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ORIGINAL ARTICLE

Physiological effects of standard versus gradual pneumoperitoneum in patients undergoing laparoscopic cholecystectomy.

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ABSTRACT… Objective: To compare the physiological effects of standard versus gradual open pneumoperitoneum in patients undergoing laparoscopic cholecystectomy. **Study Design:** Prospective Comparative study. **Setting:** Operation Room, Tertiary Care Hospital Jizan, Saudi Arabia. **Period:** Sep 2024 to Aug 2025. **Methods:** Hundred patients recruited for study were randomly divided in two Groups. In Group A, a pressure of 14mmHg was achieved by creating open pneumoperitoneum by CO2 in a standard fashion, while in the intervention Group B, pressure of 5, 10, and 14 mmHg was achieved gradually. At different time intervals, BP, heart rate, SpO2 and EtCO2 were measured. **Results:** Mean heart rate in group A and B was 77.66±8.21and 76.41±7.47 respectively (P-value=0.051). Mean systolic BP in group A and B was 117.7±12.13 and 119.14±7.75 respectively (P-value=0.082). Mean diastolic BP in Group A and B was 77.96±6.45 and 77.38 ± 5.01 respectively (P-value=0.023). Mean SpO2 in group A and B was 99.59 ± 0.53 and 99.6±0.76 (P-value=0.8). Mean EtCO2 in group A and B was 36.86±2.38 and 36.6±2.35 respectively (P-value=0.17). Mean VAS score in group A and B was 2.34±0.72 and 2.06±0.24 respectively (P-value=0.01). In Group A, 13 (26%) patients received injection pethidine due to pain while in Group B only 4 (8%) patients received pethidine (P-value=0.017). **Conclusion:** Gradual open pneumoperitoneum results in more stable physiological and hemodynamic parameters compared to standard rapid open insufflation, without compromising surgical conditions. This is particularly beneficial in patients with cardiovascular compromise.

Key words: Gradual Pneumoperitoneum, Laparoscopic Cholecystectomy, Low-pressure Pneumoperitoneum, Pneumoperitoneum, Standard Pressure.

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INTRODUCTION

Laparoscopic cholecystectomy is presently the gold standard treatment for symptomatic cholelithiasis and is among the most performed laparoscopic procedures globally.[1-2] Compared with open cholecystectomy, it is associated with reduced postoperative pain, shorter hospital stays, earlier return to work, and improved cosmetic outcomes.[3] Despite its clear advantages, the procedure needs the creation of a carbon dioxide (CO_2) pneumoperitoneum, which is not without physiologic changes.

The creation of pneumoperitoneum raises intra-abdominal pressure (IAP), producing a cascade of hemodynamic, respiratory, and metabolic consequences. Increased IAP compresses the inferior vena cava, reducing venous return and preload, while simultaneously elevating systemic vascular resistance (SVR) and afterload.[4] In healthy patients, these changes are well tolerated, but in those with cardiovascular comorbidities, they may result in hemodynamic instability.[5-6] Furthermore, increases in mean arterial pressure, pulmonary artery pressures, and heart rate are observed during standard pneumoperitoneum.[7]

Respiratory dynamics are also altered. Elevation of the diaphragm due to raised IAP reduces thoracic compliance, lowers functional residual capacity (FRC), and increases peak airway pressures.[8] These effects may result in ventilation-perfusion mismatch, hypoxemia, and hypercarbia, particularly in patients with high BMI or chronic respiratory disease.[9] The absorption of CO_2 during pneumoperitoneum further increases hypercarbia and myocardial oxygen demand.[10]

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Given these physiological disturbances, strategies to reduce the adverse effects of pneumoperitoneum have been explored. Among these, the use of low-pressure pneumoperitoneum has been shown to decrease postoperative pain and shoulder tip pain, with some evidence suggesting improved cardiopulmonary stability.[11] However, lower pressures may compromise the operative field and increase difficulty due to inadequate exposure. Another promising approach is the gradual or stepwise insufflation of CO_2 to achieve the required IAP. This technique allows the body to adapt gradually to rising intra-abdominal pressures, potentially minimizing abrupt hemodynamic changes and improving respiratory parameters.[12]

Several studies have investigated the comparative effects of standard rapid versus gradual pneumoperitoneum. One group of researchers concluded that gradual insufflation attenuated increases in heart rate and mean arterial pressure compared with standard rapid insufflation, without increasing operative time.[13] Despite these encouraging outcomes, the available evidence remains limited. In addition, most of these studies have been conducted in mixed laparoscopic procedures, and few have specifically studied laparoscopic cholecystectomy, a procedure in which the duration of pneumoperitoneum is relatively short but widely performed across the globe.

Therefore, further research work is warranted to measure the physiological impact of gradual versus standard pneumoperitoneum in laparoscopic cholecystectomy.

The present study was designed to compare the physiological effects of standard rapid versus gradual pneumoperitoneum in patients undergoing laparoscopic cholecystectomy, with emphasis on hemodynamic and respiratory parameters. We hypothesized that gradual pneumoperitoneum decreases adverse cardiovascular and respiratory changes compared to standard insufflation, without compromising operative conditions.

METHODS

This Prospective comparative study conducted at Operation room, Tertiary Care Hospital Jizan, Kingdom of Saudia Arabia. Hundred patients were recruited for study from Sep 2024 to Aug 2025.

Inclusion Criteria

All patients with symptomatic gallstones, aging between 18 to 65 years, undergoing laparoscopic cholecystectomy with ASA class 1 and 2.

Exclusion Criteria

ASA 3 and above, age >65, bronchial asthma, COPD and coagulopathy.

Patients were enrolled after approval by the hospital ethics committee (JAFH240014), and written informed consent was obtained.

Pre-op assessment was done in clinic by consultant, Patient age, gender, comorbidities, preoperative symptoms, previous surgeries were recorded. Patients fulfilling inclusion criteria were admitted on day of surgery in short stay unit, informed written consent was taken, Injection cefazolin 2 gm will be administered 30 min before making skin incision, four port laparoscopic cholecystectomy was performed by consultant surgeon under general anaesthesia. The patients were randomly assigned two Groups, 50 patients in each, A and B, using Balanced Block Randomization. In the control Group, a pressure of 14mmHg was achieved by creating open pneumoperitoneum by CO2 in a standard fashion, while in the intervention Group B, pressure of 5, 10, and 14 mmHg was achieved gradually at interval of 1 minute. Each patient was assigned a number by the supervisor and recorded. At time zero, before the start of insufflation, Systolic blood pressure (SBP), Diastolic blood pressure (DBP) heart rate (HR), arterial oxygen saturation (SpO2) and end-tidal CO2(EtCO2) were measured and recorded. All patients were positioned in the standard American position (30-degree reverse Trendelenburg and 30-degree left tilt). CO2 gas insufflation was performed in three stages with pressure levels of 5, 10, and 14 mmHg, in Group B, each stage lasting 1 minute. In Group A, only a pressure of 14 mmHg was applied to the patient. After each stage, hemodynamic variables were reassessed at 5,20,40 and 60 minutes. Once the surgery was completed and the surgeon desufflated the intra-abdominal gas, hemodynamic parameters were measured again at the time of extuabation.

According to the visual analogue scale (VAS) system, patients were given a pain score during recovery. Injection Pethidine was administered to patients with VAS 3 or above in recovery.

The data was analyzed using SPSS version 31 software. Continuous variables were expressed as mean± standard deviation (SD) and compared using Student t-test or repeated measures Anova as appropriate. Categorical variables were analyzed with chi-square or Fischer's test. A p-value<0.05 was considered statistically significant.

Based on studies conducted in the past a minimum difference of 10 mmHg in mean arterial pressure was considered clinically significant with standard deviation of 12, power of 80% and $\alpha = 0.05$.[14] The required sample size was calculated as 40 patients per Group. To account for potential dropouts, 100 patients were recruited, 50 in each Group.

RESULTS

Mean age of Group A was 44.10±9.17 years, mean age of Group B was 42.08±8.81 years. Mean age of all patients was 43.09±9.0 years. Difference between two Groups was insignificant as p-value was 0.123.

Female to male ratio was 2.4:1. There was no significant difference between two Groups in terms of gender. Detailed comparison is shown in Table-I below.

TABLE-I

Comparison of gender difference

Group	N	Frequency (%)		P-Value
		Male	Female	
Group A	50	16 (32%)	34 (68%)	0.509
Group B	50	13 (26%)	37 (74%)	

The analysis of heart rate, blood pressure, SpO_2, and $EtCO_2$ revealed that the two groups were largely similar throughout most of the procedure.

No statistically significant differences were found between Group A and Group B in terms of heart rate at any measured time point (all p-values > 0.05).

A single, statistically significant difference in systolic BP was observed at the 5-minute mark, where Group B had a higher mean systolic blood pressure than Group A ($p < 0.001$). At all other times, including for Diastolic BP, there were no significant differences between the groups.

No statistically significant differences were found for oxygen saturation or end-tidal CO_2 at any time point.

The only notable difference was a higher systolic blood pressure in Group B at the 5-minute mark. For all other parameters and time points, the groups were statistically comparable. Please refer to Figure-1 for a graphical representation of these results.

All the data collected at different intervals was combined and analyzed. Detailed results are shown in the Table-II below.

TABLE-II

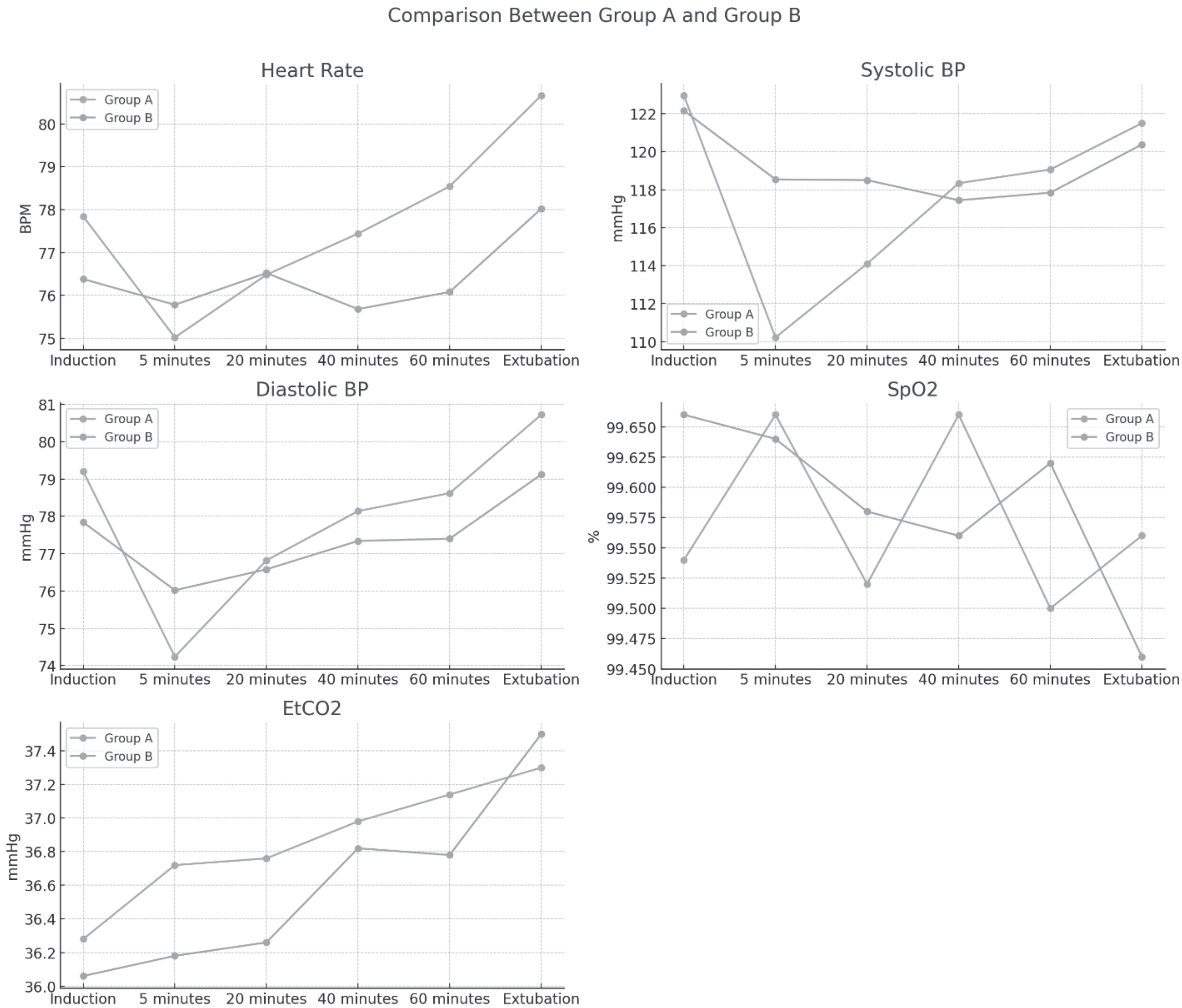
Comparison of hemodynamic and respiratory parameter with all intervals combined

Parameter	Group A (Mean ± SD)	Group B (Mean ± SD)	P-Value
Heart Rate (bpm)	77.66 ± 8.21	76.41 ± 7.47	0.051
Systolic BP (mmHg)	117.7 ± 12.13	119.14 ± 7.75	0.082
Diastolic BP (mmHg)	77.96 ± 6.45	77.38 ± 5.01	0.23
SpO_2 (%)	99.59 ± 0.53	99.6 ± 0.76	0.80
$EtCO_2$ (mmHg)	36.86 ± 2.38	36.6 ± 2.346	0.17

In group A, mean score for VAS was 2.34±0.72 while it was 2.06±0.24 for Group B. This difference was significant with p-value of 0.01. In Group A, 13 (26%) patients received injection pethidine due to pain while in Group B only 4 (8%) patients received pethidine, this difference was statistically significant. P-value was 0.017.

FIGURE-1

Comparison of hemodynamic and respiratory parameter at different intervals



DISCUSSION

Cholelithiasis is a significant global health problem affecting large portion of population. Cholelithiasis prevalence is 10-15% in western population and in KSA prevalence is approximately 11.7%.[15-16] This high number of cases lead to increased number of cholecystectomy procedures performed in the Kingdom.[17]

In our study, mean age of Group A was 44.10±9.17, and the mean age of Group B was 42.08±8.81. Mean age of all patients was 43.09±8.99 years. Difference between two Groups was insignificant as p-value was 0.123. These results correspond to studies conducted by Qassem MG et al.[18]

Female to male distribution was 2.4:1 which corresponds to studies conducted by Mirghani HO et al.[19]

In our study, heart rate values at various intraoperative intervals showed comparable trends between the two groups. At induction, both groups demonstrated similar baseline heart rates, and no significant differences were noted at 5, 20, or 40 minutes. Although a modest increase in heart rate was observed in Group A compared with Group B at 60 minutes, this difference reached statistical significance (p = 0.048) but was not considered clinically meaningful. At extubation, heart rates again showed no significant difference between the groups. Overall, the hemodynamic response in both groups remained stable, and no persistent intergroup differences were observed. In A study conducted by Marimuthu et al. mean heart rate was significantly higher in high pressure pneumoperitoneum than low pressure pneumoperitoneum.[20] In their study this difference was due to reason that there was significant IAP difference between two methods but in our study this difference only at the start of the procedure as later there was no pressure difference.

In the present study, systolic blood pressure (SBP) differed significantly between the two groups at 5 minutes and 20 minutes following induction. Group A demonstrated a lower mean SBP compared with Group B at both intervals (p < 0.001 and p = 0.030, respectively). However, at subsequent time points no significant differences were observed, indicating that the early changes were transient. This initial reduction in SBP in Group A may be explained by the sudden increase in intra-abdominal pressure (IAP), whereas in Group B, the gradual elevation in IAP appeared to attenuate abrupt hemodynamic fluctuations. Similar to our findings, Ahila et al reported that patients in gradual pressure CO_2 pneumoperitoneum group patients had more stable systolic blood pressures during early intraoperative periods compared to the standard-pressure group, suggesting the rise in IAP dynamics plays a key role in BP fluctuations.[21]

Mean Diastolic Blood Pressure difference was insignificant at the start of the procedure. Mean Diastolic Blood Pressure at 60 minutes for Group A was 79.44±4.210 mmHg and Group B was 77.40±4.673 mmHg. P-value was0.012. Mean Diastolic Blood Pressure at the time of extubation for Group A was 80.72±5.099 mmHg and Group B was 79.12±4.835 mmHg. The results of our study were like study conducted by Küçüköztaş et al.[22]

SPO2 measurement showed insignificant differences at all intervals. Similar results were shown by study conducted by Oncu et al.[23]

EtCO_2 measurements in our study showed no significant differences between the two groups at any of the recorded intervals, indicating that both groups maintained comparable ventilatory status throughout the procedure. Similarly, in a study conducted by Marimuthu et al, no significant variation in EtCO_2 levels was observed between groups, further supporting the finding that pneumoperitoneum technique does not markedly affect end-tidal CO_2 when ventilation is adequately controlled.[24]

In our study, we found out that VAS score was significantly higher in group A (2.34±0.72) as compared to group A (2.06±0.24) with p-value of 0.01. Resultantly significantly lesser number of patients required the rescue analgesia in group B [4 (8%) vs 13 (26%)] with p-value of 0.017. This difference of pain and increased analgesia required in group A could be due to sudden stretch of the peritoneum. Similar results were observed in a study conducted by Rosenberg. On the other hand, Chang W et al in their study concluded that the pneumoperitoneum pressure does not significantly affect the post-operative pain.[25]

CONCLUSION

Gradual open pneumoperitoneum results in more stable physiological and hemodynamic parameters compared to standard rapid open insufflation, without compromising surgical conditions. This is particularly beneficial in patients with cardiovascular compromise.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHORSHIP AND CONTRIBUTION DECLARATION	
1	**Maqsood Ahmad:** Manuscript writing.
2	**Shafaqat Ali:** Data collection.
3	**Tajeddin Mansoor:** Data entry.
4	**Aftab Hussain:** Data analysis.
5	**Sajid Munir:** References.
6	**Nuraddin Hakami:** Data collection.