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ORIGINAL RESEARCH

General anesthesia vs. Segmental spinal anesthesia: hemodynamic stability and ease of doing surgery in laparoscopic cholecystectomy

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ABSTRACT

Background and Objectives: While general anesthesia (GA) remains the standard anesthetic modality for performing laparoscopic cholecystectomy (LC), it may not be optimal for all patient populations. This prospective, randomized controlled study was designed to evaluate and compare the hemodynamic profiles associated with GA and thoracic segmental spinal anesthesia (TSSA) during LC. **Materials and Methods:** A total of 124 adult participants scheduled for elective LC were randomly allocated into two groups: Group A (TSSA) and Group B (GA), with 62 individuals in each arm. Group B underwent standard GA, including endotracheal intubation and mechanical ventilation. Group A received TSSA, wherein 1.5 mL of 0.75% ropivacaine combined with 6 mcg of dexmedetomidine was administered intrathecal between thoracic vertebrae T7 and T12. The primary endpoint was assessment of intraoperative hemodynamic variation. The secondary outcomes included comparison of adverse events during and following the procedure, and ease of doing surgery. Data entry was performed using Microsoft Excel and analyzed with SPSS version 25. **Results:** Analysis included all randomized subjects. In Group A, a transient decrease in heart rate and blood pressure was noted at the 5-minute mark, followed by sustained hemodynamic stability. In contrast, Group B exhibited more pronounced increases in intraoperative cardiovascular parameters, particularly following pneumoperitoneum. No neurological adverse events were observed in the TSSA cohort. Reports of abdominal pain in the early postoperative phase and sore throat were more prevalent in the GA group. **Conclusion:** TSSA demonstrates superior intraoperative cardiovascular stability and fewer postoperative complications when compared with GA, positioning it as a viable and effective anesthetic alternative for laparoscopic cholecystectomy.

Key Words: General Anesthesia, Segmental Spinal Anesthesia, Hemodynamic stability, Laparoscopic Cholecystectomy

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INTRODUCTION

General anesthesia (GA), which is widely regarded as the standard approach for laparoscopic cholecystectomy (LC), is associated with various side effects, including complications from airway management and mechanical ventilation. Additionally, it can lead to significant hemodynamic variations due to the pneumoperitoneum and positional adjustments during the procedure. The pneumoperitoneum affects the body through the absorption of CO2, increased intra-abdominal pressure, and by amplifying the neuroendocrine stress response to surgery [1–3].

Thoracic segmental spinal anesthesia (TSSA) has emerged as an effective and acceptable alternative technique for LC. In certain cases, it may offer

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superior benefits by circumventing the limitations of GA [4,5]. MRI studies have demonstrated that the spinal cord in the thoracic region is positioned more anteriorly in relation to the duramater, compared to the cervical and lumbar regions. This, along with the thinner nerve roots and reduced cerebrospinal fluid (CSF) volume, results in a faster onset of local anesthetic (LA) action at the thoracic level, even when using only half the dose typically required at the lumbar level. The lower dose of LA provides improved hemodynamic stability, minimal thoracic motor block, and a brief lumbar motor block. This transient lumbar motor block allows for early postoperative voiding and ambulation [6,7]. Given that relaxation requirements during laparoscopic procedures are generally minimal, lower doses of isobaric drugs can be employed to achieve a preferential sensory block. Additionally, these drugs are not affected by table tilts, offering further advantages [8,9].

Ropivacaine's limited penetration into larger myelinated motor fibers, due to its low lipophilicity, contributes to its ability to provide a preferential sensory block [10,11]. The inclusion of an adjuvant like dexmedetomidine, a selective alpha-2 adrenergic receptor agonist, has been shown to extend the duration and improve the quality of postoperative analgesia [12-15].The choice of anaesthesia whether regional or general can also influence patient's comfort and surgeon's comfort and ability to perform the procedure.

This study aims to compare conventional GA with TSSA in patients undergoing LC. The primary objective is to assess intraoperative hemodynamic variations between the two techniques. The secondary objective is to evaluate the intraoperative and postoperative adverse effects associated with each technique and ease of doing surgery.

MATERIAL AND METHODS

The study enrolled 124 patients scheduled for elective laparoscopic cholecystectomy (LC) at a tertiary care medical institution.

Inclusion criteria comprised patients aged 18–75 years, classified as ASA physical status I, II, or III, who provided written informed consent. Individuals with a body mass index (BMI) exceeding 35 kg/m² or those with contraindications to spinal anesthesia, the patients contraindicated for Laparoscopic cholecystectomy and the patients who underwent conversion from spinal to general anesthesiawere excluded. Participants were randomly assigned into two groups using a computer-generated randomization sequence, with group allocation concealed through sealed opaque envelopes opened by the attending anesthesiologist immediately prior to the procedure.

Group A (Thoracic Segmental Spinal Anesthesia; TSSA) patients received a subarachnoid block in the sitting position using a midline or paramedian approach at the T7–T11 interspinous level. A 25-gauge Quincke spinal needle was used, with a maximum of three attempts permitted to obtain cerebrospinal fluid. Upon successful access, 1.5 mL of 0.75% isobaric ropivacaine mixed with 6 µg of dexmedetomidine was injected intrathecally. In cases where block could not be achieved within three attempts, general anesthesia (GA) was administered. Patients were placed supine, and oxygen was delivered via Hudson's mask at 5 L/min. Intraoperative monitoring followed ASA standards, including ECG, non-invasive blood pressure, pulse oximetry, and capnography. Vital signs were recorded every minute for the first 15 minutes, then every 5 minutes thereafter. Sensory level was assessed with pinprick testing until a block from T6 to L1 was achieved. Motor block was graded using the modified Bromage scale. Inadequate block at 10 minutes post-injection was deemed a failure.

At the onset of pneumoperitoneum, patients received 30 mg of IV ketamine to alleviate diaphragmatic stretch discomfort, and 50 µg fentanyl IV was administered prior to incision. Intra-abdominal pressure was maintained at 12 mmHg. Hemodynamic alterations including bradycardia (HR < 55 bpm) and hypotension (SBP < 80 mmHg) were treated with IV atropine 0.6 mg and 6 mg IV mephentermine boluses, respectively. Ringer's lactate was administered at approximately 25 mL/min. Ketamine 20 mg aliquots were used as required for movement suppression.

Group B (General Anesthesia) received standard intravenous premedication identical to Group A. Induction was achieved with IV fentanyl (2 µg/kg) and IV propofol (1.5–2.5 mg/kg), followed by atracuriumbesylate (0.5 mg/kg) for endotracheal intubation. Mechanical ventilation was delivered in volume-controlled mode, targeting a tidal volume of 6–8 mL/kg and maintaining end-tidal CO_2 at 35–40 mmHg. Anesthesia was maintained with isoflurane (1.0–1.2%) in a 40% oxygen-air mixture. At the end of surgery, neuromuscular blockade was reversed with IV neostigmine (2.5 mg) and glycopyrrolate (0.5 mg).

Ease of doing surgery can be viewed from different aspects like patient comfort, complexity of procedure, surgical team experience & skill of doing procedure. The Patient comfort can be viewed from preparation type of Anesthesia technique, intra-operative and post-operative pain management and smooth recovery.

Postoperatively, all patients received intravenous diclofenac sodium (75 mg) every 8 hours. Transfer from the post-anesthesia care unit (PACU) to the surgical ward was based on achieving clinical criteria such as stable vitals, pain control, and absence of nausea or vomiting.

Complications monitored intraoperatively and up to postoperative day two included hypertension (SBP > 140 mmHg), hypotension (SBP < 80 mmHg), nausea, vomiting, pruritus, shoulder pain, sore throat, backache, urinary retention, headache, and severe pain requiring rescue analgesia (VAS ≥ 3). Rescue

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analgesia involved IV acetaminophen (500 mg) and tramadol (50 mg) as needed. Discharge was allowed on postoperative day two upon fulfillment of standard clinical criteria.

Statistical analysis was carried out using SPSS v.25. Continuous data were presented as medians with ranges due to potential outliers. Categorical data were expressed as frequencies and percentages. The chi-square test or Fisher's exact test, as appropriate, was applied to compare categorical variables. A p-value of <0.05 was deemed statistically significant, while p < 0.001 was considered highly significant.

RESULTS

The baseline demographic and clinical characteristics of patients in both study groups were found to be comparable, with no statistically significant differences observed in age, gender distribution, anthropometric parameters (weight, height, BMI), ASA grading, or duration of surgery (Table 1). This suggests that the two cohorts were appropriately matched, ensuring the reliability of subsequent comparisons regarding anesthetic techniques.

Table 1: Basic profile of study patients

Variable	Group A (n = 62)	Group B (n = 62)	P value
Age (years)	45.12 ± 13.78	42.65 ± 11.84	0.75
Gender (M/F)	51 / 11	47 / 15	0.66
Weight (kg)	60.45 ± 9.33	63.11 ± 7.24	0.25
Height (cm)	158.02 ± 9.11	153.89 ± 8.12	0.58
BMI (kg/m²)	22.87 ± 3.68	23.32 ± 3.91	0.33
ASA (Grade 1/2/3)	35 / 25 / 2	46 / 16 / 0	0.11
Duration of Surgery (min)	39.83 ± 5.42	37.52 ± 4.03	0.13

Evaluation of heart rate trends demonstrated a significantly higher mean heart rate in Group A (General Anesthesia) at baseline and from 15 minutes post-insufflation up to 10 minutes after exsufflation when compared to Group B (Segmental Spinal Anesthesia) (Table 2). This pattern indicates greater hemodynamic stability under segmental spinal anesthesia, as reflected by the consistently lower heart rates throughout the perioperative period in Group B.

Table 2: Comparison of heart rate (beats/min) between the study groups

Time (min) since insufflation	Group A (Mean ± SD)	Group B (Mean ± SD)	P value
0 min	107.25 ± 21.55	87.53 ± 16.52	<0.05
5 min (during insufflation)	93.81 ± 24.93	86.41 ± 13.27	0.47
10 min	87.54 ± 15.21	92.03 ± 14.18	0.16
15 min	86.88 ± 14.09	94.06 ± 12.83	<0.05
20 min	85.12 ± 14.09	94.55 ± 12.14	<0.05
30 min	81.72 ± 12.28	94.03 ± 10.72	<0.01
40 min	80.09 ± 10.71	93.88 ± 11.25	<0.01
At exsufflation	76.99 ± 10.95	94.51 ± 12.09	<0.01
10 min after exsufflation	77.61 ± 10.92	95.82 ± 10.13	<0.01

Systolic blood pressure (SBP) measurements revealed that Group B maintained significantly higher values from the point of insufflation through the postoperative phase, with all time points except baseline reaching statistical significance (Table 3). This consistent difference emphasizes the more stable systolic profile associated with segmental spinal anesthesia during laparoscopic procedures.

Table 3: Comparison of SBP (mmHg) between the study groups

Variable	Group A (Mean ± SD)	Group B (Mean ± SD)	P value
0 min	137.85 ± 16.75	126.25 ± 16.94	0.06
5 min (during insufflation)	108.14 ± 17.46	120.03 ± 13.07	<0.01
10 min	97.61 ± 18.29	122.15 ± 17.33	<0.01
15 min	99.82 ± 21.37	127.82 ± 17.31	<0.01
20 min	97.14 ± 13.18	128.55 ± 16.12	<0.01
30 min	101.46 ± 10.02	129.87 ± 13.23	<0.01
40 min	99.78 ± 10.59	128.03 ± 11.51	<0.01
At exsufflation	99.93 ± 9.38	129.67 ± 10.94	<0.01
10 min after exsufflation	100.94 ± 11.76	128.46 ± 11.03	<0.01

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Similarly, diastolic blood pressure (DBP) readings were significantly elevated in Group B compared to Group A across all intraoperative and postoperative time points, barring the initial baseline value (Table 4). These findings collectively support the conclusion that patients receiving segmental spinal anesthesia experienced more stable hemodynamic parameters, particularly in relation to arterial pressure control.

Table 4: Comparison of DBP (mmHg) between the study groups

Variable	Group A (Mean ± SD)	Group B (Mean ± SD)	P value
0 min	79.96 ± 21.33	82.42 ± 10.14	0.48
5 min (during insufflation)	62.47 ± 15.13	76.90 ± 8.12	<0.01
10 min	61.25 ± 13.65	76.98 ± 13.96	<0.01
15 min	59.38 ± 15.33	82.09 ± 12.01	<0.01
20 min	61.78 ± 10.54	75.91 ± 20.68	<0.01
30 min	63.44 ± 9.13	82.37 ± 15.11	<0.01
40 min	64.55 ± 8.79	81.12 ± 11.01	<0.01
At exsufflation	65.71 ± 9.53	81.97 ± 9.12	<0.01
10 min after exsufflation	68.23 ± 9.21	82.64 ± 9.64	<0.01

Assessment of adverse events (Table 5) further highlighted distinct profiles for each anesthetic approach. Group A experienced a significantly higher incidence of intraoperative hypotension, while Group B reported increased cases of intraoperative hypertension. Postoperatively, abdominal pain and sore throat were significantly more common in Group B, potentially attributable to the systemic effects and airway manipulation associated with general anesthesia. However, occurrences of nausea, vomiting, shoulder pain, urinary retention, headache, and backache were comparable between groups, with no statistically significant differences noted.

Table 5: Comparison of adverse effects between the study groups

Adverse Effect	Group A	Group B	P value
Intraoperative			
Hypotension	20	0	<0.01
Bradycardia	4	0	0.28
Hypertension	0	30	<0.01
Postoperative			
Abdominal pain	0	16	<0.01
Sore throat	0	10	<0.05
Nausea/vomiting	5	6	1
Shoulder pain	2	4	1
Urinary retention	5	2	0.69
Headache	2	0	0.49
Backache	1	0	1

Table 6: Surgeon's rating of ease of surgery [24]

Surgeon's Opinion (Ease of Procedure)	Group A (n = 62)	Group B (n = 62)
No difficulty	60	61
Slight difficulty	2	1
Moderate difficulty	0	0

DISCUSSION

A review of existing literature highlights that Van Zundert et al. (2007) provided early insights into the utility of thoracic segmental spinal anesthesia (TSSA) for laparoscopic cholecystectomy (LC), reporting favorable outcomes in a cohort of 20 healthy individuals, with minimal associated adverse effects. He also noted that cardiovascular perturbations could be more pronounced in elderly individuals or those with underlying comorbid conditions [16]. Although numerous investigations have examined the differences between general anesthesia (GA) and spinal anesthesia in LC, studies specifically comparing TSSA with GA remain limited [2,3]. Ellakany (2013) and Paliwal et al. (2020) both conducted such comparative evaluations and found TSSA to be a viable alternative [4,5]. Our findings align closely with the results observed in these prior studies.

In GA, both mechanical factors and neurohumoral responses contribute to elevated arterial pressure. Abdominal insufflation leads to increased systemic vascular resistance through reflex mechanisms, while CO_2 absorbed from the peritoneal cavity stimulates the sympathetic nervous system [1,17]. The observed decline in systolic blood pressure following

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exsufflation is attributed to the cessation of the pressor effects induced by pneumoperitoneum. Tachycardia is frequently observed as a compensatory response to reduced venous return and diminished cardiac output, and is further amplified by hypercarbia and catecholamine release due to CO_2 insufflation [18,19].

Conversely, neuraxial blockade such as TSSA effectively blunts the neuroendocrine response to surgical stimuli, thereby conferring superior hemodynamic control. The sympathetic block across thoracic levels T4–L1 results in splanchnic venous pooling, mitigating hypertensive responses. Moreover, the preservation of lower sympathetic segments limits excessive hypotensive effects. The absence of CO_2-induced hypercarbia in patients undergoing TSSA contributes to enhanced cardiovascular stability [4,5]. Central respiratory regulation remains intact during TSSA, and the physiological rise in respiratory rate ensures effective CO_2 elimination. The diaphragm, innervated by the C3–C5 roots, remains unaffected, allowing preserved inspiratory function. Since expiration is largely passive, only forceful exhalation and coughing may be transiently impaired due to intercostal muscle blockade. This motor block is typically brief, attributable to the use of low-dose isobaric agents [8,9]. Previous evidence suggests that larger volumes of local anesthetics may adversely impact ventilation, especially in chronic obstructive pulmonary disease (COPD) patients, where active expiration is crucial [4,16,20].

In LC procedures, maintaining a controlled intra-abdominal pressure (IAP) is crucial to permit optimal diaphragmatic excursion. Elevated IAP may also elicit vagally mediated bradycardia. To minimize such risks, the insufflation rate of CO_2 should ideally be restricted to 5–6 L/min, with IAP maintained below 14 mmHg and only a modest anti-Trendelenburg tilt applied intraoperatively [17–19].

Several reports have explored the frequency of paraesthesia and neurological sequelae associated with TSSA. Imbelloni et al. (2010) documented paraesthesia in 6.6% of cases during low thoracic spinal needle placement; however, no permanent neurological impairments were reported [20]. Paraesthesia is typically indicative of direct needle contact with neural structures. At mid-thoracic levels, the posterior subarachnoid space is relatively deeper (T5 $\approx$ 5.8 mm) compared to upper (T2 $\approx$ 3.9 mm) and lower (T10 $\approx$ 4.1 mm) thoracic segments. The angulated needle trajectory at 45°, necessitated by the spinal curvature at mid-thoracic levels, further increases the needle's traversal distance. MRI-based evaluations by Imbelloni corroborated these findings, confirming a greater depth of the posterior subarachnoid space in mid-thoracic regions compared to lumbar and upper thoracic levels [21-23].

CONCLUSION

The findings of this investigation demonstrated that thoracic segmental spinal anaesthesia offered superior haemodynamic stability and ease of doing surgery and was associated with a lower incidence of adverse effects in comparison to general anaesthesia, suggesting its feasibility and effectiveness as an alternative anaesthetic technique for laparoscopic cholecystectomy in appropriately selected patients under the care of skilled anaesthesiologists.

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