groups: low pressure pneumoperitoneum (LPP) (6-10mmHg)and standard pressure pneumoperitoneum (SPP) (12-15mmHg). Postoperative shoulder tip pain was assessed using the Visual Analog Scale (VAS) at 12, 24 and 48 hours. Operative duration, analgesic requirement, hospital stay and postoperative complications were also evaluated.
Results: Patients managed with lower pneumoperitoneum pressure exhibited a markedly lower occurrence of pain (27.4% vs 53.7%) and consistently higher proportions of pain-free status at 12 hours (72.6% vs 46.3%; p=0.001) and 24 hours (82.1% vs 60.0%; p=0.001), with sustained benefit even at 48 hours (11.6% vs 30.5%; p=0.001). These outcomes were accompanied by a significant decrease in analgesic requirement (15.8% vs 2.1%; p=0.001) and a prolonged time to first analgesic demand (5.8 ± 2.3 vs 3.1 ± 1.7 hours), indicating improved postoperative comfort. Recovery metrics including time to ambulation and hospital stay were improved in the LPP group without compromising surgical safety or visualisation.
Conclusion: Low pressure pneumoperitoneum is a safe and effective alternative to a standard pressure pneumoperitoneum during laparoscopic cholecystectomy and is associated with reduced postoperative shoulder tip pain and enhanced recovery.

Keywords: *Laparoscopic cholecystectomy, Standard pressure pneumoperitoneum, Low pressure pneumoperitoneum, Shoulder tip pain.*

INTRODUCTION

Cholelithiasis, commonly known as gallstone disease, is a condition characterized by the formation of solid particles, known as gallstones, in the gallbladder. Gallstones can range in size from tiny particles to large, stone-like formations. These stones are composed primarily of cholesterol, bile salts, or bilirubin and can lead to various symptoms such as abdominal pain, nausea, vomiting, and jaundice, especially when they obstruct the bile ducts. While many individuals with gallstones are asymptomatic, a significant number experience symptoms that may require intervention, typically in the form of cholecystectomy (surgical removal of the gallbladder).[1] Globally, cholelithiasis is one of the most common gastrointestinal disorders. It is estimated that 10–15% of the adult population in Western countries is affected by gallstones, with the prevalence increasing with age, obesity, and certain risk factors such as diabetes and pregnancy.[2] In India, the prevalence is approximately 4% in the general population, but it has been rising in recent years, particularly in urban areas due to changes in lifestyle and diet.[3] Laparoscopic cholecystectomy has become the gold standard for treating symptomatic gallstones due to its minimal invasiveness, shorter recovery time, and reduced postoperative pain compared to traditional open surgery.[4] While laparoscopic cholecystectomy has significantly reduced morbidity and mortality associated with

gallstone disease, the procedure itself is not without its complications. One of the most common post-operative issues is shoulder tip pain, often attributed to the irritation of the phrenic nerve due to residual CO2 from the pneumoperitoneum used to create a working space during the surgery.[5] The exact mechanism of this pain, though widely observed, remains partially understood, with theories suggesting that it arises from diaphragmatic stretching and the resultant referred pain to the shoulder.[6] Another challenge is determining the optimal pneumoperitoneum pressure to minimize these post-surgical complications. While low-pressure pneumoperitoneum (LPP) is thought to reduce the adverse effects of standard pneumoperitoneum (SPP), such as shoulder pain, its clinical advantages in terms of pain management, procedure duration, and patient recovery remain inadequately studied. This study aims to compare the impact of low-pressure versus standard pressure pneumoperitoneum on shoulder tip pain following laparoscopic cholecystectomy. The significance of this study lies in its potential to provide valuable, evidence-based insights into optimizing pneumoperitoneum pressure during laparoscopic cholecystectomy. By comparing low-pressure (6–10 mmHg) and standard-pressure (12–15 mmHg) pneumoperitoneum, this research aims to address critical knowledge gaps regarding postoperative shoulder tip pain, and other key surgical outcomes, including recovery time, complication rates, and overall patient satisfaction.

METHODS

The study was conducted in the Department of General Surgery, Venkateshwara Institute of Medical Sciences, Gajraula, Amroha over a period of one year. This was a prospective randomized controlled study. The calculated sample size was approximately 190 and a total of 190 patients (95 in each group) were included in the study based on well-defined inclusion and exclusion criteria. Patients who provided written informed consent aged > 18 years, had acute, chronic cholecystitis or uncomplicated symptomatic cholelithiasis were included. Patients not giving consent or having cholelithiasis with CBD stone, gallbladder malignancy, cervical spondylosis, any shoulder joint pathology, joint diseases, pregnant women, patients with cognitive impairment were excluded.

Written informed consent was obtained from all patients prior to inclusion in the study. All patients underwent pre-operative evaluation, including ultrasound abdomen, routine blood investigations and cardiopulmonary fitness assessment. Patients were randomized using a computer-generated random number table into two groups: Group A: Standard-pressure pneumoperitoneum (SPP) and group B: Low-pressure pneumoperitoneum (LPP). All patients underwent laparoscopic cholecystectomy under general anesthesia. In the LPP group, intra-abdominal pressure was maintained at 10 mmHg, while in the SPP group, it was kept at 14 mmHg throughout the procedure. Intraoperatively, if the surgeon met difficulty in visualization or operative manipulation, the pneumoperitoneum pressure was reassessed. In cases of LPP, conversion to standard pressure was considered, and in both groups, conversion to open cholecystectomy was performed if deemed necessary. Port closure was performed using standard techniques. All ports were closed using Vicryl 1-0 for fascial closure and Ethilon 2-0 for skin closure.

Post-operative shoulder tip pain was assessed using the Visual Analog Scale (VAS) (Figure no.1) at 12 hours, 24 hours and 48 hours after surgery. Post-operative antibiotics and analgesics were standardized for all patients.

The VAS allowed objective comparison of pain intensity between the low-pressure pneumoperitoneum (LPP) and standard-pressure pneumoperitoneum (SPP) groups, providing a reliable primary outcome measure for postoperative discomfort.

Statistical analysis

Data were analysed using Statistical Package for social sciences (SPSS) version 22 (SPSS, IBM Inc., Armonk, NY, USA). For statistical significance, $p < 0.05$ was considered as statistically significant.

RESULTS

The present study was a prospective randomized controlled trial conducted over a duration of one year. A total of 190 patients were randomized into two equal groups: low-pressure pneumoperitoneum (LPP, n=95) and standard-pressure pneumoperitoneum (SPP, n=95). Randomization was performed using a computer-generated random number table. All patients underwent laparoscopic cholecystectomy under general anaesthesia, with standardized perioperative protocols including antibiotic prophylaxis, uniform port placement, and comparable anaesthetic regimens.

The primary outcome was focused on post-operative shoulder tip pain assessed using the Visual Analog Scale at 12, 24, and 48 hours, while secondary parameters included operative characteristics, hemodynamic responses, analgesic requirements, and early recovery indicators. The findings revealed that low pressure pneumoperitoneum was associated with a significantly lower incidence of shoulder tip pain (27.4% vs 53.7%) (Figure 2) and reduced severity across all time intervals. A significantly higher proportion of patients in the LPP group reported no pain (72.6%) compared with the SPP group (46.3%) at 12 hours post procedure (Figure 3). Conversely, patients in the SPP arm experienced higher grades of pain: mild pain in 29.5% versus 20.0%, moderate pain in 20.0% versus 7.4%, and severe pain in 4.2% versus none in the LPP group. The overall difference between groups was statistically significant ($p = 0.001$).

At 24 hours postoperatively, the trend of reduced pain severity in the LPP group persisted. A significantly larger proportion of patients in the LPP arm were pain-free (82.1%) compared with the SPP group (60.0%) (Figure 4). Conversely, a higher proportion of SPP patients continued to report mild pain (28.4% vs 15.8%) and moderate pain (11.6% vs 2.1%). Notably, no patient in either group experienced severe pain at this stage. The difference between groups was statistically significant ($p = 0.001$).

By 48 hours postoperatively, the overall incidence of shoulder-tip pain had declined markedly in both groups. However, the proportion of patients experiencing any residual pain (VAS >0) remained significantly higher in the SPP group (30.5%) compared with the LPP group (11.6%), with the difference reaching statistical significance ($p = 0.001$) (Figure 5).

The postoperative analgesic requirement within the first 48 hours was significantly different between the two study groups (Table 1). In the LPP group, 15.8% of patients did not require any additional analgesia compared with only 2.1% in the SPP group. A single dose of tramadol was sufficient for half of the LPP patients (50.5%), while less than a quarter (23.2%) of SPP patients managed with just one dose. On the contrary, higher analgesic use was substantially more frequent in the SPP group. Nearly half (47.4%) required two doses compared to 29.5% in LPP, and over one-quarter (27.4%) needed three or more doses compared to only 4.2% in LPP. This difference was statistically highly significant ($p = 0.001$).

The mean time to first analgesic requirement was significantly longer in the low-pressure pneumoperitoneum (LPP) group compared to the standard-pressure pneumoperitoneum (SPP) group. Patients in the LPP arm required their first analgesic dose at an average of 5.8 ± 2.3 hours, whereas those in the SPP arm required it much earlier, at 3.1 ± 1.7 hours ($p = 0.001$).

The postoperative analgesic requirement within the first 48 hours was significantly different between the two study groups. In the LPP group, 15.8% of patients did not require any additional analgesia compared with only 2.1% in the SPP group. A single dose of tramadol was sufficient for half of the LPP patients (50.5%), while less than a quarter (23.2%) of SPP patients managed with just one dose. On the contrary, higher analgesic use was substantially more frequent in the SPP group. Nearly half (47.4%) required two doses compared to 29.5% in LPP, and over one-quarter (27.4%) needed three or more doses compared to only 4.2% in LPP. This difference was statistically highly significant ($p = 0.001$).

Baseline demographic, clinical, socioeconomic, and physiological parameters were comparable between groups ($p>0.05$), confirming appropriate randomization and minimizing confounding bias. Operative time was slightly longer in the low-pressure group (63.4 ± 12.7 vs 58.1 ± 10.9 minutes, $p=0.002$) reflecting technical considerations associated with reduced insufflation pressure. CO_2 consumption was significantly lower in the low-pressure group (38.5 ± 9.2 vs 52.8 ± 11.4 L, $p=0.001$), indicating improved resource utilization and reduced physiological burden. Hemodynamic responses showed a significantly smaller rise in heart rate (82.1 ± 7.1 bpm in LPP vs 88.5 ± 8.3 bpm in SPP, $p < 0.001$) and mean arterial pressure after pneumoperitoneum in the low-pressure group (95.2 ± 6.5 mmHg vs 102.7 ± 7.9 mmHg, $p < 0.001$), suggesting better cardiovascular stability. Early recovery parameters, including time to oral intake (5.2 ± 1.1 vs 6.8 ± 1.6 hours), incidence of PONV (13.7% vs 28.4%), and time to ambulation (7.5 ± 2.0 vs 8.9 ± 2.4 hours), were significantly improved in the low-pressure group ($p \leq 0.001$). Intraoperative complications were minimal and comparable between groups (7.4% vs 5.3%, $p=0.547$), confirming that low-pressure pneumoperitoneum does not compromise surgical safety.

DISCUSSION

The incidence of post-operative shoulder-tip pain was significantly lower in the LPP group (27.4%) compared to the SPP group (53.7%, $p = 0.001$), demonstrating a clear advantage of low-pressure pneumoperitoneum. Similar reductions in pain incidence have been reported by Sandhu et al. (2009)[7] (27.9% vs 44.3%) and Tip PP (2025)[8] (12% vs 28%, $p = 0.046$), supporting the trend of lower pain with reduced insufflation pressure. Thapa et al. (2021)[9] also reported significantly higher pain in the standard-pressure group (64% vs 28%, $p = 0.001$), closely aligning with the magnitude of difference observed here. Shaha et al. (2024)[10] and Abdallah et al. (2024)[11] similarly demonstrated significantly reduced pain incidence in LPP groups. In contrast, Sandhu et al. (2009)[7] did not find statistical significance despite higher incidence in SPP, highlighting variability across studies, although the directional trend remains consistent. The pronounced difference observed here reinforces the clinical impact of pneumoperitoneum pressure on diaphragmatic irritation and referred shoulder pain.

At 12 hours postoperatively, a significantly higher proportion of patients in the LPP group were pain-free (72.6% vs 46.3%), with lower proportions experiencing mild (20.0% vs 29.5%), moderate (7.4% vs 20.0%), and severe pain (0% vs 4.2%), with $p = 0.001$. Similar early postoperative pain reduction has been reported by Bhattacharjee et al. (2017)[12] (VAS 2.6 vs 4.3 at 6 hours) and Goel et al. (2019)[13] (VAS 3.5 vs 5.0 at 6 hours) all demonstrating significantly lower pain scores in LPP groups. Yasir et al. (2012)[14] also reported significantly lower pain intensity in low-pressure patients at early time points. At 24 hours, the trend persisted with a significantly higher proportion of pain-free patients in LPP (82.1% vs 60.0%), and lower mild (15.8% vs 28.4%) and moderate pain (2.1% vs 11.6%), with $p = 0.001$, while severe pain was absent in both groups. Similar sustained pain reduction has been reported by Thapa et al. (2021)[9] and Agarwal et al. (2021)[15], who demonstrated significantly lower pain scores at 24 hours in LPP groups. Tian et al. (2024)[16] (VAS 3.1 vs 4.5) and Serrano et al. (2024)[17] (VAS 3.0 vs 4.7) also showed continued pain reduction at 24 hours with low-pressure pneumoperitoneum.

Viknesh KRP et al. (2026)[18] similarly reported significantly lower pain scores up to 24 hours, after which differences diminished. No major contrasting findings were noted, although the complete absence of severe pain in both groups at this stage is a consistent and reassuring clinical observation. At 48 hours, the incidence of residual shoulder-tip pain remained significantly lower in LPP (11.6%) compared to SPP (30.5%, p = 0.001), indicating sustained benefit of low-pressure pneumoperitoneum. Similar findings of reduced residual pain have been reported by Thapa et al. (2021)[9] and Agarwal et al. (2021)[15], who noted continued lower pain levels in LPP groups during later postoperative periods. Tip PP (2025)[8] also demonstrated sustained reduction in pain intensity across time intervals. Viknesh KRP et al. (2026)[18], however, observed that beyond 48 hours, differences were not statistically significant, suggesting that the benefit of LPP may diminish over time, which contrasts with the persistent difference observed here. Post-operative analgesic requirement was significantly lower in the LPP group, with 15.8% requiring no analgesia versus 2.1% in SPP, and only 4.2% requiring ≥3 doses compared to 27.4% in SPP (p = 0.001). Similar reductions in analgesic requirement have been reported by Mandal A et al. (2020)[19], Thapa et al. (2021)[9], and Agarwal et al. (2021)[15], all demonstrating significantly lower analgesic consumption in LPP groups. Bhattacharjee et al. (2017)[12] and Shaha et al. (2024)[10] also reported reduced analgesic use with low-pressure pneumoperitoneum. Gaiwal et al. (2025)[20] further demonstrated significantly lower analgesic requirements ($p < 0.001$) with LPP combined with adjuncts. No major contrasting findings were reported, as most studies consistently support reduced analgesic demand with low-pressure techniques. The time to first analgesic requirement was significantly longer in the LPP group (5.8 ± 2.3 hours vs 3.1 ± 1.7 hours, p = 0.001), indicating prolonged pain-free intervals. Similar findings have been reported by Yasir et al. (2012)[14] and Thapa et al. (2021)[9], who noted reduced and delayed analgesic requirements in low-pressure groups. Mandal A et al. (2020)[19] also reported delayed need for analgesia in LPP patients. Post-operative recovery parameters showed significant advantages in the LPP group, including earlier oral intake (5.2 ± 1.1 vs 6.8 ± 1.6 hours, p = 0.001), lower incidence of PONV (13.7% vs 28.4%, p = 0.011), and earlier ambulation (7.5 ± 2.0 vs 8.9 ± 2.4 hours, p = 0.001). Similar improvements in recovery have been reported by Mandal A et al. (2020)[19] and Arun et al. (2024)[21], who demonstrated shorter hospital stay, earlier feeding, and faster recovery with LPP. Abdallah et al. (2024)[11] and Kandoi RK et al. (2025)[22] also reported shorter hospital stay and improved recovery parameters in LPP groups. Gaiwal et al. (2025)[20] further showed reduced PONV and enhanced recovery with low-pressure strategies. The findings of this randomized comparison demonstrate that low-pressure pneumoperitoneum is associated with a significant reduction in both the incidence and severity of post-operative shoulder tip pain across all evaluated time intervals.

Limitations

The study was conducted at a single tertiary care institution with a defined patient population, which may limit the external validity and generalizability of the findings across different healthcare settings, geographic regions, and varying surgical expertise, particularly where operative protocols, patient profiles, and perioperative care pathways differ.

Although randomization was performed using a computer-generated method, the study did not incorporate blinding of the operating surgeon or outcome assessor, which may introduce performance and observer bias.

The assessment of shoulder-tip pain was based on patient-reported VAS scores at fixed intervals (12, 24, and 48 hours), which, despite being a validated tool, remains inherently subjective and influenced by individual pain thresholds, psychological factors, and cultural perceptions of pain, potentially affecting the precision of intergroup comparisons.

The follow-up period was limited to the early postoperative phase (up to 48 hours), thereby restricting the evaluation of longer-term outcomes such as persistent pain, delayed complications, or functional recovery, and limiting the ability to assess the sustained clinical impact of low-pressure pneumoperitoneum beyond the immediate postoperative period.

CONCLUSION

This randomized controlled evaluation demonstrates that modulation of pneumoperitoneum pressure has a significant and clinically meaningful impact on postoperative outcomes following laparoscopic cholecystectomy, particularly with respect to shoulder tip pain. Patients undergoing surgery under low-pressure pneumoperitoneum consistently exhibited a lower incidence of shoulder tip pain, reduced severity across all assessed time intervals, and a greater proportion of pain-free status when compared to those subjected to standard-pressure pneumoperitoneum, indicating a direct relationship between intra-abdominal pressure and diaphragmatic irritation leading to referred pain. This reduction in pain translated into decreased analgesic requirements, fewer patients requiring multiple doses of opioids, and a delayed onset of first analgesic demand, thereby reflecting improved postoperative comfort and reduced pharmacological burden. Collectively, these findings substantiate that low-pressure pneumoperitoneum offers a balanced approach that prioritizes patient-centred outcomes without adversely affecting operative feasibility, thereby supporting its routine consideration in laparoscopic cholecystectomy, particularly in settings where minimizing postoperative discomfort and optimizing early recovery are key clinical objectives.

Ethical considerations

This study was approved by the institutional ethical committee with approval number . The study was conducted with informed consent from the participants before enrolment into the study.

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Conflicts of interest
There are no conflicts of interest.

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