



Haemodynamic Changes with Different Pressure Pneumoperitoneum in Patients Undergoing Laparoscopic Cholecystectomy

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ABSTRACT

Background: Laparoscopic cholecystectomy commonly involves the creation of pneumoperitoneum using carbon dioxide (CO₂), which can significantly influence cardiovascular dynamics. **Objective:** To compare the mean hemodynamic changes associated with different pneumoperitoneum pressures in patients undergoing laparoscopic cholecystectomy. **Methodology:** This randomized controlled trial was conducted in the Department of Surgery at Central Park Teaching Hospital, Lahore, from December 16, 2023, to June 17, 2024. A total of 70 patients were enrolled and randomly allocated into two groups of 35 each. Group 1 underwent laparoscopic cholecystectomy with low-pressure pneumoperitoneum (8–10 mmHg), while Group 2 had standard-pressure pneumoperitoneum (11–13 mmHg). **Results:** At 60 minutes, the mean MAP in Group 1 (low pressure) was significantly lower at 85.14 ± 5.93 mmHg compared to 97.83 ± 9.38 mmHg in Group 2 (p < 0.001). The mean heart rate was also lower in Group 1 (98.97 ± 12.45 bpm) versus Group 2 (108.51 ± 11.71 bpm; p = 0.002). Similarly, oxygen saturation was higher in Group 1 (96.80 ± 1.41%) than in Group 2 (94.43 ± 1.70%; p < 0.001). These findings indicate more stable hemodynamic parameters in patients subjected to lower pneumoperitoneum pressures. **Conclusion:** Low-pressure pneumoperitoneum (8–10 mmHg) during laparoscopic cholecystectomy results in significantly more favorable hemodynamic outcomes compared to standard-pressure pneumoperitoneum (11–13 mmHg). These findings support the clinical benefit of using reduced pressure settings when feasible.

INTRODUCTION

Laparoscopic cholecystectomy has emerged as the gold standard treatment for symptomatic gallstone disease, owing to its minimally invasive nature, shorter hospital stays, and quicker recovery. One of the essential requirements for successful laparoscopic surgery is the creation of adequate intra-abdominal working space, which ensures optimal visualization and maneuverability for the surgeon. This is most commonly achieved through pneumoperitoneum or, less frequently, via mechanical abdominal wall lifting techniques such as the laparotensor and laparolift systems [1-3]. The establishment of pneumoperitoneum, typically using carbon dioxide (CO₂), leads to an increase in intra-abdominal pressure, which in turn causes significant physiological alterations, particularly in the cardiovascular and respiratory systems [4]. The most widely accepted insufflation pressure ranges from 12 to 16 mmHg. However, this pressure range has been shown to increase central venous pressure and induce various hemodynamic changes, including fluctuations in mean arterial pressure, heart rate, and systemic vascular resistance [5,6]. These effects may be

particularly concerning in patients with underlying cardiopulmonary conditions. Emerging evidence suggests that using lower insufflation pressures may help reduce intraoperative and postoperative cardiopulmonary complications and diminish postoperative discomfort, such as shoulder tip pain and the need for analgesics [7,8]. Nevertheless, lower pressures may compromise the clarity of the surgical field, potentially increasing operative difficulty and time, thereby posing safety concerns during the procedure. While visual clarity remains crucial for surgical precision, perioperative factors such as hemodynamic stability, reduced analgesic requirements, and faster recovery are equally significant when evaluating patient outcomes holistically [9,10]. Hemodynamics (or haemodynamics) refers to the dynamics of blood flow within the circulatory system, which is regulated by intricate homeostatic mechanisms akin to control systems in hydraulic circuits. The hemodynamic response continuously monitors and adjusts to internal and external environmental changes. It encompasses the physical principles that govern blood movement through vessels and is fundamental to ensuring

proper delivery of nutrients, oxygen, hormones, and waste removal across the body. Hemodynamics also maintains essential physiological balances such as pH, temperature, osmotic pressure, and immune protection [11]. Unlike classical fluids, blood is a non-Newtonian fluid; therefore, its behavior is better explained using rheological principles rather than traditional hydrodynamics. Moreover, since blood vessels are compliant and not rigid, classical viscometer-based fluid mechanics fail to fully explain the complexities of hemodynamic regulation [12]. Thus, balancing optimal visualization with minimal physiological disturbance is a clinical priority. The rationale for this study stems from the limited regional data evaluating the hemodynamic consequences of different pneumoperitoneum pressures. Existing literature indicates an increased risk of cardiovascular instability at higher pressures, whereas low-pressure pneumoperitoneum offers potential protective benefits. However, only one study on this subject has been conducted in Pakistan, highlighting a critical gap in localized evidence. Therefore, this study aims to assess and compare the hemodynamic impact of low versus standard pneumoperitoneum pressures during laparoscopic cholecystectomy in a local population. Findings from this investigation may guide the implementation of low-pressure protocols in clinical practice and enhance surgical safety standards in our setting.

Objective

To compare the mean haemodynamic changes with different pressures of pneumoperitoneum in patients undergoing laparoscopic cholecystectomy.

METHODOLOGY

This randomized controlled trial was conducted in the Department of Surgery at Central Park Teaching Hospital, Lahore from December 16, 2023, to June 17, 2024. A total of 70 patients (35 in each group) were enrolled. The sample size was calculated using OpenEpi.com with a 95% confidence level, 80% power, and based on a difference in mean heart rate: 81.60 ± 5.88 bpm in the >11 mmHg group vs. 77.01 ± 5.55 bpm in the 8–10 mmHg group. Non-probability consecutive sampling was used to recruit participants.

Inclusion Criteria

- Age between 20 to 70 years
- Both males and females
- Patients undergoing laparoscopic cholecystectomy under general anesthesia

Exclusion Criteria

- ASA class IV
- Known chronic cardiovascular disease
- Liver cirrhosis or hepatitis
- Chronic renal disease (serum creatinine >2.0 mg/dL)
- Bleeding disorders (INR >2 , PT >20 seconds)
- Recurrent gallbladder disease
- Significant portal hypertension
- Suspected gallbladder carcinoma
- Generalized peritonitis (as per medical record)

Data Collection

After obtaining ethical approval from the hospital's ethics committee, patients meeting the selection criteria were enrolled from the operating theatre. Informed written consent was obtained from all participants. Baseline demographic and clinical data were recorded, including age, sex, BMI, duration of symptoms, ASA status, smoking history (>5 pack-years), anemia (Hb <10 g/dL), dyslipidemia (total cholesterol >200 mg/dL), diabetes (BSR >200 mg/dL), and hypertension (BP $>140/90$ mmHg). Patients were then randomized into two groups using the lottery method. Group 1 underwent laparoscopic cholecystectomy with a pneumoperitoneum pressure of 8–10 mmHg, while Group 2 received a pressure of 11–13 mmHg. All procedures were performed under general anesthesia by a single surgical team, assisted by the researcher. Hemodynamic parameters, blood pressure, heart rate, oxygen saturation, and end-tidal CO₂, were recorded at three time points: preoperatively, after 60 minutes of pneumoperitoneum, and at the end of the procedure. All measurements were documented in a predesigned data collection proforma.

Statistical Analysis

Data were analyzed using SPSS version 25.0. The Shapiro-Wilk test was applied to assess the normality of continuous variables. Quantitative data such as age, BMI, disease duration, and hemodynamic parameters were expressed as mean \pm standard deviation. Qualitative variables like sex, ASA status, smoking, diabetes, anemia, dyslipidemia, and hypertension were presented as frequencies and percentages. The independent samples t-test was used to compare mean blood pressure, heart rate, oxygen saturation, and end-tidal CO₂ between the two groups. A p-value ≤ 0.05 was considered statistically significant. Data were also stratified for potential confounders, including age, sex, BMI, duration of symptoms, ASA class, smoking, diabetes, dyslipidemia, anemia, and hypertension. Post-stratification, independent samples t-tests were reapplied within each stratum to evaluate the significance of differences between the groups.

RESULTS

Data were collected from 70 patients. The mean age of the study participants was 45.75 ± 13.59 years, ranging from 21 to 69 years, with a mean BMI of 27.64 ± 4.70 kg/m². Most patients belonged to ASA class II (55.7%), followed by class I (37.1%) and class III (7.1%). The average duration of disease before surgery was 3.11 ± 1.35 years. Regarding comorbidities, 35.7% of patients were smokers, while 64.3% had no smoking history. Diabetes mellitus and dyslipidemia were present in 35.7% and 37.1% of patients, respectively. Anemia was observed in 15.7% of participants, whereas the majority (84.3%) were non-anemic.

Table 1

Descriptive Statistics of Sociodemographic and Disease-Related Factors (n = 70)

Variable	Frequency (n) / Mean \pm SD (Range)	Percentage (%)
Age (Years)	45.75 ± 13.59 (21.0–69.0)	–
BMI (kg/m ²)	27.64 ± 4.70 (20.0–35.0)	–
ASA Status		

- I	26	37.1%
- II	39	55.7%
- III	5	7.1%
Duration of Disease (Years)	3.11 ± 1.35 (1.0-5.0)	-
Smoking		
- Yes	25	35.7%
- No	45	64.3%
Diabetes Mellitus (DM)		
- Yes	25	35.7%
- No	45	64.3%
Dyslipidemia		
- Yes	26	37.1%
- No	44	62.9%
Anemia		
- Yes	11	15.7%
- No	59	84.3%

Preoperative hemodynamic parameters were comparable between the two groups, with no significant differences in MAP, heart rate, oxygen saturation, or end-tidal CO₂ ($p > 0.05$). However, after 60 minutes of pneumoperitoneum, the 11-13 mmHg group showed a significantly higher MAP (97.83 ± 9.38 mmHg) compared to the 8-10 mmHg group (85.14 ± 5.93 mmHg; $p < 0.001$). Heart rate was also significantly elevated in the higher-pressure group (108.51 ± 11.73 bpm vs. 98.97 ± 12.45 bpm; $p = 0.002$). Additionally, oxygen saturation was lower in the 11-13 mmHg group (94.43 ± 1.70%) compared to the low-pressure group (96.80 ± 1.41%; $p < 0.001$). End-tidal CO₂ levels were markedly higher in the standard pressure group (47.91 ± 4.55 mmHg vs. 40.71 ± 2.83 mmHg; $p < 0.001$), indicating greater CO₂ absorption.

Table 2

Comparison of Pre- and Post-Hemodynamic Responses Between Study Groups ($n = 70$)

Parameter	Time Point	8-10 mmHg (n = 35)	11-13 mmHg (n = 35)	p-value
MAP (mmHg)	Pre-op	84.94 ± 8.81	84.97 ± 8.37	0.989
	After 60 minutes	85.14 ± 5.93	97.83 ± 9.38	<0.001
Heart Rate (bpm)	Pre-op	85.94 ± 8.29	84.14 ± 9.81	0.410
	After 60 minutes	98.97 ± 12.45	108.51 ± 11.73	0.002
Oxygen Saturation (%)	Pre-op	97.14 ± 1.44	97.00 ± 1.49	0.685
	After 60 minutes	96.80 ± 1.41	94.43 ± 1.70	<0.001

Table 4

Comparison of Hemodynamic Responses After 60 Minutes Between Study Groups (Stratified Analysis)

Stratification	MAP (mmHg)	Heart Rate (bpm)	Oxygen Saturation (%)	End-tidal CO ₂ (mmHg)
Age ≤ 50	85.56 ± 5.55 vs 100.28 ± 9.67	98.48 ± 11.45 vs 111.43 ± 11.33	96.78 ± 1.31 vs 94.90 ± 1.57	41.00 ± 2.95 vs 46.95 ± 4.28
Age > 50	84.33 ± 6.77 vs 94.14 ± 7.86	99.92 ± 14.68 vs 104.14 ± 11.32	96.83 ± 1.64 vs 93.71 ± 1.68	40.17 ± 2.62 vs 49.35 ± 4.72
Gender: Male	84.41 ± 5.24 vs 98.67 ± 8.58	98.41 ± 12.25 vs 108.50 ± 11.54	96.89 ± 1.34 vs 94.61 ± 1.57	40.59 ± 2.71 vs 48.50 ± 4.79
Gender: Female	87.62 ± 7.71 vs 96.94 ± 10.35	100.87 ± 13.79 vs 108.53 ± 12.29	96.50 ± 1.69 vs 94.23 ± 1.85	41.12 ± 3.39 vs 47.29 ± 4.34
BMI ≤ 25	84.58 ± 6.88 vs 96.87 ± 8.62	94.25 ± 12.85 vs 110.43 ± 13.03	97.08 ± 1.50 vs 94.56 ± 1.82	40.25 ± 2.76 vs 48.94 ± 4.62
BMI > 25	85.43 ± 5.51 vs 98.63 ± 10.14	101.43 ± 11.77 vs 106.89 ± 10.61	96.65 ± 1.36 vs 94.31 ± 1.63	40.95 ± 2.89 vs 47.05 ± 4.42

End-tidal CO ₂ (mmHg)	Pre-op	35.91 ± 3.15	34.51 ± 3.12	0.066
	After 60 minutes		40.71 ± 2.83	47.91 ± 4.55

When stratified by age, significant hemodynamic differences were observed between the pressure groups. Among patients aged ≤50 years, those in the 11-13 mmHg group had significantly higher MAP (100.28 ± 9.67 mmHg vs. 85.56 ± 5.55 mmHg; $p < 0.001$), heart rate (111.43 ± 11.33 bpm vs. 98.48 ± 11.45 bpm; $p = 0.001$), and end-tidal CO₂ (46.95 ± 4.28 mmHg vs. 41.00 ± 2.95 mmHg; $p < 0.001$), with lower oxygen saturation (94.90 ± 1.57% vs. 96.78 ± 1.31%; $p < 0.001$). In patients >50 years, similar trends were observed in MAP (94.14 ± 7.86 vs. 84.33 ± 6.77 mmHg; $p = 0.002$), oxygen saturation (93.71 ± 1.68% vs. 96.83 ± 1.64%; $p < 0.001$), and end-tidal CO₂ (49.35 ± 4.72 vs. 40.17 ± 2.62 mmHg; $p < 0.001$), though the heart rate difference was not statistically significant ($p = 0.416$).

Table 3

Comparison of Hemodynamic Responses After 60 Minutes Between Study Groups Stratified by Age ($n = 70$)

Parameter	Age Group	8-10 mmHg (n)	11-13 mmHg (n)	p-value
MAP (mmHg)	≤ 50 yrs	85.56 ± 5.55	100.28 ± 9.67	<0.001
	> 50 yrs	84.33 ± 6.77	94.14 ± 7.86	0.002
Heart Rate (bpm)	≤ 50 yrs	98.48 ± 11.45	111.43 ± 11.33	0.001
	> 50 yrs	99.92 ± 14.68	104.14 ± 11.32	0.416
Oxygen Saturation (%)	≤ 50 yrs	96.78 ± 1.31	94.90 ± 1.57	<0.001
	> 50 yrs	96.83 ± 1.64	93.71 ± 1.68	<0.001
End-tidal CO ₂ (mmHg)	≤ 50 yrs	41.00 ± 2.95	46.95 ± 4.28	<0.001
	> 50 yrs	40.17 ± 2.62	49.35 ± 4.72	<0.001

Stratified analysis revealed that patients undergoing laparoscopic cholecystectomy with low-pressure pneumoperitoneum (8-10 mmHg) consistently demonstrated more stable hemodynamic profiles compared to those with standard pressure (11-13 mmHg) across all subgroups. Mean arterial pressure and end-tidal CO₂ were significantly lower, while oxygen saturation was higher in the low-pressure group irrespective of age, gender, BMI, ASA status, or presence of comorbidities like hypertension, diabetes, dyslipidemia, and anemia.

Duration ≤ 3 years	83.22 ± 5.69 vs 96.90 ± 9.37	98.05 ± 13.54 vs 107.15 ± 11.49	96.61 ± 1.28 vs 94.55 ± 1.87	40.44 ± 2.83 vs 47.20 ± 4.46
Duration > 3 years	87.17 ± 5.63 vs 99.07 ± 9.57	99.94 ± 11.52 vs 110.33 ± 12.20	97.00 ± 1.54 vs 94.27 ± 1.48	41.00 ± 2.89 vs 48.87 ± 4.64
ASA I	87.00 ± 4.47 vs 96.87 ± 9.64	91.90 ± 12.32 vs 107.56 ± 12.01	96.30 ± 1.42 vs 94.81 ± 1.72	41.20 ± 2.04 vs 48.50 ± 4.00
ASA II & III	84.40 ± 6.34 vs 98.63 ± 9.33	101.80 ± 11.56 vs 109.31 ± 11.76	97.00 ± 1.38 vs 94.10 ± 1.66	40.52 ± 3.11 vs 47.42 ± 5.02
Hypertension: Yes	85.40 ± 5.58 vs 98.00 ± 8.02	96.80 ± 11.99 vs 107.86 ± 11.05	96.40 ± 1.50 vs 94.47 ± 1.50	40.60 ± 3.13 vs 48.53 ± 4.94
Hypertension: No	85.04 ± 6.17 vs 97.70 ± 10.48	99.84 ± 12.76 vs 109.00 ± 12.48	96.96 ± 1.36 vs 94.40 ± 1.87	40.76 ± 2.77 vs 47.45 ± 4.31
DM: Yes	84.58 ± 6.54 vs 97.46 ± 8.94	98.33 ± 14.94 vs 106.38 ± 10.46	96.50 ± 1.45 vs 94.31 ± 1.84	39.08 ± 2.46 vs 49.15 ± 3.69
DM: No	85.43 ± 5.71 vs 98.04 ± 9.83	99.30 ± 11.30 vs 109.77 ± 12.48	96.95 ± 1.39 vs 94.50 ± 1.65	41.56 ± 2.67 vs 47.18 ± 4.92
Dyslipidemia: Yes	89.11 ± 5.95 vs 94.88 ± 7.65	101.22 ± 12.49 vs 109.23 ± 11.31	97.11 ± 1.54 vs 94.41 ± 1.94	41.44 ± 2.74 vs 48.23 ± 4.52
Dyslipidemia: No	83.76 ± 5.37 vs 100.61 ± 10.19	98.19 ± 12.59 vs 107.83 ± 12.41	96.69 ± 1.37 vs 94.44 ± 1.50	40.46 ± 2.87 vs 47.61 ± 4.69
Anemia: Yes	82.00 ± 7.55 vs 98.00 ± 11.02	111.33 ± 5.85 vs 106.25 ± 11.67	96.67 ± 1.53 vs 94.62 ± 2.13	41.67 ± 2.31 vs 48.50 ± 4.50
Anemia: No	85.44 ± 5.81 vs 97.78 ± 9.07	97.81 ± 12.32 vs 109.18 ± 11.89	96.81 ± 1.42 vs 94.37 ± 1.59	40.62 ± 2.89 vs 47.74 ± 4.64

DISCUSSION

Laparoscopic cholecystectomy, while minimally invasive, involves the creation of pneumoperitoneum, which alters intra-abdominal pressure and can significantly influence a patient's hemodynamic profile. The extent of these hemodynamic changes largely depends on factors such as the pressure level achieved during insufflation, the volume of carbon dioxide (CO₂) absorbed, and the patient's baseline intravascular volume status. In the current study, it was found that after 60 minutes of pneumoperitoneum, patients in the low-pressure group (8–10 mmHg) exhibited significantly more stable hemodynamic parameters compared to those in the standard-pressure group (11–13 mmHg) [13]. Specifically, the mean arterial pressure (MAP) was significantly lower in the low-pressure group (85.14 ± 5.93 mmHg) compared to the high-pressure group (97.83 ± 9.38 mmHg; $p < 0.001$). Similarly, heart rate was lower (98.97 ± 12.45 vs. 108.51 ± 11.71 bpm; $p = 0.002$), and oxygen saturation was higher (96.80 ± 1.41% vs. 94.43 ± 1.70%; $p < 0.001$) in the low-pressure group. End-tidal CO₂ levels were also significantly lower in the 8–10 mmHg group (40.71 ± 2.83 vs. 47.91 ± 4.55 mmHg; $p < 0.001$), suggesting less CO₂ absorption and reduced respiratory compromise [14] [15]. These findings align with existing literature supporting the use of low-pressure pneumoperitoneum to mitigate adverse hemodynamic effects. High intra-abdominal pressure has been consistently linked to increased systemic vascular resistance, decreased venous return, and enhanced CO₂ absorption, which collectively result in cardiovascular stress and compromised pulmonary gas exchange [16]. Kivanç Oncu et al. also observed significant differences in cerebral oxygenation parameters, with better preservation of regional oxygen saturation (rSO₂) in patients undergoing low-pressure pneumoperitoneum [17]. Their findings showed that while none of the low-pressure group experienced cerebral desaturation, three patients in the high-pressure group did, reinforcing the potential systemic benefits of

lower insufflation pressures. Similarly, previous randomized trials have demonstrated comparable trends. One trial reported that at the end of surgery, patients exposed to >11 mmHg pressure had higher heart rates (81.60 ± 5.88 bpm vs. 77.01 ± 5.55 bpm), MAP (95.42 ± 6.32 vs. 80.76 ± 5.98 mmHg), and end-tidal CO₂ (43.37 ± 2.34 vs. 33.05 ± 2.91 mmHg) compared to those in the 8–10 mmHg group ($p < 0.05$) [18]. Another study showed a progressive increase in these parameters with rising pneumoperitoneum pressures: heart rate increased from 92.16 ± 10.32 bpm at 8–10 mmHg to 104.52 ± 12.79 bpm at ≥14 mmHg; MAP rose from 95.36 ± 5.98 to 105.64 ± 6.51 mmHg, and end-tidal CO₂ climbed from 33.00 ± 2.95 to 40.12 ± 1.92 mmHg ($p < 0.05$). Furthermore, Shailendra Pal Singh and colleagues also reported that low-pressure pneumoperitoneum was associated with less disturbance in both systolic and diastolic blood pressure, as well as reduced elevation in end-tidal CO₂ levels during laparoscopic cholecystectomy. They concluded that these physiological benefits likely contribute to smoother anesthesia recovery, reduced postoperative complications, and improved overall patient safety.

CONCLUSION

This study demonstrated that low-pressure pneumoperitoneum (8–10 mmHg) results in significantly more stable hemodynamic parameters including lower mean arterial pressure, heart rate, and end-tidal CO₂, along with higher oxygen saturation compared to standard pressure (11–13 mmHg) during laparoscopic cholecystectomy. These findings support the feasibility and clinical benefit of utilizing low insufflation pressures to minimize cardiovascular and respiratory compromise. Based on the evidence, we recommend the adoption of low-pressure pneumoperitoneum in routine laparoscopic cholecystectomy, particularly in patients with increased cardiopulmonary risk, to optimize intraoperative stability and postoperative recovery.

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