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ORIGINAL ARTICLE

Safety and Efficacy of Thoracic Segmental Spinal Anesthesia Using Fentanyl and Dexmedetomidine as Adjuvants to Ropivacaine in Patients Undergoing Laparoscopic Cholecystectomy: A Prospective Randomized Comparative Study

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Abstract

Background: Segmental thoracic spinal anesthesia (STSA) is gaining attention as an alternative to general anesthesia as advanced regional technique that targets specific segment (dermatomes) to provide precise anesthesia in laparoscopic procedures.The present study aimed to compare efficacy and safety of Thoracic Segmental Spinal Anesthesia using fentanyl and dexmedetomidine as adjuvants to Ropivacaine in patients scheduled forlaparoscopic cholecystectomy. **Methods:** Seventy patients were divided randomly into two groups (n=35 each): Group F received hyperbaric and isobaric ropivacaine with fentanyl; Group D received the same with dexmedetomidine. Primary objective was to assess sensory block characteristics and secondary objective was to evaluate the onset of motor block, incidence of adverse effects like hypotension and bradycardia, and patient satisfaction (using Likert scale). **Results:** Both groups showed similar onset times. Group D had significantly longer sensory block duration (223.2 min vs. 163.4 min, $p < 0.001$). Bradycardia and hypotension were more frequent in Group D. Patient satisfaction was higher in Group D ($p=0.027$). **Conclusion:** Dexmedetomidine provided prolonged analgesia and higher satisfaction but was associated with greater incidence of bradycardia and hypotension.

Key Words

Thoracic Spinal Anesthesia, Laparoscopic Cholecystectomy, Ropivacaine, Fentanyl, Dexmedetomidine, Segmental Block, Neuraxial Anesthesia.

Introduction

Segmental thoracic spinal anesthesia is a feasible alternative to general anesthesia, particularly in high-risk patients undergoing laparoscopic cholecystectomy.[1] Unlike traditional spinal anesthesia, thoracic segmental spinal anesthesia targets the specific thoracicdermatomes relevant to the surgical field, allowing for a more focused and tailored anesthetic effect with a lower dose of drugs required and hence fewer side effects.[2] This technique offers potential benefits, including improved hemodynamic stability,early bladder control,effective postoperative analgesia and shorter recovery time.

Thoracic spinal anesthesia has been performed for

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various surgical procedures including abdominal cancer surgery, open nephrectomy, etc.[3] It has been utilized by anesthetists as an alternative anesthetic technique for numerous surgical procedures when general anesthesia posed a higher risk to the patient.[4]

The present study was formulated to assess the efficacy and safety using Fentanyl and Dexmedetomidine as adjuvants to Ropivacaine in patients undergoing Laparoscopic Cholecystectomy under segmental spinal anaesthesia. Hyperbaric Ropivacaine offers faster onset and better quality of blockwhile, addition of isobaric ropivacaine offers slow and evenly spread of drug resulting in long lasting block.[5] Addition of adjuvants like Fentanyl or Dexmedetomidine enhances the block characteristics making it more effective anesthetic technique for high risk patients. **Primary objective** was to assess sensory block characteristics and **secondary objective** was to evaluate the onset of motor block, incidence of adverse effects and patient satisfaction.

Material and Methods

This was a prospective, randomized, comparative clinical study conducted in the tertiary care institute. The study period spanned one year from May 1, 2024 to April 30, 2025, following approval from the Institutional Ethics Committee IEC/GMCJ/1819 dated 07-06-2024.Written informed consent was obtained by all participants before enrollment.

Sample size calculation

Using G*Power software (version 3.0.10), sample size was calculated based on an effect size of 0.4, a power of 90%, and a significance level of 5%. It was determined that a minimum of 34 patients per group was required. Thus, a total of 70 patients were included and randomly divided into two groups (n=35 per group).

Inclusion Criteria

- Age between 25 and 55 years
- ASA (American Society of Anesthesiologists) physical status I or II
- Scheduled for elective laparoscopic cholecystectomy

Exclusion Criteria

- ASA physical status III or IV
- Cardiovascular diseases (e.g., active heart block, fixed cardiac output lesions, ejection fraction <45%)
- Coagulopathy or bleeding disorders
- Infection at the site of spinal injection
- Spine deformities detected on preoperative imaging
- Motor neuron disease
- Pregnancy
- Patient refusal

Patients were randomly assigned to two equal groups (n=35 each) using a computer-generated randomization schedule.Group F (Fentanyl Group) received 0.5 ml of 0.5% hyperbaric ropivacaine + 12.5 µg fentanyl, followed by 1.2 ml of 0.75% isobaric ropivacaine + 12.5 µg fentanyl, making it a total volume of 2.2 ml.Group D (Dexmedetomidine Group) received 0.5 ml of 0.5% hyperbaric ropivacaine with 5µg dexmedetomidine, followed by 1.2 ml of 0.75% isobaric ropivacaine with 5 µg dexmedetomidine, making the total volume of 2.2 ml.

All patients underwent pre-anesthetic evaluation and were advised to fast for at least 8 hours before surgery. They were premedicated with tablet *al*prazolam 0.5 mg (the night before surgery) and tablet Pantoprazole 40 mg (morning of surgery with a sip of water).In the operating room, patients were monitored using Non-invasive blood pressure (NIBP), Electrocardiogram (ECG), and Pulse oximeter (SpO_2). An 18-G or 20G intravenous cannula was secured, and Ringer's Lactate (10 ml/kg) was infused over 30 minutes for preload.

Under strict aseptic precautions, with the patient in the sitting position,the T_8–T_{10} interspace was identified (T7: inferior angle of scapula; T8–T10: one- two spaces below). The area was infiltrated with 3 ml of 2% lidocaine. A 25G/26G Quincke spinal needle was inserted midline. Upon visualization of free-flowing cerebrospinal fluid (CSF), the appropriate intrathecal drug (as per group allocation) was administered. Patients were immediately placed in a supine position without any tilt.

Block Assessment was done.Sensory block was tested using swab method for loss of cold sensation at 2-minute intervals until the peak level was reached.Peak levels of sensory and motor block were defined as consistent block levels over 4 consecutive readings.Heart rate and NIBP were recorded every 2 minutes for the first 10 minutes, then every 5 minutes until the end of surgery. Hypotension with $\geq$20% drop from baseline SBP was treated with IV fluids, and Injection Mephentermine 6 mg IV (incremental) was given.Heart rate less than 50 bpm was treated with Injection Atropine 0.6 mg IV. Patient was sedated with Midazolam 1 mg IV, and additional fentanyl (25 µg IV) if needed was given for shoulder pain. Laparoscopic cholecystectomy performed with pneumoperitoneum at 8–10 mm Hg.Inj. Diclofenac 75 mg IM was given as rescue analgesia postoperatively.

Outcome Measures were recorded. The Primary outcome included the time of onset and duration of sensory block. Secondary outcomes included onset of motor blockade, incidence of side effects and patient satisfaction assessed postoperatively using Likert scale.

Statistical Analysis

The recorded data were compiled and entered in a

spreadsheet (Microsoft Excel) and then exported to the data editor of SPSS Version 20.0 (SPSS Inc., Chicago, Illinois, USA). Frequencies and percentages were used to summarise categorical variables, while Mean ± SD was used to represent continuous variables. Bar and line diagrams were used to graphically display the data. The data's normality was examined using the Shapiro-Wilk test. For comparing continuous variables, the Mann-Whitney U-test or the Student's independent t-test, whicheverpractical, was used. When comparing categorical variables, chi-square test or Fisher's exact test was used as applicable. P-values below 0.05 was considered statistically significant.

Results

Table-1 depicts the demographic characteristics for both groups. No statistically significant differences were observed between Group F and Group D in any demographic parameter (p>0.05).

Table 2 summarizes the onset times for sensory and motor blockade. No statistically significant differences were found between the groups. However, A statistically significant difference was observed in sensory block duration, with longer duration observed in Group D.

Figure 1 shows significant differences in intra-operative heart rates between Group F and Group D. Heart rates varied during the procedure, with significant differences at all measured time points. Overall, a statistically significant difference ($p < 0.001$) was observed, indicating a greater decrease in heart rate for Group D compared to Group F.

Fig. 2 shows significant differences in intra-operative mean arterial blood pressure (MAP) between Group F and Group D at various times. Significant differences in MAP were observed throughout the procedure, with Group D showing a greater decrease compared to Group F ($p < 0.05$).

Table 3 compares side effects in two groups.In group Fnausea and vomiting occurred in 22.9% of Group F and 17.1% in Group D ($p = 0.551$). Bradycardia was found in 20% of Group F and 65.7% of Group D ($p < 0.001$). Hypotension was seen in 25.7% of Group F and 71.4% of Group D ($p < 0.001$). No patients in either group experienced respiratory depression. Pruritus was present in 2.9% of Group F but none in Group D ($p = 1.000$). Shoulder tip pain was observed in 1 patient in group F but none in Group D which was stastically not significant.

Discussion

An extension of traditional spinal anesthesia is segmental thoracic spinal anesthesia (STSA), where a spinal anesthetic is injected at a low or mid-thoracic level to facilitate upper abdominal and thoracic surgery. It has

Table 1: Demographic characteristics of patients in two groups

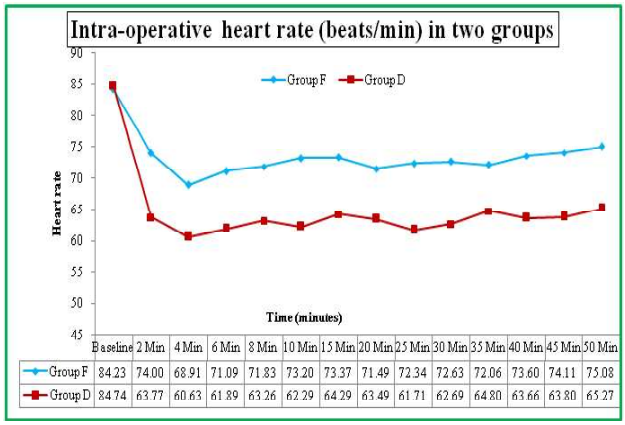
Parameter	Group F (n=35)	Group D (n=35)	p-value
Age (years)	38.7 ± 9.83	39.5 ± 10.59	0.726
Gender Male Female	 13 (37.1%) 22 (62.9%)	 11 (31.4%) 24 (68.6%)	0.615
Weight (kg)	65.4 ± 3.51	64.5 ± 3.76	0.297
ASA Status ASA I ASA II	 27 (77.1%) 8 (22.9%)	 29 (82.9%) 6 (17.1%)	0.309

Statistical methods used Unpaired t-test for age and weight Chi-square test for gender and ASA status

Table 2: Block characteristics of patients in two groups

Blockade Type	Group F (mean ± SD in minutes)	Group D (mean ± SDin minutes)	p-value
Onset of Sensory block	6.05 ± 0.234	5.94 ± 0.197	>0.001
Onset of Motor block	4.41 ± 0.168	4.34 ± 0.176	0.204
Duration of sensory block	163.4 ± 12.71	223.2 ± 16.64	<0.001

Statistical methods used -Unpaired student's t-test



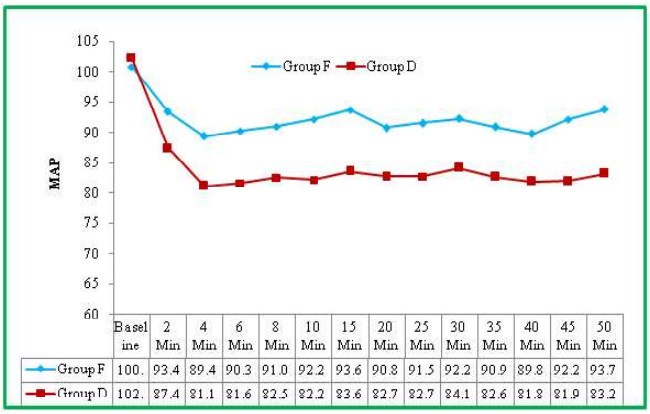
Statistical methods used- ANOVA test

Fig.1 : Intra-operative Heart Rate (Beats/ Min) in two groups

Table 2. Outcome parameters in two groups

Parameter	Group F (n=35, %)	Group D (n=35, %)	p-value
Side Effects			
Nausea and Vomiting	22.9	17.1	0.551
Bradycardia	20.0	65.7	<0.001
Hypotension	25.7	71.4	<0.001
Respiratory Depression	0	0	-
Pruritus	2.9	0	1.000
Shoulder Tip Pain	2.9	0	1.0
Patient Satisfaction (Likert Scale)			
Not satisfied or satisfied	2 (5.7%)	0 (0 %)	0.027
Satisfied	10 (28.6%)	3 (8.6%)	
Totally satisfied	23 (65.7%)	32 (91.4%)	

Statistical methods used- Chi-square test/Mann-Whitney U test.



Statistical methods used- ANOVA test

Fig. 2: Intra-operative MAP (mmHg) in two groups

been used as an alternative anesthetic technique for various surgical procedures when general anesthesia posed a higher risk to the patient.[4] Regardless of baricity, the thoracic spinal puncture at T8–T10 demonstrated a quick onset of action, a lower incidence of hypotension with a quicker block recovery, a low incidence of paraesthesia, and no spinal cord damage.[6]

Main issues related to segmental spinal include neuronal injury, respiratory involvement and cephalad spread of local anesthetic drugs leading to high or total block.[7,8] Imbelloni and Gouveia conducted a study using MRI observed that mid to lower thoracic segment of spinal cord lies anteriorly leaving sufficient space between posterior dura and cord, while lumbar spinal cord lies dorsally. Hence, there are very low chances of neurological injuries after thoracic segmental spinal. Regarding respiratory involvement, forceful expiration and coughing may get affected because of paralysis of anterior abdominal muscles. Bradycardia and hypotension may result from a compromised cardioaccelerator fibre (T1–T5), but the outflow from intrinsic chronotropic stretch receptors in the right atrium is sustained because lumbosacral sparing and reduced venodilation in the lower limbs maintain right atrial filling pressure.[6]

Shoulder tip pain was a common side effect observed in laparoscopic cholecystectomywhich was attributed to subdiaphragmatic irritation.[9] Techniques to reduce shoulder tip pain include avoiding excessive carbon dioxide pressure (<12 mmHg) for pneumoperitoneum and avoiding excessive head-down tilts. This reduces the diaphragmatic stretching and referred pain.[10]

This study compared the efficacy and safety of thoracic segmental spinal anesthesia (TSSA) using fentanyl or dexmedetomidine as intrathecal adjuvants to ropivacaine in patients undergoing laparoscopic cholecystectomy. Both techniques proved clinically viable; however, distinct differences were observed in block characteristics, hemodynamic parameters, side effects, and patient satisfaction.

The onset times for both sensory and motor blocks were statistically similar between the two groups. This suggests that the addition of either adjuvant does not significantly impact the rapidity of onset when combined with ropivacaine in thoracic segmental spinal anesthesia. This is consistent with the findings of Singhal *et al*., who also reported a median sensory block onset time of approximately 5 minutes using TSSA. However, the duration of sensory block was significantly prolonged in Group D (dexmedetomidine) compared to Group F (fentanyl). Similar observations were reported by Singhal *et al*, reinforcing that intrathecal dexmedetomidine enhances block duration without causing significant sedation or respiratory depression.[11]

One of the notable findings was the greater hemodynamic suppression in Group D. Patients receiving dexmedetomidine exhibited significantly lower heart rates

and blood pressure throughout the intraoperative period, with a higher incidence of bradycardia (65.7%) and hypotension (71.4%). These effects are pharmacologically expected due to dexmedetomidine's central sympatholytic activity.This is consistent with other studies, such as Singhal *et al* and Gupta *et al*, who also reported increased but treatable bradycardia and hypotension with dexmedetomidine.[11,12]

Pruritus occurred in 2.9% of Group F patients and none in Group D patients, but this difference was not statistically significant (p=1.000). Kumar K *et al.* concluded in his study that the duration of neuraxial opioid-induced pruritus induced by lipid-soluble opioids, including fentanyl and sufentanil, is shorter, and the prevalence and intensity of itching appear to be reduced by using the lowest effective dosage and adding local anaesthetics.Pruritus invoked by lipid-soluble opioids such as fentanyl is of shorter duration and use of minimum effective dose and addition of local anesthetics seems to decrease the prevalence and the severity of itching.[13]

In our study, in Group F, 65.7% of the patients were totally satisfied as compared to 91.4 % in Group D patients,which is statistically significant (p=0.027). Chandra R *et al* in their studyof Thoracic Spinal Anesthesia for laparoscopic cholecystectomy also found that the majority of patients (94.0%) were very satisfied with the procedure and were comfortable during surgery with a quick postoperative recovery, which was consistent with our findings.[1] Quality of postoperative analgesia is better in segmental spinal as also observed by Paliwal *et al*.[14,15]

Conclusion

Thoracic segmental spinal anesthesia with dexmedetomidine as an adjuvant to ropivacaine provides longer sensory blockade and higher patient satisfaction than fentanyl but was associated with increased incidence of hypotension and bradycardia. Patient selection and monitoring are essential.

Limitations of the study

It was a single center study with a small sample size (n = 70). A large sample size is required to confirm and validate the findings of our study. Also, the study focused only on laparoscopic cholecystectomy surgeries, which may not be representative of other types of surgeries or patient population.

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Conflict of Interest: Nil

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