

## Feasibility and Safety of Maintaining Pneumoperitoneum Pressure $\leq 12$ mmHg During Laparoscopic Cholecystectomy: A Retrospective Cohort Study of 246 Patients

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### Abstract

**Background:** The optimal pneumoperitoneum pressure in laparoscopic cholecystectomy remains debated, particularly in difficult laparoscopic cholecystectomy and patients with significant cardiopulmonary comorbidity.

**Aim:** To evaluate whether laparoscopic cholecystectomy can be completed without pneumoperitoneum pressure escalation beyond 12 mmHg and to assess the feasibility of pressure reduction in high-risk patients.

**Methods:** This single-center retrospective observational cohort study included 246 consecutive patients undergoing laparoscopic cholecystectomy over the study period. Data were extracted from prospectively maintained hospital records. Pneumoperitoneum was maintained at 12 mmHg as the maximum operating pressure. In selected high-risk patients with significant cardiopulmonary comorbidity, lower pressures were permitted at the discretion of the operating surgeon. Outcomes assessed included operative feasibility, complications, and hospital stay. Difficult laparoscopic cholecystectomy was classified into predictive and intraoperative categories based on established preoperative risk factors and operative findings respectively. Preoperative predictors were derived from established risk factors described in standard surgical literature and textbooks. Study reporting adhered to STROBE recommendations.

**Results:** Mean age was  $54.5 \pm 17.4$  years; 145 patients (58.9%) were female. Comorbidities included 41 patients (16.8%) with hypertension, 18 patients (7.4%) with diabetes, and 26 patients (10.5%) with COPD/asthma. Difficult cases accounted for 205/246 patients (83.2%; 95% CI 78.1–87.4). The high proportion of difficult cases reflects broad predefined difficulty criteria and tertiary-care referral patterns. Predictive difficult cases accounted for 164/246 patients (66.7%). Mean operative time was  $62.1 \pm 14.9$  minutes (95% CI 60.2–64.0), and mean blood loss was  $21.9 \pm 6.7$  mL (95% CI 21.1–22.7). Median hospital stay was 3 days (IQR 2–4). Critical View of Safety was achieved in 240 patients (97.6%). Mean VAS pain scores were  $2.51 \pm 1.10$  at 6 hours, decreasing to  $0.24 \pm 0.54$  at 24 hours. Laparoscopic cholecystectomy was completed in all included patients without escalation of pneumoperitoneum pressure beyond 12 mmHg. In 8 high-risk patients, pneumoperitoneum pressure was reduced to a mean of 10 mmHg without conversion or procedure-related complications. Operative time was significantly longer in difficult cases than non-difficult cases ( $68.4 \pm 12.1$  vs  $42.3 \pm 8.7$  min;  $p < 0.001$ ). No major complications (bile duct injury, bile leak) were observed within the study cohort during the 30-day follow-up period.

**Conclusion:** Laparoscopic cholecystectomy was completed in this retrospective cohort without requirement for pressure escalation beyond 12 mmHg, even in difficult cases. In selected high-risk patients, pressure reduction appeared feasible in carefully selected patients with significant cardiopulmonary comorbidity while maintaining operative feasibility; however, larger prospective comparative studies are required for validation.

**Keywords:** Laparoscopic Cholecystectomy; Pneumoperitoneum; Low-Pressure Pneumoperitoneum; Standard-Pressure Pneumoperitoneum; Difficult Laparoscopic Cholecystectomy; Critical View Of Safety; Minimally Invasive Surgery; Gallstone Disease; Comorbid Patients; Intra-Abdominal Pressure.

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## Introduction

Laparoscopic cholecystectomy (LC) is the gold standard treatment for symptomatic gallstone disease and is among the most commonly performed abdominal surgical procedures worldwide. Creation of carbon dioxide pneumoperitoneum is essential for adequate visualization and operative workspace during laparoscopic surgery, with commonly used intra-abdominal pressures ranging from 12 to 15 mmHg.[1] Although higher pneumoperitoneum pressures may improve operative exposure, they are associated with important physiological effects including reduced venous return, increased systemic vascular resistance, elevated airway pressures, decreased pulmonary compliance, reduced splanchnic perfusion, and increased postoperative shoulder pain.[2,12,13] These effects may become clinically relevant in elderly patients and in individuals with cardiovascular, respiratory, or metabolic comorbidities.

To minimize these physiological disturbances, several studies have evaluated low-pressure pneumoperitoneum techniques, generally defined as pressures between 7 and 10 mmHg. Previous randomized studies and meta-analyses have demonstrated that low-pressure pneumoperitoneum may reduce postoperative pain and improve early postoperative recovery.[1,3] However, evidence regarding its superiority remains inconsistent, as reduced pressure may compromise visualization and operative exposure, especially in technically difficult cases.

Difficult laparoscopic cholecystectomy remains a major surgical challenge and may occur in the setting of dense adhesions, severe inflammation, empyema, mucocele, fibrosis, contracted gallbladder, impacted stones, or distorted Calot's anatomy. [4,10,11]

Such cases are associated with prolonged operative time, increased blood loss, higher conversion rates, and greater risk of bile duct injury. Contemporary safe cholecystectomy principles emphasize structured dissection strategies, achievement of the critical view of safety (CVS), recognition of anatomical landmarks such as Rouviere's sulcus, and appropriate bailout procedures rather than reliance on increased pneumoperitoneum pressure alone.[5–9,14,15]

The present study was therefore conducted to evaluate the feasibility and safety of performing laparoscopic cholecystectomy at a maximum pressure limit of 12 mmHg in all patients, including difficult cases and patients with significant comorbidities.

Although numerous studies have compared low-pressure (7–10 mmHg) and standard-pressure (12–15 mmHg) pneumoperitoneum during laparoscopic cholecystectomy, evidence specifically evaluating a deliberate no-escalation strategy remains limited. In routine surgical practice, pneumoperitoneum pressure is frequently increased during technically difficult procedures to improve operative exposure; however, the benefits of this approach remain inadequately defined. Few studies have evaluated whether a maximum pressure limit of 12 mmHg can be consistently maintained across the full spectrum of laparoscopic cholecystectomy, including difficult cases and patients with significant cardiopulmonary comorbidity. Consequently, evidence supporting routine pressure escalation during difficult laparoscopic cholecystectomy remains limited.

Although several studies have compared low-pressure and standard-pressure pneumoperitoneum, evidence regarding deliberate avoidance of pressure escalation during difficult laparoscopic cholecystectomy remains scarce. Most studies focus on postoperative pain and physiological outcomes rather than the practical feasibility of maintaining a predefined upper pressure limit throughout surgery.

**Aim:** To evaluate whether laparoscopic cholecystectomy can be completed without pneumoperitoneum pressure escalation beyond 12 mmHg and to assess the feasibility of pressure reduction in high-risk patients.

## Objectives

**Primary Objectives:** Evaluate feasibility of maintaining maximum pressure of 12 mmHg.

## Secondary Objectives:

1. Evaluate difficult LC outcomes.
2. Evaluate reduced-pressure subgroup.

## Materials and Methods

**Study Design:** Single-center retrospective observational cohort study.

**Study Center:** Department of General Surgery, Mahatma Gandhi Hospital, Jaipur, India

**Sample Size:** All consecutive patients undergoing laparoscopic cholecystectomy during the study period were included.

As this was an exploratory retrospective study, no formal sample size calculation was performed. This study was conducted and reported according to the STROBE guidelines for observational studies.

**Data Collection:** Demographic, clinical, radiological, operative and postoperative variables

were extracted from prospectively maintained institutional records. Variables included age, sex, body mass index, ASA grade, comorbidities, and previous attacks of cholecystitis, gallbladder wall thickness, impacted neck stone, operative duration, blood loss, conversion rate, postoperative complications and hospital stay.

Variables were independently extracted from electronic medical records and operative notes by trained investigators. Any discrepancies were resolved through review of source documents.

Missing data were assessed before analysis. Patients with incomplete perioperative records were excluded according to predefined exclusion criteria.

**Study duration:** February 2025 to May 2026 (16 months)

Consecutive sampling methodology was used to minimize selection bias. The study population represented all eligible patients undergoing laparoscopic cholecystectomy during the study period.

#### **Inclusion Criteria:**

- All consecutive adult patients ( $\geq 18$  years) undergoing elective or emergency laparoscopic cholecystectomy during the study period.
- Patients with symptomatic cholelithiasis, chronic cholecystitis, acute cholecystitis, gallbladder polyps, mucocele, or empyema gallbladder.
- Patients with associated medical comorbidities including diabetes mellitus, hypertension, chronic respiratory disease, and cardiac disease. Comorbidity was defined as the presence of one or more documented chronic medical conditions requiring ongoing medical management.

#### **Exclusion Criteria:**

- Patients planned for primary open cholecystectomy.
- Patients requiring concurrent major abdominal procedures.
- Patients with suspected or confirmed gallbladder malignancy.
- Patients with incomplete medical records or missing perioperative data.
- Patients unfit for general anesthesia.

#### **Ethics Approval and Consent**

This retrospective study involved analysis of anonymized hospital records. At the time of study conduct, formal Institutional Ethics Committee approval/exemption was not obtained. Patient confidentiality was maintained throughout the study. The authors acknowledge this as a limitation.

**Definition of Difficult Laparoscopic Cholecystectomy:** Difficult laparoscopic cholecystectomy was classified into two categories:

Predictive difficult laparoscopic cholecystectomy, defined by the presence of one or more recognized risk factors associated with operative difficulty, including male sex, age greater than 65 years, delayed presentation of acute cholecystitis, multiple previous attacks, previous upper abdominal surgery, previous cholecystostomy, morbid obesity, high ASA score, abnormal liver function tests, thick-walled gallbladder ( $>4-5$  mm), contracted gallbladder, impacted gallstone in the neck, gangrenous gallbladder, Mirizzi syndrome, cirrhosis, or portal hypertension.

Intraoperative difficult laparoscopic cholecystectomy, defined by operative findings including dense adhesions in Calot's triangle, contracted gallbladder, empyema, mucocele, distorted anatomy, impacted stones, difficult traction, inflammatory fibrosis, prolonged adhesiolysis, or requirement for advanced dissection techniques.

Difficulty classification was adapted from Sugrue et al. and contemporary difficult cholecystectomy literature. Difficulty classification was not mutually exclusive and multiple criteria could be present in the same patient.

**Operative Technique:** All procedures were performed using a standard four-port laparoscopic cholecystectomy technique under general anesthesia. Pneumoperitoneum was established using a closed Veress needle technique through the supraumbilical port. Standard four-port laparoscopic cholecystectomy was performed using monopolar electrocautery for dissection. A  $30^\circ$  laparoscope was utilized. Pneumoperitoneum was established using carbon dioxide and maintained at a maximum pressure of 12 mmHg throughout the procedure. Dissection was performed according to accepted safe cholecystectomy principles, including identification of Rouviere's sulcus. The Critical View of Safety (CVS) was attempted in all patients and achieved whenever anatomically feasible. The cystic duct and cystic artery were clipped and divided conventionally. Gallbladder retrieval was performed through the epigastric port, and drains were placed selectively at the discretion of the operating surgeon.

Bailout strategies available when standard dissection was considered unsafe included fundus-first dissection, subtotal cholecystectomy, placement of additional ports, and conversion to open surgery. These strategies remained available throughout the study period but were not required due to pressure-related limitations. No pressure

escalation beyond 12 mmHg was used as a bailout strategy.

**Definition of Feasibility:** Feasibility was defined as successful completion of laparoscopic cholecystectomy without conversion to open surgery and without requirement for pneumoperitoneum pressure escalation beyond 12 mmHg. All procedures were performed by

consultant surgeons with more than five years of independent laparoscopic practice, following standardized institutional protocols. Patients were followed up for 30 days postoperatively through outpatient visits, hospital record review, and telephonic follow-up where required for detection of complications including surgical site infection, bile leak, and readmission.

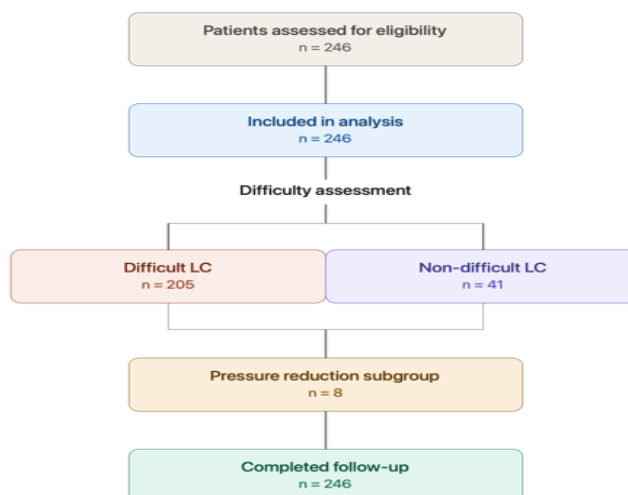


**Figure 1:**

**Statistical Analysis:** Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables are presented as mean  $\pm$  standard deviation, and categorical variables as frequencies and percentages. Comparative analysis between subgroups was performed where applicable, with  $p < 0.05$  considered statistically significant. Due to absence of events for several complications, inferential statistical analysis for these outcomes was limited. Confidence intervals were calculated where appropriate. Normality of continuous variables was assessed using the Shapiro–Wilk test before parametric analysis. Continuous variables were compared using the independent t-test, while categorical variables were analyzed using the chi-square or Fisher’s exact test as appropriate.

## Results

A total of 246 patients were included. Mean age was  $54.5 \pm 17.4$  years, with 145 (58.9%) females.

Comorbidity was present in 93 (37.9%) patients. Difficult laparoscopic cholecystectomy was analyzed using both predictive and intraoperative classifications.

Predictive difficulty was determined according to established risk factors for difficult cholecystectomy, while intraoperative difficulty was determined according to operative findings encountered during surgery. Overall, 205 patients (83.2%) fulfilled criteria for difficult laparoscopic cholecystectomy.

Baseline demographic and clinical characteristics are summarized in Table 1. No case required intraoperative escalation of pneumoperitoneum pressure.

Pressure reduction below 12 mmHg was utilized in 8 high-risk patients with cardiopulmonary comorbidities, with a mean pressure of 10 mmHg. No conversion or pressure-related complications occurred in this subgroup. No patient required conversion to open surgery.

**Table 1: Baseline Characteristics**

| Variable                                      | Value           |
|-----------------------------------------------|-----------------|
| Total patients                                | 246             |
| Age (years)                                   | $54.5 \pm 17.4$ |
| Female                                        | 145 (58.9%)     |
| BMI ( $\text{kg}/\text{m}^2$ ), mean $\pm$ SD | $29.9 \pm 4.8$  |
| ASA I                                         | 201 (81.7%)     |
| ASA II                                        | 30 (12.2%)      |

|                            |            |
|----------------------------|------------|
| ASA III                    | 15 (6.1%)  |
| Previous abdominal surgery | 5 (2.0%)   |
| Acute cholecystitis        | 29 (11.8%) |
| Chronic cholecystitis      | 67 (27.2%) |
| Empyema                    | 3 (1.2%)   |
| Mucocele                   | 3 (1.2%)   |
| Hypertension               | 41 (16.8%) |
| Diabetes                   | 18 (7.4%)  |
| COPD/Asthma                | 26 (10.5%) |
| Cardiac disease            | 18 (7.4%)  |

Some patients had multiple comorbidities; therefore, subgroup totals exceed the total number of patients with comorbidities.

**Table 2: Feasibility**

| Outcome                                           | Result     |
|---------------------------------------------------|------------|
| Total patients                                    | 246        |
| Pressure escalation required                      | 0          |
| Conversion to open                                | 0          |
| Successful completion without pressure escalation | 246 (100%) |
| Pressure reduction subgroup                       | 8          |

No patient required escalation of pneumoperitoneum pressure beyond 12 mmHg during any stage of the procedure.

**Table 3: Difficult LC Assessment**

| Predictive factors               |             |
|----------------------------------|-------------|
| Risk Factor                      | n (%)       |
| Male sex                         | 101 (41.1%) |
| Age >65 years                    | 58 (23.6%)  |
| Previous attacks                 | 92 (37.4%)  |
| Previous upper abdominal surgery | 21 (8.5%)   |
| Morbid obesity                   | 18 (7.3%)   |
| High ASA score                   | 34 (13.8%)  |
| Abnormal LFTs                    | 46 (18.7%)  |
| Thick GB wall (>4 mm)            | 87 (35.4%)  |
| Contracted GB on imaging         | 22 (8.9%)   |
| Impacted neck stone              | 19 (7.7%)   |
| Predictive classification        | n (%)       |
| Predicted difficult LC           | 164 (66.7%) |
| Predicted non-difficult LC       | 82 (33.3%)  |
| Intraoperative findings          | n (%)       |
| Contracted gallbladder           | 16 (6.3%)   |
| Empyema                          | 3 (1.1%)    |
| Mucocele                         | 3 (1.1%)    |
| Adhesions (moderate-severe)      | 73 (29.5%)  |
| Impacted Stone                   | 16 (6.3%)   |
| Difficult Traction               | 21 (8.4%)   |
| Variable                         | n (%)       |
| Total difficult LC               | 205 (83.2%) |
| Predictive difficult LC          | 164 (66.7%) |
| Predictive non-difficult LC      | 82 (33.3%)  |

Patients were classified as predictive difficult laparoscopic cholecystectomy if one or more predefined preoperative risk factors were present. Multiple predictive risk factors could be present in the same patient; therefore, percentages do not total 100%. Overall, 205 patients (83.2%) fulfilled criteria for difficult laparoscopic cholecystectomy. Among the difficult cases, predictive difficulty was

identified preoperatively in 164 patients. Intraoperative difficulty was characterized by findings including adhesions, contracted gallbladder, empyema, mucocele, impacted stones, and difficult traction. This high proportion may reflect intraoperative classification criteria and the tertiary-care case mix of the study center. Multiple overlapping intraoperative findings were present in

several patients. Additional difficult features included inflammatory edema, fibrosis, unclear Calot's anatomy, prolonged adhesiolysis, and

difficult gallbladder retraction, which contributed to overall difficult laparoscopic cholecystectomy classification.

**Table 4: Operative Outcomes**

| Outcome                          | Value                              |
|----------------------------------|------------------------------------|
| Operative time (min)             | 62.1 ± 14.9 min (95% CI 60.2–64.0) |
| Estimated blood loss (mL)        | 21.9 ± 6.7 mL (95% CI 21.1–22.7)   |
| Drain placed                     | 3 (1.2%)                           |
| Conversion to open               | 0 (0.0%)                           |
| Bile duct injury                 | 0                                  |
| Bowel injury                     | 0                                  |
| SSI                              | 0                                  |
| Bile leak                        | 0                                  |
| Pulmonary complications          | 0                                  |
| Fever                            | 0                                  |
| Readmission                      | 0                                  |
| Mortality                        | 0                                  |
| Hospital stay (days)             | Median 3 days (IQR 2–4)            |
| Critical View of Safety achieved | 240 (97.6%)                        |

No major complications were detected during the 30-day follow-up period; however, the cohort size may not be sufficient to detect rare adverse events such as bile duct injury.

**Table 5: Pain Score (VAS)**

| Time     | Mean ± SD   |
|----------|-------------|
| 0 hours  | 3.8 ± 1.2   |
| 2 hours  | 3.2 ± 1.1   |
| 4 hours  | 2.9 ± 1.0   |
| 6 hours  | 2.51 ± 1.10 |
| 8 hours  | 1.9 ± 0.9   |
| 10 hours | 1.4 ± 0.8   |
| 12 hours | 1.05 ± 0.96 |
| 24 hours | 0.24 ± 0.54 |

All patients received standardized postoperative analgesia consisting of intravenous diclofenac sodium 75 mg every 8 hours on postoperative day zero, followed by oral aceclofenac 100 mg with paracetamol 325 mg as required from postoperative day one according to institutional protocol. Progressive reduction in postoperative pain was observed over time, with mean VAS decreasing from 2.51 ± 1.10 at 6 hours to 0.24 ± 0.54 at 24 hours.

**Table 6: Subgroup Analysis**

| Variable             | Difficult LC (n=205) vs Non-Difficult LC (n=41) | p-value |
|----------------------|-------------------------------------------------|---------|
| Operative time (min) | 68.4 ± 12.1 vs 42.3 ± 8.7                       | <0.001  |
| Blood loss           | 24.2±7.1 vs 15.8±4.6                            | <0.001  |
| Hospital stay        | 3.1±0.7 vs 2.8±0.5                              | 0.08    |

Operative time was significantly higher in difficult cases, while no statistically significant differences were observed in hospital stay or complication rates.

**Table 7: Reduced-pressure subgroup**

| Variable                               | Value   |
|----------------------------------------|---------|
| Patients undergoing pressure reduction | 8       |
| Mean pressure used                     | 10 mmHg |
| Additional ports                       | 0       |
| Fundus-first approach                  | 0       |
| Subtotal cholecystectomy               | 0       |
| COPD/Asthma                            | 3       |
| Cardiac disease                        | 5       |
| Conversion rate                        | 0       |
| Complications                          | 0       |

## Discussion

**Principal Findings:** The present study evaluated the feasibility of maintaining a maximum pneumoperitoneum pressure of 12 mmHg during laparoscopic cholecystectomy across a broad spectrum of patients, including those with difficult operative findings and significant medical comorbidities. Among 246 consecutive patients, no procedure required escalation of pneumoperitoneum pressure beyond 12 mmHg, and no conversion to open surgery was necessary. Difficult laparoscopic cholecystectomy was encountered in 83.2% of patients according to predefined intraoperative criteria, yet successful completion was achieved in all cases. Furthermore, a subgroup of high-risk patients tolerated pressure reduction to approximately 10 mmHg without adverse operative consequences. The high rate of Critical View of Safety achievement (97.6%) supports the feasibility of maintaining a maximum pressure of 12 mmHg while adhering to contemporary safe cholecystectomy principles. These findings support the feasibility of a no-escalation pneumoperitoneum strategy when safe cholecystectomy principles and structured dissection techniques are consistently applied.

**Comparison with Previous Studies:** Previous studies evaluating pneumoperitoneum pressure during laparoscopic cholecystectomy have primarily focused on comparisons between low-pressure and standard-pressure techniques. Gurusamy et al., in a Cochrane review, reported that low-pressure pneumoperitoneum may reduce postoperative pain but can compromise operative exposure and increase technical difficulty in selected patients. Similarly, Wallace et al. demonstrated differences in postoperative outcomes between varying insufflation pressures but found no clear superiority regarding major

operative endpoints. Unlike these studies, the present investigation did not compare different pressure levels but instead evaluated whether escalation beyond a standard pressure of 12 mmHg was required during routine practice. The absence of pressure escalation in all cases suggests that successful completion of laparoscopic cholecystectomy may depend more on operative strategy and surgical expertise than on routine increases in intra-abdominal pressure.

Dexter et al. demonstrated that higher pneumoperitoneum pressures are associated with greater cardiovascular and respiratory physiological effects. Although the present study was not designed to evaluate physiological outcomes directly, the successful completion of procedures at 12 mmHg and lower pressures in selected high-risk patients supports the concept that avoiding unnecessary pressure escalation may reduce physiological stress without compromising operative feasibility.

Gurusamy et al. reported reduced postoperative pain with low-pressure pneumoperitoneum but noted concerns regarding operative exposure.

In contrast, the present study demonstrated successful completion of all procedures without pressure escalation beyond 12 mmHg, including 205 difficult laparoscopic cholecystectomies. These findings suggest that maintenance of standard-pressure pneumoperitoneum may be sufficient for most cases when safe cholecystectomy principles are applied.

The present findings suggest that surgeon experience, adherence to safe cholecystectomy principles, and structured dissection techniques may have a greater influence on successful completion than routine increases in insufflation pressure.

**Table 8: Study**

| Study         | Design/Sample          | Pressure Strategy   | Main Finding              |
|---------------|------------------------|---------------------|---------------------------|
| Gurusamy      | Cochrane Meta-analysis | Low vs Standard     | Less pain                 |
| Wallace       | n = 100                | Different pressures | Similar outcomes          |
| Dexter        | n = 40                 | Hemodynamic effects | Higher physiologic stress |
| Present Study | n = 246                | No escalation >12   | Feasible in all cases     |

**Difficult Cholecystectomy:** Difficult laparoscopic cholecystectomy remains one of the most important challenges in hepatobiliary surgery. Dense adhesions, inflammatory fibrosis, contracted gallbladder, empyema, and impacted stones may obscure critical anatomy and increase the risk of bile duct injury. Contemporary surgical literature increasingly emphasizes structured safe cholecystectomy principles rather than aggressive dissection or reliance on improved exposure obtained through higher insufflation pressures. In the present study, operative difficulty was assessed

using both predictive and intraoperative classifications. Predictive difficulty allowed identification of patients at increased risk of operative complexity before surgery, while intraoperative difficulty reflected the actual technical challenges encountered during dissection. The combination of both approaches provided a comprehensive assessment of difficult laparoscopic cholecystectomy and may facilitate improved preoperative counselling, operative planning, and resource allocation.

The high prevalence of difficult laparoscopic cholecystectomy observed in this study likely reflects the tertiary referral nature of the institution, inclusion of emergency cases, and broad difficulty criteria. Nevertheless, successful completion without pressure escalation suggests that difficult operative findings alone may not mandate increases in pneumoperitoneum pressure.

**High-Risk Patients:** Patients with significant cardiopulmonary comorbidities are particularly susceptible to the physiological consequences of pneumoperitoneum. Elevated intra-abdominal pressure has been associated with reduced venous return, increased systemic vascular resistance, decreased pulmonary compliance, elevated airway pressures, and impaired splanchnic perfusion. These effects may be especially relevant in elderly patients and those with chronic respiratory or cardiovascular disease.

In the present series, eight high-risk patients underwent laparoscopic cholecystectomy with pressure reduction to approximately 10 mmHg. No conversion or pressure-related complications occurred in this subgroup. Although the sample size is limited, these observations are consistent with previous reports suggesting that selective pressure reduction may be feasible in carefully chosen patients when adequate operative exposure can be maintained.

**Clinical Implications:** The findings of this study have practical implications for everyday laparoscopic practice. Surgeons frequently increase pneumoperitoneum pressure during technically difficult procedures to improve exposure. However, the present results suggest that optimization of patient positioning, effective traction-counter traction techniques, identification of Rouviere's sulcus, achievement of the critical view of safety, and timely use of bailout strategies may be more important determinants of operative success than routine pressure escalation.

Adoption of a no-escalation strategy may also encourage greater emphasis on safe cholecystectomy principles and deliberate dissection techniques while potentially minimizing the physiological consequences associated with higher insufflation pressures. The observed difficult laparoscopic cholecystectomy rate was higher than that reported in most published series. This likely reflects broad difficulty criteria, inclusion of both predictive and intraoperative factors, overlap between multiple difficulty variables, and the tertiary referral nature of the institution.

#### Strengths

- Consecutive patient inclusion minimizing selection bias.

- Inclusion of a substantial proportion of difficult laparoscopic cholecystectomy cases.
- Evaluation of a no-pressure-escalation strategy in routine clinical practice.
- Inclusion of high-risk patients undergoing selective pressure reduction.
- Standardized surgical technique and postoperative follow-up.
- Inclusion of both preoperative and intraoperative difficulty assessment.
- Inclusion of 246 consecutive patients over a fixed study period.

**Clinical Relevance:** The present findings support a pragmatic approach to pneumoperitoneum management in laparoscopic cholecystectomy. Rather than routine pressure escalation in difficult cases, emphasis should be placed on safe dissection strategies, optimal exposure, and timely use of bailout techniques. This approach may be particularly relevant in patients with significant cardiopulmonary comorbidity.

#### Limitations

- Single-center study design.
- The study did not include direct comparison with patients undergoing pneumoperitoneum pressures greater than 12 mmHg.
- Lack of a control or comparison group limits causal inference regarding the direct effect of pneumoperitoneum pressure on operative outcomes.
- Retrospective design with potential selection bias and information bias related to retrospective data collection.
- Outcomes may be influenced by surgeon experience.
- Despite inclusion of 246 patients, the retrospective design and single-center setting limit generalizability.
- Preoperative difficulty assessment was based on established risk factors reported in the surgical literature rather than a formally validated scoring model.
- Absence of formal ethics approval/exemption.
- Absence of randomization.
- Potential documentation bias inherent to retrospective records.
- No long-term follow-up beyond 30 days.
- Lack of postoperative quality-of-life assessment.
- The study was not powered to detect rare complications such as bile duct injury.
- Difficulty classification was not based on a single validated scoring system and therefore may overestimate the prevalence of difficult laparoscopic cholecystectomy.
- The absence of pressure escalation in all cases may reflect surgeon-specific practice patterns and may not be reproducible in all institutions.

- External validation in multicenter cohorts is required before generalization of these findings.
- The reduced-pressure subgroup consisted of only eight patients, limiting conclusions regarding selective pressure reduction strategies.

The low incidence of major complications such as bile duct injury limits the ability to draw definitive conclusions regarding rare adverse events. Findings from a single high-volume center may not be generalizable to all surgical settings. These limitations should be considered when interpreting the findings.

### Conclusion

In this retrospective cohort study, laparoscopic cholecystectomy was completed without pneumoperitoneum pressure escalation beyond 12 mmHg in all included patients. The findings suggest that maintenance of a maximum pressure of 12 mmHg is feasible in routine practice, including selected difficult cases and patients with significant comorbidities. Surgical expertise, adherence to safe cholecystectomy principles, and structured dissection strategies may be more important determinants of operative success than routine pressure escalation. Prospective multicenter comparative studies are required to validate these findings.

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