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Original Article

Low-Pressure Versus Normal-Pressure Laparoscopic Cholecystectomy and its Effect on Intra-Operative Parameters and Post-Operative Pain: An Observational Study

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Abstract

Background: Pneumoperitoneum, created by insufflating carbon dioxide (CO_2), is essential for surgical visualization, but conventional intra-abdominal pressures (12-15 mmHg) can negatively impact cardiac and respiratory functions. To mitigate these effects, low-pressure pneumoperitoneum (7-10 mmHg) has been suggested. The present study aimed to compare the outcomes of laparoscopic cholecystectomy at low intra-abdominal pressure with conventional standard pressure laparoscopic cholecystectomy.

Methodology: A prospective observational study was conducted in a tertiary care hospital in Eastern India over a period of one year, involving 100 patients undergoing elective LC for symptomatic uncomplicated cholelithiasis. Participants were divided into two groups: low-pressure pneumoperitoneum (LPP) (7-10 mmHg) and standard-pressure pneumoperitoneum (SPP) (12-15 mmHg). Key parameters such as operative time, hemodynamic changes, CO_2 consumption, postoperative pain, and hospital stay were recorded. Statistical analysis was performed using SPSS version 16.0, with $p<0.05$ considered significant.

Results: The study found no significant difference in operative duration between LPP and SPP groups. However, CO_2 consumption was significantly lower in the LPP group ($p=0.040$). Postoperative shoulder tip pain was more frequent in the SPP group ($p=0.041$). Additionally, patients in the LPP group had a significantly shorter hospital stay ($p=0.042$). Hemodynamic changes, particularly in heart rate and systolic blood pressure, were less pronounced in the LPP group compared to the SPP group.

Conclusion: Low-pressure pneumoperitoneum in laparoscopic cholecystectomy is associated with reduced CO_2 consumption, less postoperative pain, better preservation of hemodynamics, and shorter hospital stays compared to standard-pressure pneumoperitoneum. Despite potential challenges for surgeons, LPP appears to be a safe and feasible alternative for uncomplicated gallstone surgery in the hands of skilled professionals.

Keywords: Gallstones; Laparoscopic Cholecystectomy; Low-Pressure Pneumoperitoneum; CO2 Insufflation; Postoperative Pain; Hemodynamic Changes.

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Introduction

Globally, biliary problems account for a substantial portion of gastrointestinal illnesses [1]. Among these, gallstones stand out as a major contributor, affecting approximately 10% of the adult population, with cholecystectomy being the most frequently performed surgical procedure for their treatment [2]. For symptomatic cholelithiasis, laparoscopic cholecystectomy (LC) is currently the most acceptable treatment of choice. The initial step in a laparoscopic cholecystectomy is to use carbon dioxide to produce pneumoperitoneum, which creates sufficient working space in the abdominal cavity for guiding the instruments into the field of operation. Pneumoperitoneum is commonly achieved by insufflating carbon dioxide gas into the peritoneal cavity, thereafter, maintaining it at a constant pressure until the surgery is completed [3,4]. Conventionally, for visualization and instrument operation, an intra-abdominal pressure of 12 to 15 mmHg was previously regarded as appropriate [5]. This "standard pressure," however, has been reported to negatively affect both cardiac and respiratory functions [6]. To reduce the influence of pneumoperitoneum on normal physiology and consequent postoperative discomfort, international guidelines advocate using “the minimum intra-abdominal pressure allowing adequate exposure of the operative field rather than a routine pressure” without compromising patient safety [7].

Given that the safety of LC has been established, the focus has shifted to lowering the perioperative complications and morbidity associated with the procedure. Surgeons are increasingly using gases with a pressure of 7-10 mmHg instead of the normal pressure to minimize complications. Low-pressure pneumoperitoneum has been increasingly evaluated as an alternative to standard pressure pneumoperitoneum, with studies examining its potential to reduce complications and improve feasibility [8-11].

With this background in mind, the present study was conducted to compare the advantages and disadvantages of laparoscopic cholecystectomy at low intra-abdominal pressure with conventional standard pressure laparoscopic cholecystectomy.

Methodology

The present prospective observational study was conducted in the Department of General Surgery, in a tertiary care hospital in Eastern India from November 2021 to October 2022 after approval from the Institutional Ethics Committee. The study has been reported in line with the STROBE guidelines.

Study participants. The study included 100patients, more than 12 years of age, diagnosed with symptomatic uncomplicated cholelithiasis and were posted for elective laparoscopic cholecystectomy. Exclusion criteria included patients with high anaesthesia risk defined as American Society of Anaesthesiologists (ASA) score of 3 or 4, biliary obstruction, choledocholithiasis, cholangitis, an attack of acute cholecystitis within the last 3 weeks, pregnancy, severe comorbidities or morbid obesity and patients on NSAIDS or other analgesics.

Study procedure. All patients admitted in the Surgery in-patient department with cholelithiasis were subjected to detailed history taking and clinical examination followed by biochemical and radiological confirmation of cholelithiasis. The patients underwent routine investigations and pre-anaesthetic evaluation was also done prior to surgery as per institutional protocol. Informed written consent for undergoing cholecystectomy and for participation in the study was obtained separately from the patient.

The American ‘four punctures' (4-port) technique reported by Dubois et al. [12] or the 3-port technique was used to perform a standard laparoscopic cholecystectomy. In all patients in both study groups, an open approach was employed to gain entrance into the abdomen after general anaesthesia was administered, and a 10-mm laparoscope was introduced into the abdomen through the umbilical port. Pneumoperitoneum was created and sustained with an intra-abdominal pressure of 7-10 mmHg in the low-pressure pneumoperitoneum group (LPP group) and an intra-abdominal pressure of 12-15 mmHg in

the standard-pressure pneumoperitoneum group (SPP group). The decision on the pressure of pneumoperitoneum was taken at the discretion of the surgeon.

The surgeon's comfort level was measured using two parameters: ease of port insertion and adequate exposure. If the surgeon reported surgical difficulties or a problem with surgical field visualization at any point during the procedure, the surgery in the LPP group was converted to standard pressure pneumoperitoneum (in the event of low-pressure pneumoperitoneum) or open cholecystectomy (in either pressure situation).

Outcomes. The following parameters were recorded and compared:

The operative time was noted starting from the time of making the incision to the time of closure of the skin. The pulse rate and intra-operative BP were noted just before intubation, after CO_2 insufflation, and after CO_2 exsufflation. The peak airway pressure was noted after CO_2 insufflation and after CO_2 exsufflation. Intraoperative CO_2 consumption, bleeding, bile spillage, and visceral/vessel injury during operation were also noted. Post-operative shoulder tip pain and any other post-operative complications were recorded. The duration of hospital stay in the post-operative period was also noted. All details were recorded in a predesigned, pretested proforma.

Data analysis. Data was entered in Microsoft Excel 2016 and statistical analysis was done using SPSS version 16.0and represented by various tables, graphs, diagrams, etc. Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables were expressed as relative frequency and percentage. The comparison of study outcomes was done for categorical variables using the Chi-square test or Fisher Exact test (as applicable) and for continuous variables using Mann Whitney U test (non-parametric). P-value<0.05 was considered as statistically significant.

Results

The study included 50 participants in whom laparoscopic cholecystectomy was initiated with low pressure pneumoperitoneum (LPP group) and 50 participants with standard pressure pneumoperitoneum (SPP group). The mean (± SD) age was 36.4 (± 12.5) years in the LPP group and 46.0 (± 6.6) years in the SPP group. The LPP group comprised of 74% females, while there were 82% females in the SPP group. Also, 22% of the patients in the LPP group had associated comorbidities, while the figure was 30% in the SPP group. The mean age, gender distribution, and presence of comorbidities were comparable between the study groups (Table 1).

Table 1: Baseline demographic characteristics of the study participants in low pressure pneumoperitoneum (LPP) group and standard pressure pneumoperitoneum (SPP) group (N=100)

Characteristics	LPP group (N=50)	SPP group (N=50)	p-value*
Mean age (years)	36.4 ± 12.5	46.0 ± 6.6	0.73
Female sex	37 (74%)	41 (82%)	0.52
Presence of comorbidities	11 (22%)	15 (30%)	0.83

Values are presented as n (%) or mean ± SD

* The p-value was calculated using the Mann-Whitney U test for age and the Chi-square test for sex and comorbidity, with p<0.05 considered statistically significant.

In the LPP group, surgeons faced difficult port insertion in 18 cases and inadequate exposure in 11 cases (Figure 1).

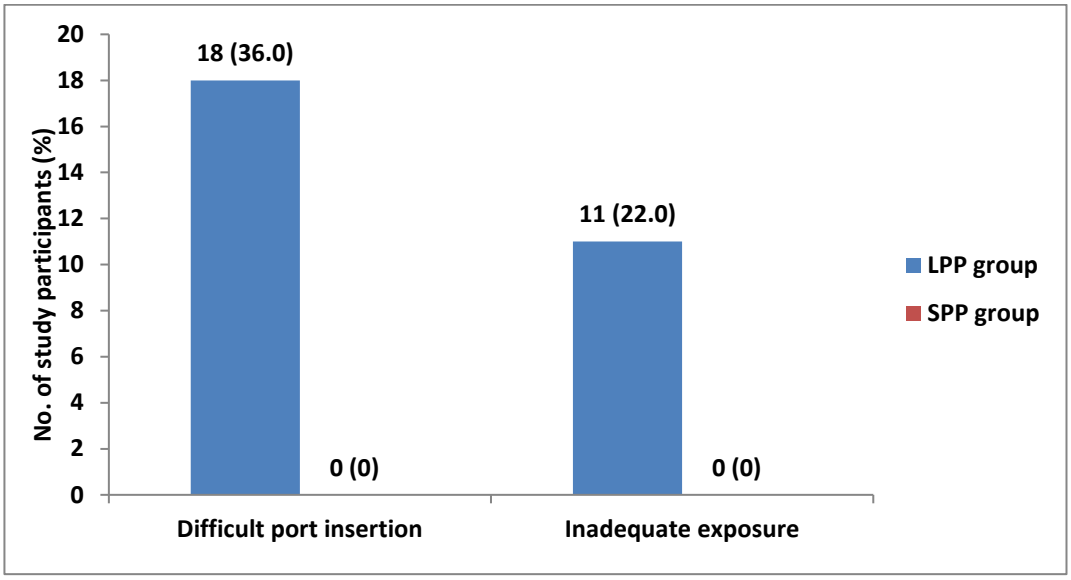

Figure 1: Comparison of ease of port insertion and adequacy of exposure between study groups (N=100)

Owing to the difficulty of port insertion and inadequacy of exposure, 11 cases of low-pressure pneumoperitoneum were converted to standard pressure pneumoperitoneum. These cases were re-categorized to the SPP group and further analysis was done among 39 participants in the LPP group was 39 and 61 participants in the SPP group.

While the mean duration of surgery was comparable between the study groups, the mean volume of CO_2 utilized during the surgery was significantly lower in the LPP group as compared to the SPP group (p=0.040) (Table 2). The proportions of patients with bleeding and bile spillage were statistically comparable between study groups (p>0.05). There were 7 reported cases of post-operative shoulder tip pain, and all of these were observed in the SPP group (p=0.041). None of the patients reported enteral feed intolerance or developed surgical site infection in the post-operative period. There was no mortality in either of the study groups. The proportion of patients with a duration of post-operative stay ≤24 hours were more in the LPP group as compared to the SPP group and this difference is statistically significant (p=0.042).

Table 2: Comparison of outcomes between study groups (N=100)

Parameters	LPP group (N=39)	SPP group (N=61)	p-value*
Mean duration of surgery (from incision to closure in minutes)	51.6 ± 6.8	54 ± 12.1	0.592
Mean volume of CO_2 utilized (liters)	78.1 ± 20.3	125.1 ± 24.5	**0.040**
Bleeding from the liver bed	15 (38.5%)	13 (21.3%)	0.624

Visceral injury/ vessel injury	0	0	-
Bile spillage	11 (28.2%)	14 (23.0%)	0.554
Post-operative shoulder tip pain	0	7 (11.5%)	**0.041**
Post-operative hospital stay			
≤ 24 hours	29 (74.4%)	33 (54.1%)	**0.042**
24-48 hours	10 (25.6%)	28 (45.9%)	
Enteral feed intolerance	0	0	-
Surgical site infection	0	0	-
Mortality	0	0	-

Values are presented as n (%) or mean ± SD

* The p-value was calculated using the Chi-square test or Fisher Exact test for categorical data, and the Mann-Whitney U test for continuous data (non-parametric). A p-value of less than 0.05 was considered statistically significant.

The mean (± SD) heart rates at baseline and after intubation were comparable in the LPP and SPP groups. However, there was a statistically significant difference in HR after insufflation of the abdomen and after the release of CO_2 in LPP and SPP groups ($p<0.05$). Moreover, differences in SBP were obvious in observations taken after pneumoperitoneum and after the release of CO_2($p<0.05$). However, there was no significant difference between the two groups in terms of diastolic blood pressure and peak airway pressure at specific intervals ($p>0.05$) (Table 3).

Table 3: Comparison of intraoperative haemodynamic changes between study groups (N=100)

Intraoperative parameters	LPP group (N=39)	SPP group (N=61)	p-value*
Heart rate			
Baseline (pre-intubation)	79 ± 4.5	82 ± 4.1	0.673
After intubation	93 ± 4.9	95 ± 5.5	0.824
After CO_2insufflation	84 ± 4.6	106 ± 6.3	**0.011**
After CO_2 exsufflation	88 ± 4.1	97 ± 5.0	**0.040**
Systolic BP			
Baseline (pre-intubation)	128 ± 8.6	127.1 ± 9.2	0.885
After intubation	139 ± 9.9	136 ± 10.2	0.713
After CO_2insufflation	132 ± 7.5	146 ± 6.1	**<0.001**

After CO_2 exsufflation	133 ± 8.7	144 ± 7.9	**0.031**
Diastolic BP			
Baseline (pre-intubation)	76 ± 3.5	73 ± 4.1	0.638
After intubation	92 ± 4.3	91 ± 4.4	0.349
After CO_2insufflation	88 ± 4.0	94 ± 5.6	0.196
After CO_2 exsufflation	91 ± 5.7	87 ± 5.5	0.423
Peak airway pressure			
After intubation	16.2 ± 2.1	18.2 ± 1.7	0.739
After CO_2insufflation	23.2 ± 2.6	26.3 ± 2.4	0.464
After CO_2 exsufflation	18.9 ± 1.8	19.3 ± 1.6	0.385

Values are presented as mean ± SD

The *p-value was calculated using the Mann-Whitney U test and $p<0.05$ was considered to be statistically significant.

Discussion

Our study assessed the surgeon's comfort in surgery by the parameters - ease of port insertion and exposure in the working space for better visibility and maneuvering of operating instruments. It was observed that 36% of the cases in the LPP group had difficulty in port insertion, contrary to those in the SPP group, where the port was easy in all the cases. Likewise, exposure to the surgical field was inadequate in 22% of the cases in the LPP group, while exposure was cent percent adequate in the SPP group. These findings were at par with the findings of other studies reporting inadequate exposure while operating in low pressure pneumoperitoneum [13]. However, studies by Mandal A. et al. [14] and Kanwer DB et al. [15] reported that there were a greater number of cases with difficulties in surgery and surgical field visualization in the low-pressure group, but did not have any statistical significance when compared to standard pressure group.

As a consequence, of operative difficulty, 11 cases initially started with LPP were converted to SPP, and finally, there were 39 patients in the LPP group and 61 patients in the SPP group for further comparison. There was evidence in the literature suggesting the low-pressure pneumoperitoneum group had a higher conversion rate [16-18].

In the present study, we did not observe any significant difference in operative duration in the two study groups ($p=0.592$). Mandal et al. [14] defined LPP as intra-abdominal pressure of 10 mm Hg and SPP as 14 mm Hg in their study, which reported that the mean duration of LC with LPP was higher than that with SPP due to difficulty in visualization and maneuvering of instruments in the working space. The systematic review and meta-analysis by Hua et al. [19], included 22 trials where the pressure of pneumoperitoneum utilized ranged from 7 to 10 mmHg in the low-pressure group and from 12 to 15 mmHg in the standard-pressure group; and reported a significantly longer duration of LPLC. Although most studies found significant differences in the duration of surgery, Joshipura et al. [20] did not report any statistical difference in the duration of surgery between the two groups, which is consistent with our study findings. LPLC is more time-consuming in the initial phase of the surgery, during port insertion

and establishment of the operating field. In our study, all cases of laparoscopic cholecystectomy were conducted by expert surgeons, thus, once the working space is established, the surgeons operated in LPP cases as efficiently as in SPP cases. In the setting of similar intra-abdominal pressure ranges in both LPP and SPP groups in the aforementioned studies and in our study, the experience and expertise of the surgeons could be attributed to the contradictory findings.

It was also found that CO_2 gas consumption was less in the LPP group as compared to the SPP group (78.1± 20.3 litres in the LPP cases and 125.1 ± 24.5 litres in the SPP cases) and this difference was statistically significant (p=0.040). The literature search revealed studies reporting similar findings [13,14]. To maintain an intra-abdominal pressure of around 15 mmHg, additional CO_2 is required to insufflate the peritoneal cavity, ensuring proper pressure for optimal surgical exposure and an effective operating field. [21].

Hemodynamic alterations during CO_2 peritoneal insufflation, including decreased cardiac output, increased systemic vascular resistance, hypertension, heart rate fluctuations, and elevated airway pressure, are among the most common complications of laparoscopy [15]. Our study found that changes in mean heart rate and systolic blood pressure were of less magnitude in LPP cases when compared to SPP cases, and this difference was statistically significant ($p<0.05$). Detrex et al. [22] examined the post-operative outcomes of procedures with 15 mmHg $PaCO_2$ versus surgeries with 7 mmHg $PaCO_2$. They observed that lowered cardiac output, stroke volume, and heart rate alterations were substantially lower in the low-pressure group when compared to high-pressure group, and both groups had good surgical outcomes [22].

Postoperative pain after an uneventful laparoscopy is influenced by several factors, mainly the stretching of the peritoneum, abdominal wall, and diaphragm, as well as discomfort from access ports and dissected viscera. Furthermore, the mechanical stretching from the insufflated gas contributes to the pain, with the degree of stretching depending on the intra-abdominal pressure, flow rate, and tissue elasticity [20].In our study, the overall incidence of shoulder tip pain was 7% which is lower than the values reported by other similar studies [18,23-25].

The mean (± SD) duration of post-operative stay was 26.8 (± 7.6) hours with a minimum stay of 20 hours and a maximum stay of 48 hours. Post-operative of <24 hours was reported in 62% of patients, with frequency of early discharge higher in the LPP group (p=0.042). Prior research has shown that using low-pressure pneumoperitoneum promotes quicker recovery of the gastrointestinal system from ileus [13]. This, along with reduced postoperative pain, contributes to a shorter hospital stay after surgery. The findings of this study are supported by other studies [10,26,27].

The study had the following limitations. The conversion of 11 LPP cases to SPP reduced the sample size in the LPP group, potentially affecting the power of the analysis and introducing bias. Additionally, the sample size itself was relatively small, limiting the generalizability of the findings. The study also did not include long-term follow-up data, which could have provided insights into the recovery trajectory and any delayed complications related to either approach. Finally, surgeon experience and comfort were not extensively quantified, which could influence the decision to convert to standard pressure. Further research with larger sample sizes and long-term follow-up is needed to better understand the full scope of benefits and risks associated with low-pressure pneumoperitoneum.

Conclusion

To summarize, the present study observed that the use of low-pressure pneumoperitoneum in laparoscopic cholecystectomy resulted in lesser consumption of CO_2 gas, consequently, resulting in lesser frequency of post-operative shoulder tip pain, and shorter duration of hospital stay post-operatively. Also, the adverse hemodynamic changes in heart rate, blood pressure, and airway pressure following the establishment of pneumoperitoneum were lesser in patients undergoing LPLC.

Therefore, it can be concluded that laparoscopic cholecystectomy is feasible and safe at 7-10 mm Hg intra-abdominal pressure in patients with uncomplicated symptomatic gallstone disease and in the hands of skilled surgeons. Although LPLC has its own challenge for the surgeons, which is difficult during dissection, but it has considerable advantages in terms of CO_2 gas consumption, postoperative pain, preservation of hemodynamics, and hospital stay.

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