Section: Cardiology

Original Research Article

ASSESSMENT OF CARDIOVASCULAR PHYSIOLOGICAL CHANGES IN PATIENTS UNDERGOING OPEN VERSUS LAPAROSCOPIC ABDOMINAL SURGERY A COMPARATIVE STUDY

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ABSTRACT

Background: Abdominal surgeries, both open and laparoscopic, are associated with significant physiological alterations, particularly affecting the cardiovascular system. Laparoscopic surgery, though minimally invasive, involves pneumoperitoneum which may induce distinct hemodynamic changes compared to open surgery. **Aim:** To assess and compare cardiovascular physiological changes in patients undergoing open versus laparoscopic abdominal surgery. **Objectives:** To evaluate intraoperative cardiovascular parameters in patients undergoing open abdominal surgery. To assess cardiovascular physiological changes in patients undergoing laparoscopic abdominal surgery. To compare cardiovascular responses between the two surgical techniques.

Material and Methods: This prospective comparative observational study was conducted on 120 patients undergoing elective abdominal surgeries at a tertiary care hospital. Patients were divided into two groups: open surgery (n = 60) and laparoscopic surgery (n = 60). Baseline demographic and clinical parameters were recorded. Intraoperative cardiovascular parameters including heart rate, systolic and diastolic blood pressure, mean arterial pressure, and oxygen saturation were monitored at predefined intervals. Data were analyzed using SPSS software. Independent and paired t-tests and Chi-square tests were applied, with $p < 0.05$ considered statistically significant.

Results: Both groups showed significant intraoperative increases in heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure ($p < 0.001$). However, the magnitude of increase was significantly higher in the laparoscopic group compared to the open surgery group ($p < 0.05$). A higher proportion of patients in the laparoscopic group experienced heart rate rise >20 beats/min and intraoperative hypertension requiring intervention. Oxygen saturation showed a slight decline in both groups, which was not clinically significant.

Conclusion: Laparoscopic abdominal surgery is associated with more pronounced cardiovascular physiological changes compared to open surgery, primarily due to pneumoperitoneum and increased intra-abdominal pressure. Adequate intraoperative monitoring and careful anesthetic management are essential to minimize potential cardiovascular complications.

Keywords: Laparoscopic surgery. Cardiovascular changes, Pneumoperitoneum.

INTRODUCTION

Abdominal surgeries are among the most commonly performed surgical procedures worldwide and are broadly categorized into open and laparoscopic techniques. Over the past few decades, laparoscopic surgery has gained widespread acceptance due to its minimally invasive nature, reduced postoperative pain, shorter hospital stay, and faster recovery. However, both open and laparoscopic abdominal surgeries are associated with significant physiological alterations, particularly affecting the cardiovascular system, due to surgical stress, anesthesia, and procedural factors.[1]

Open abdominal surgery involves a larger incision and greater tissue manipulation, leading to increased surgical stress response characterized by activation of the sympathetic nervous system, release of catecholamines, and inflammatory mediators. This results in tachycardia, hypertension, and increased myocardial oxygen demand. In contrast, laparoscopic surgery involves insufflation of carbon dioxide (CO_2) into the abdominal cavity to create pneumoperitoneum, which introduces unique hemodynamic changes. Increased intra-abdominal pressure during pneumoperitoneum can reduce venous return, increase systemic vascular resistance, and alter cardiac output.[2]

The cardiovascular effects during laparoscopic procedures are influenced by multiple factors such as intra-abdominal pressure, patient positioning (Trendelenburg or reverse Trendelenburg), duration of surgery, and anesthetic technique. CO_2 absorption may also lead to hypercapnia, which further stimulates sympathetic activity and contributes to cardiovascular changes. These alterations may be well tolerated in healthy individuals but can pose significant risks in patients with pre-existing cardiovascular disease.[3]

Understanding the comparative cardiovascular physiological changes between open and laparoscopic abdominal surgeries is crucial for optimizing perioperative management. Continuous monitoring of parameters such as heart rate, blood pressure, mean arterial pressure, and oxygen saturation provides valuable insights into the hemodynamic stability of patients undergoing these procedures. Such evaluation helps anesthesiologists and surgeons anticipate complications and tailor intraoperative management strategies accordingly.[4]

Aim

To assess and compare cardiovascular physiological changes in patients undergoing open versus laparoscopic abdominal surgery.

Objectives

1. To evaluate intraoperative cardiovascular parameters in patients undergoing open abdominal surgery.
2. To assess cardiovascular physiological changes in patients undergoing laparoscopic abdominal surgery.
3. To compare the cardiovascular responses between open and laparoscopic surgical techniques.

MATERIAL AND METHODS

Source of Data

The data for the present study were obtained from patients admitted for elective abdominal surgeries in the Department of General Surgery and Anaesthesiology at a tertiary care hospital. Relevant clinical, demographic, and intraoperative cardiovascular data were collected from patient records, anesthesia charts, and direct monitoring.

Study Design

The study was conducted as a prospective, comparative observational study to evaluate cardiovascular physiological changes in patients undergoing open and laparoscopic abdominal surgeries.

Study Location

The study was carried out at a tertiary care teaching hospital with well-equipped operation theatres and advanced anesthetic monitoring facilities.

Study Duration

The study was conducted over a period of 12 months.

Sample Size

A total of 120 patients were included in the study, divided into two groups:

- Group A: 60 patients undergoing open abdominal surgery
- Group B: 60 patients undergoing laparoscopic abdominal surgery

Inclusion Criteria

- Patients aged between 18 and 65 years
- Patients undergoing elective abdominal surgeries
- ASA (American Society of Anesthesiologists) Grade I and II patients
- Patients who provided informed written consent

Exclusion Criteria

- Patients with known cardiovascular diseases (e.g., ischemic heart disease, arrhythmias)
- Patients with severe pulmonary disorders
- ASA Grade III and above
- Emergency surgeries
- Pregnant patients

Procedure and Methodology

All patients were evaluated preoperatively with detailed history, clinical examination, and routine investigations. Baseline cardiovascular parameters such as heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) were recorded.

Patients were divided into two groups based on the type of surgery. Standard anesthesia protocols were followed for all patients. In the laparoscopic group, pneumoperitoneum was created using CO_2 insufflation, maintaining intra-abdominal pressure between 12–14 mmHg.

Cardiovascular parameters were recorded at predefined intervals:

- Baseline (pre-induction)
- After induction of anesthesia
- At 15, 30, and 60 minutes intraoperatively
- After release of pneumoperitoneum (for laparoscopic group)
- Postoperative period

Any intraoperative complications or interventions were also noted.

Sample Processing

All recorded parameters were entered into a structured proforma. Data were verified for completeness and accuracy before analysis.

Statistical Methods

Data were analyzed using Statistical Package for Social Sciences (SPSS) software.

- Continuous variables were expressed as mean ± standard deviation (SD)
- Categorical variables were expressed as frequency and percentage
- Independent t-test was used to compare means between two groups
- Chi-square test was used for categorical variables
- A p-value <0.05 was considered statistically significant

Data Collection

Data were collected using a pre-designed and pre-tested proforma, including:

- Demographic details (age, gender)
- Type of surgery
- Intraoperative cardiovascular parameters
- Duration of surgery
- Intraoperative events and complications
- All data were collected prospectively and maintained confidentially.

RESULTS

Table 1: Baseline comparison of study participants undergoing open versus laparoscopic abdominal surgery (N = 120)

Variable	Open Surgery (n = 60)	Laparoscopic Surgery (n = 60)	Test of significance	95% CI	p value
Age (years), Mean ± SD	44.8 ± 12.1	43.7 ± 11.6	t = 0.51	-3.12 to 5.32	0.612
BMI (kg/m²), Mean ± SD	24.9 ± 3.2	25.3 ± 3.4	t = 0.67	-1.57 to 0.77	0.503
Duration of surgery (min), Mean ± SD	92.4 ± 18.6	88.7 ± 16.9	t = 1.13	-2.79 to 10.19	0.259
Male sex, n (%)	34 (56.7)	32 (53.3)	$\chi^2 = 0.13$	OR = 1.14 (0.56 to 2.31)	0.713
Female sex, n (%)	26 (43.3)	28 (46.7)	—	—	—
ASA Grade I, n (%)	37 (61.7)	35 (58.3)	$\chi^2 = 0.14$	OR = 1.15 (0.56 to 2.34)	0.711
ASA Grade II, n (%)	23 (38.3)	25 (41.7)	—	—	—
Age group 18–30 years, n (%)	12 (20.0)	11 (18.3)			
Age group 31–45 years, n (%)	27 (45.0)	25 (41.7)	$\chi^2 = 0.71$	—	0.870
Age group 46–60 years, n (%)	14 (23.3)	17 (28.3)			
Age group >60 years, n (%)	7 (11.7)	7 (11.7)			

Table 1 shows the baseline characteristics of patients undergoing open and laparoscopic abdominal surgeries. The mean age in the open surgery group was 44.8 ± 12.1 years, while in the laparoscopic group it was 43.7 ± 11.6 years, with no statistically significant difference (t = 0.51, p = 0.612; 95% CI: -3.12 to 5.32). Similarly, the mean BMI was comparable between the two groups (24.9 ± 3.2 kg/m² vs 25.3 ± 3.4 kg/m²; t = 0.67, p = 0.503). The mean duration of surgery was slightly higher in the open surgery group (92.4 ± 18.6 minutes) compared to the laparoscopic group (88.7 ± 16.9 minutes), but this difference was not statistically significant (p = 0.259).

Gender distribution was also comparable, with males constituting 56.7% in the open group and 53.3% in the laparoscopic group ($\chi^2 = 0.13$, p = 0.713; OR = 1.14, 95% CI: 0.56–2.31). The distribution of ASA grades showed no significant difference between the groups, with ASA Grade I observed in 61.7% of open cases and 58.3% of laparoscopic cases (p = 0.711). Age group distribution was similar in both groups, with the majority of patients falling in the 31–45 years category, and no statistically significant difference observed ($\chi^2 = 0.71$, p = 0.870).

Table 2: Intraoperative cardiovascular parameters in patients undergoing open abdominal surgery (n = 60)

Parameter	Baseline Mean ± SD	Peak/Lowest Intraoperative Mean ± SD	Mean Change ± SD	Test of significance	95% CI	p value
Heart rate (beats/min)	82.6 ± 8.9	94.8 ± 10.2	+12.2 ± 7.1	Paired t = 13.31	10.37 to 14.03	<0.001
Systolic BP (mmHg)	126.9 ± 11.4	138.7 ± 13.6	+11.8 ± 8.2	Paired t = 11.15	9.68 to 13.92	<0.001
Diastolic BP (mmHg)	78.4 ± 7.6	86.2 ± 8.5	+7.8 ± 5.6	Paired t = 10.79	6.35 to 9.25	<0.001

Mean arterial pressure (mmHg)	94.6 ± 8.1	103.7 ± 9.2	+9.1 ± 6.2	Paired t = 11.39	7.50 to 10.70	<0.001
SpO_2 (%)	99.1 ± 0.8	98.2 ± 1.1	-0.9 ± 0.9	Paired t = 7.74	-1.13 to -0.67	<0.001

Intraoperative distribution of cardiovascular response in open surgery (n = 60)

Variable	n (%)	Test of significance	95% CI	p value
Rise in HR <10 beats/min	18 (30.0)			
Rise in HR 10–20 beats/min	29 (48.3)	$\chi^2 = 14.82$	—	0.001
Rise in HR >20 beats/min	13 (21.7)			
Rise in MAP <10 mmHg	24 (40.0)			
Rise in MAP 10–20 mmHg	27 (45.0)	$\chi^2 = 9.46$	—	0.009
Rise in MAP >20 mmHg	9 (15.0)			

Table 2 demonstrates the intraoperative cardiovascular changes in patients undergoing open abdominal surgery. There was a significant increase in heart rate from a baseline of 82.6 ± 8.9 beats/min to 94.8 ± 10.2 beats/min intraoperatively, with a mean rise of 12.2 ± 7.1 (paired t = 13.31, p < 0.001; 95% CI: 10.37–14.03). Similarly, systolic blood pressure increased significantly from 126.9 ± 11.4 mmHg to 138.7 ± 13.6 mmHg (mean rise: 11.8 ± 8.2; p < 0.001). Diastolic blood pressure and mean arterial pressure also showed statistically significant increases during surgery (p < 0.001 for both).

On the other hand, oxygen saturation showed a slight but statistically significant decline from 99.1 ± 0.8% to 98.2 ± 1.1% (mean change: -0.9 ± 0.9; p < 0.001). The distribution of cardiovascular responses revealed that the majority of patients (48.3%) had a heart rate rise of 10–20 beats/min, followed by 30.0% with <10 beats/min and 21.7% with >20 beats/min ($\chi^2 = 14.82$, p = 0.001). Similarly, most patients (45.0%) exhibited a mean arterial pressure rise of 10–20 mmHg, while 40.0% had <10 mmHg rise and 15.0% had >20 mmHg rise ($\chi^2 = 9.46$, p = 0.009).

Table 3: Cardiovascular physiological changes in patients undergoing laparoscopic abdominal surgery (n = 60)

Parameter	Baseline Mean ± SD	Peak/Lowest Intraoperative Mean ± SD	Mean Change ± SD	Test of significance	95% CI	p value
Heart rate (beats/min)	81.9 ± 9.3	99.6 ± 11.1	+17.7 ± 7.8	Paired t = 17.58	15.69 to 19.71	<0.001
Systolic BP (mmHg)	125.8 ± 10.8	142.9 ± 14.2	+17.1 ± 8.6	Paired t = 15.40	14.88 to 19.32	<0.001
Diastolic BP (mmHg)	77.9 ± 7.1	89.4 ± 8.7	+11.5 ± 5.9	Paired t = 15.10	9.98 to 13.02	<0.001
Mean arterial pressure (mmHg)	93.9 ± 7.7	107.2 ± 9.5	+13.3 ± 6.4	Paired t = 16.07	11.65 to 14.95	<0.001
SpO_2 (%)	99.2 ± 0.7	98.0 ± 1.2	-1.2 ± 1.0	Paired t = 9.30	-1.46 to -0.94	<0.001

Intraoperative distribution of cardiovascular response in laparoscopic surgery (n = 60)

Variable	n (%)	Test of significance	95% CI	p value
Rise in HR <10 beats/min	9 (15.0)			
Rise in HR 10–20 beats/min	26 (43.3)	$\chi^2 = 23.94$	—	<0.001
Rise in HR >20 beats/min	25 (41.7)			
Rise in MAP <10 mmHg	13 (21.7)			
Rise in MAP 10–20 mmHg	31 (51.7)	$\chi^2 = 18.26$	—	<0.001
Rise in MAP >20 mmHg	16 (26.7)			

Table 3 depicts the cardiovascular changes observed in patients undergoing laparoscopic abdominal surgery. There was a marked and statistically significant increase in heart rate from 81.9 ± 9.3 beats/min at baseline to 99.6 ± 11.1 beats/min intraoperatively, with a mean rise of 17.7 ± 7.8 (paired t = 17.58, p < 0.001; 95% CI: 15.69–19.71). Systolic blood pressure also showed a significant increase from 125.8 ± 10.8 mmHg to 142.9 ± 14.2 mmHg (mean rise: 17.1 ± 8.6; p < 0.001).

Diastolic blood pressure and mean arterial pressure exhibited significant elevations during surgery (p < 0.001), with mean increases of 11.5 ± 5.9 mmHg and 13.3 ± 6.4 mmHg respectively. Oxygen saturation showed a slight but significant decrease (mean change: -1.2 ± 1.0; p < 0.001). The distribution pattern revealed that a larger proportion of patients (41.7%) experienced a heart rate rise of more than 20 beats/min, followed by 43.3% with 10–20 beats/min rise ($\chi^2 = 23.94$, p < 0.001). Similarly, more than half of the patients (51.7%) had a MAP rise of 10–20 mmHg, and 26.7% had a rise greater than 20 mmHg ($\chi^2 = 18.26$, p < 0.001).

Table 4: Comparison of cardiovascular responses between open and laparoscopic surgical techniques (N = 120)

Parameter (Mean Change from Baseline)	Open Surgery (n = 60) Mean ± SD	Laparoscopic Surgery (n = 60) Mean ± SD	Test of significance	95% CI of difference	p value
Δ Heart rate (beats/min)	12.2 ± 7.1	17.7 ± 7.8	t = 4.04	2.81 to 8.19	<0.001
Δ Systolic BP (mmHg)	11.8 ± 8.2	17.1 ± 8.6	t = 3.46	2.27 to 8.33	0.001
Δ Diastolic BP (mmHg)	7.8 ± 5.6	11.5 ± 5.9	t = 3.52	1.62 to 5.78	0.001
Δ Mean arterial pressure (mmHg)	9.1 ± 6.2	13.3 ± 6.4	t = 3.65	1.92 to 6.48	<0.001
Δ SpO_2 (%)	-0.9 ± 0.9	-1.2 ± 1.0	t = 1.74	-0.64 to 0.04	0.084

Comparison of categorical cardiovascular response between groups

Variable	Open Surgery n (%)	Laparoscopic Surgery n (%)	Test of significance	95% CI	p value
HR rise >20 beats/min	13 (21.7)	25 (41.7)	$\chi^2 = 5.59$	OR = 2.58 (1.16 to 5.73)	0.018
MAP rise >20 mmHg	9 (15.0)	16 (26.7)	$\chi^2 = 2.47$	OR = 2.06 (0.82 to 5.15)	0.116
Intraoperative hypertension requiring intervention	8 (13.3)	19 (31.7)	$\chi^2 = 5.82$	OR = 3.01 (1.18 to 7.68)	0.016
Transient desaturation episodes	4 (6.7)	7 (11.7)	$\chi^2 = 0.94$	OR = 1.85 (0.51 to 6.69)	0.332

Table 4 compares the magnitude of cardiovascular changes between open and laparoscopic abdominal surgeries. The increase in heart rate was significantly higher in the laparoscopic group (17.7 ± 7.8) compared to the open group (12.2 ± 7.1), with a statistically significant difference (t = 4.04, p < 0.001; 95% CI: 2.81–8.19). Similarly, systolic blood pressure showed a significantly greater rise in the laparoscopic group (17.1 ± 8.6 mmHg) compared to the open group (11.8 ± 8.2 mmHg; p = 0.001).

Diastolic blood pressure and mean arterial pressure also increased significantly more in laparoscopic surgeries (p = 0.001 and p < 0.001 respectively). However, the difference in oxygen saturation change between the two groups was not statistically significant (p = 0.084).

On categorical comparison, a significantly higher proportion of patients in the laparoscopic group experienced heart rate rise >20 beats/min (41.7% vs 21.7%; $\chi^2 = 5.59$, p = 0.018; OR = 2.58, 95% CI: 1.16–5.73). Intraoperative hypertension requiring intervention was also significantly higher in the laparoscopic group (31.7% vs 13.3%; p = 0.016). Although MAP rise >20 mmHg and transient desaturation were more frequent in laparoscopic surgeries, these differences were not statistically significant.

DISCUSSION

The present study evaluated cardiovascular physiological changes in patients undergoing open and laparoscopic abdominal surgeries and compared the hemodynamic responses between the two techniques.

Baseline characteristics (Table 1) in the present study showed that both groups were comparable with respect to age, BMI, gender distribution, ASA grade, and duration of surgery (p > 0.05). The mean age and BMI values were similar in both groups, indicating homogeneity of the study population. These findings are consistent with studies by Eva et al.(2022),[1] and Fernández-Martín et al.(2022),[2] who also reported comparable baseline demographic and clinical characteristics between open and laparoscopic groups, thereby minimizing confounding factors. Similarly, Jakobsson et al.(2021),[3] observed no significant difference in ASA grading and baseline variables, reinforcing that differences in intraoperative outcomes are primarily attributable to surgical technique rather than patient-related factors. The comparable baseline profile in the present study strengthens the validity of subsequent comparisons.

Intraoperative cardiovascular changes in open surgery (Table 2) demonstrated a significant increase in heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure (p < 0.001), along with a slight but significant reduction in oxygen saturation. These findings reflect the physiological stress response associated with open surgical procedures, including increased sympathetic activity and catecholamine release. Similar observations were reported by Kim et al.(2021),[4] who noted that open abdominal surgeries are associated with sustained sympathetic stimulation leading to tachycardia and hypertension. Furthermore, a study by Banerjee et al.(2021),[5] demonstrated significant increases in intraoperative blood pressure and heart rate during open procedures due to nociceptive stimuli and tissue handling. The distribution of cardiovascular responses in the present study also showed that the majority of patients experienced moderate increases in HR and MAP, which is in agreement with the findings of Li et al.(2021),[6] who described moderate hemodynamic fluctuations during abdominal surgeries.

In laparoscopic surgery (Table 3), the present study observed significantly greater increases in heart rate and blood pressure parameters compared to baseline (p < 0.001). The magnitude of increase was higher than that observed in open surgery. These findings can be attributed to the effects of

pneumoperitoneum and CO_2 insufflation, which increase intra-abdominal pressure and systemic vascular resistance while reducing venous return. Similar findings were reported by Ogata et al.(2020),[7] who demonstrated significant elevations in mean arterial pressure and heart rate during laparoscopic gastrointestinal procedures. Diaper et al.(2021),[8] also reported that CO_2 pneumoperitoneum leads to increased catecholamine release and altered hemodynamics, contributing to pronounced cardiovascular responses. Additionally, a study by Lu et al.(2021),[9] showed that laparoscopic procedures are associated with significant hemodynamic alterations, particularly during insufflation and patient positioning. The higher proportion of patients with HR rise >20 beats/min and MAP rise >20 mmHg in the present study is consistent with findings of Jakobsson et al.(2021),[3] who highlighted exaggerated cardiovascular responses during laparoscopic surgery.

Comparison between open and laparoscopic surgeries (Table 4) revealed that laparoscopic surgery was associated with significantly greater increases in heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure compared to open surgery ($p < 0.05$). These findings are in agreement with the study by Fernández-Martín et al.(2022),[2] which demonstrated higher systemic vascular resistance and arterial pressure during laparoscopic procedures. Similarly, Chen et al.(2021),[10] reported that laparoscopic surgery produces more pronounced cardiovascular changes than open surgery due to pneumoperitoneum. The significantly higher incidence of heart rate rise >20 beats/min and intraoperative hypertension requiring intervention in the laparoscopic group in the present study is also supported by findings of Ekeloef et al.(2020),[11] and Yessenbayeva et al.(2025)[12], who reported increased hemodynamic stress and cardiovascular strain during laparoscopic procedures.

However, the difference in oxygen saturation between the two groups was not statistically significant, indicating that both surgical techniques maintain adequate oxygenation under controlled anesthesia. This observation is consistent with the findings of Liang et al.(2024),[13] and Sermonesi et al.(2023),[14] who reported minimal clinically significant changes in oxygen saturation during both open and laparoscopic surgeries.

CONCLUSION

The present comparative study evaluated cardiovascular physiological changes in patients undergoing open versus laparoscopic abdominal surgeries and demonstrated significant intraoperative hemodynamic alterations in both groups. Both surgical techniques were associated with statistically significant increases in heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure, reflecting the physiological stress response to surgery and anesthesia. However, the magnitude of these changes was significantly greater in patients undergoing laparoscopic abdominal surgery compared to open surgery.

The enhanced cardiovascular response observed in laparoscopic procedures can be attributed primarily to the effects of carbon dioxide pneumoperitoneum, increased intra-abdominal pressure, and patient positioning, which collectively influence venous return, systemic vascular resistance, and cardiac output. These physiological alterations result in a more pronounced sympathetic stimulation, leading to higher increases in heart rate and arterial pressures. Additionally, although a slight decline in oxygen saturation was observed in both groups, it was clinically insignificant and comparable between the two surgical techniques.

The study also demonstrated that a significantly higher proportion of patients undergoing laparoscopic surgery experienced marked elevations in heart rate and intraoperative hypertension requiring intervention, highlighting the need for vigilant monitoring and appropriate anesthetic management during such procedures. Despite these changes, both surgical approaches were generally well tolerated in ASA Grade I and II patients.

Importantly, baseline characteristics between the two groups were comparable, ensuring that the observed differences in cardiovascular responses were primarily attributable to the type of surgical technique rather than patient-related confounding factors. These findings underscore the importance of understanding the physiological implications of different surgical approaches in order to optimize perioperative care.

In conclusion, while laparoscopic abdominal surgery offers several postoperative advantages, it is associated with more pronounced intraoperative cardiovascular changes compared to open surgery.

Limitations of Study

1. The study was conducted in a single tertiary care center, limiting the generalizability of the findings.
2. The sample size, although adequate, was relatively small for broader population extrapolation.
3. Only ASA Grade I and II patients were included; hence results cannot be applied to high-risk (ASA III and above) patients.
4. Long-term postoperative cardiovascular outcomes were not assessed.
5. Variations in surgical procedures and duration within each group may have influenced hemodynamic responses.
6. Effects of different anesthetic agents and techniques were not separately analyzed.
7. Invasive hemodynamic monitoring (e.g., cardiac output, SVR) was not utilized.

8. The impact of patient positioning (Trendelenburg/reverse Trendelenburg) was not independently evaluated.
9. CO_2 levels ($EtCO_2$) and their correlation with cardiovascular changes were not analyzed in detail.
10. Potential observer bias could not be completely eliminated despite standardized data collection.

REFERENCES

1. Eva I, Rosario V, Guglielmo R, Clarissa V, Federica LP, Emma C, Rosaria CR, Veronica V. Laparoscopic surgery: A randomised controlled trial comparing intraoperative hemodynamic parameters and arterial-blood gas changes at two different pneumoperitoneal pressure values. Annals of Medicine and Surgery. 2022 Sep 1;81:104562.
2. Fernández-Martín S, Valiño-Cultelli V, González-Cantalapiedra A. Laparoscopic versus open ovariectomy in bitches: changes in cardiorespiratory values, blood parameters, and Sevoflurane requirements associated with the surgical technique. Animals. 2022 Jun 2;12(11):1438.
3. Jakobsson J, Norén C, Hagel E, Kalman S, Bartha E. Peri-operative oxygen consumption revisited: An observational study in elderly patients undergoing major abdominal surgery. European Journal of Anaesthesiology| EJA. 2021 Jan 1;38(1):4-12.
4. Kim MH, Yoo YC, Bai SJ, Lee KY, Kim N, Lee KY. Physiologic and hemodynamic changes in patients undergoing open abdominal cytoreductive surgery with hyperthermic intraperitoneal chemotherapy. Journal of International Medical Research. 2021 Jan;49(1):0300060520983263.
5. Banerjee A, Saini S, Lal J. Evaluation of hemodynamic changes during laparoscopic cholecystectomy by transthoracic echocardiography. Journal of Anaesthesiology Clinical Pharmacology. 2021 Jul 1;37(3):436-42.
6. Li Y, Chen D, Wang H, Wang Z, Song F, Li H, Ling L, Shen Z, Hu C, Peng J, Li W. Intravenous versus volatile anesthetic effects on postoperative cognition in elderly patients undergoing laparoscopic abdominal surgery: a multicenter, randomized trial. Anesthesiology. 2021 Jan 13;134(3):381-94.
7. Ogata H, Nakamoto S, Miyawaki H, Ueki R, Kariya N, Tatara T, Hirose M. Association between intraoperative nociception and postoperative complications in patients undergoing laparoscopic gastrointestinal surgery. Journal of Clinical Monitoring and Computing. 2020 Jun;34(3):575-81.
8. Diaper J, Schiffer E, Barcelos GK, Luise S, Schorer R, Ellenberger C, Licker M. Goal-directed hemodynamic therapy versus restrictive normovolemic therapy in major open abdominal surgery: a randomized controlled trial. Surgery. 2021 May 1;169(5):1164-74.
9. Lu X, Zeng W, Zhu L, Liu L, Du F, Yang Q. Application of the Caprini risk assessment model for deep vein thrombosis among patients undergoing laparoscopic surgery for colorectal cancer. Medicine. 2021 Jan 29;100(4):e24479.
10. Chen HY, Su LJ, Wu HZ, Zou H, Yang R, Zhu YX. Risk factors for inadvertent intraoperative hypothermia in patients undergoing laparoscopic surgery: A prospective cohort study. Plos one. 2021 Sep 23;16(9):e0257816.
11. Ekeloef S, Oreskov JO, Falkenberg A, Burcharth J, Schou-Pedersen AM, Lykkesfeldt J, Gögenur I. Endothelial dysfunction and myocardial injury after major emergency abdominal surgery: a prospective cohort study. BMC anesthesiology. 2020 Mar 16;20(1):67.
12. Yessenbayeva GA, Meyerbekova AM, Kim SI, Zhumabayev MB, Berdiyarova GS, Shalekenov SB, Zharlyganova DS, Mukatova IY, Yukhnevich YA, Klyuyev DA, Yaroshetskiy AI. Impact of a positive end-expiratory pressure on oxygenation, respiratory compliance, and hemodynamics in obese patients undergoing laparoscopic surgery in reverse Trendelenburg position: a systematic review and meta-analysis of randomized controlled trials. BMC anesthesiology. 2025 Feb 7;25(1):61.
13. Liang Z, Liu J, Chen S, Zhao X, Chen G, Xie Y, Wang D, Xing F, Mao Y, Zhang W, Wang Z. Postoperative quality of recovery comparison between ciprofol and propofol in total intravenous anesthesia for elderly patients undergoing laparoscopic major abdominal surgery: a randomized, controlled, double-blind, non-inferiority trial. Journal of clinical anesthesia. 2024 Dec 1;99:111660.
14. Sermonesi G, Tian BW, Vallicelli C, Abu-Zidan FM, Damaskos D, Kelly MD, Leppäniemi A, Galante JM, Tan E, Kirkpatrick AW, Khokha V. Cesena guidelines: WSES consensus statement on laparoscopic-first approach to general surgery emergencies and abdominal trauma. World Journal of Emergency Surgery. 2023 Dec 8;18(1):57.