Original Article

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Dosage of Local Anaesthetic Drug in Spinal Anaesthesia Based on Dural Sac Cross-sectional Area Measured Using Ultrasound for Transurethral Resection and Inguinal Hernia Surgeries: A Double-blinded, Randomised Controlled Study

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ABSTRACT

Introduction: Geriatric patients undergoing surgical procedures such as Transurethral Resection of the Prostate (TURP) and inguinal hernia repair often face an increased risk of complications due to age-related anatomical and physiological changes. The Dural Sac Cross-sectional Area (DSCSA) has been proposed as a parameter to optimise the dosage of local anesthetics in spinal anaesthesia, aiming to achieve effective sensory blockade while minimising haemodynamic instability.

Aim: To determine the minimum required dose of intrathecal bupivacaine based on DSCSA for achieving a T10 sensory blockade in elderly patients undergoing TURP and inguinal hernia repair.

Materials and Methods: This was a double-blinded, randomised controlled study conducted on 70 geriatric patients {American Society of Anaesthesiology (ASA) I and II} undergoing TURP or inguinal hernia repair at Dr. DY Patil Medical College and Research Centre, Pune, Maharashtra, India from July to November 2024. Patients were randomly allocated into two groups: the Control (C) group, which received a fixed dose of 10 mg hyperbaric bupivacaine, and the Ultrasound (U) group, where DSCSA was measured using ultrasound at the L3-L4 level, and the bupivacaine dosage was adjusted accordingly. Haemodynamic parameters, sensory blockade levels, motor block duration, and two-segment regression times were analysed. Data normality was assessed using the Shapiro-Wilk test, with quantitative variables compared using the independent t-test, qualitative variables analysed using the Chi-square test or Fisher's exact test, and a p-value <0.05 considered statistically significant.

Results: Baseline characteristics such as age, height, weight, ASA grade, and surgery duration were comparable between groups (p>0.05). The mean DSCSA in the U group was 120.03±12 mm^2, with a calculated mean dose of 7.99±0.77 mg bupivacaine, significantly lower than the fixed 10 mg in the C group (p<0.0001). The highest sensory level reached was T8 in the U group and T4 in the C group (p=0.004). The U group had a significantly shorter motor block duration (157.23±11.92 min vs. 199±21.86 min, p<0.0001) and two-segment regression time (52.5±13.44 min vs. 62.64±14.49 min, p=0.003). The C group experienced a greater decrease in Mean Arterial Pressure (MAP) (p<0.0001) with a higher need for vasopressor support.

Conclusion: Tailoring the intrathecal bupivacaine dosage based on DSCSA significantly reduces the risk of excessive cephalad spread, minimising haemodynamic fluctuations while maintaining adequate anaesthesia. Ultrasound-guided DSCSA measurement can serve as a valuable tool for optimising spinal anaesthesia in geriatric patients.

Keywords: Elderly population, Haemodynamic stability, Neuraxial blockade, Subarachnoid space dimensions

INTRODUCTION

Geriatric patients often present with multiple comorbidities, including hypertension, coronary artery disease, diabetes mellitus, Alzheimer's disease, and Benign Prostatic Hyperplasia (BPH), all of which significantly contribute to poor health in the elderly. BPH is particularly common in geriatric men, with its incidence rising with age [1]. Surgical intervention is the primary treatment for BPH, with TURP being the procedure of choice. However, TURP can lead to complications such as capsular perforation and TURP Syndrome (TURS). TURS manifests with symptoms like hyponatremia, altered blood pressure, bradycardia, and altered sensorium, which are easier to detect when the patient is conscious [2]. For this reason, Spinal Anaesthesia (SAB) is generally preferred over general anaesthesia for TURP, as it allows for better intraoperative monitoring of these complications. Despite this advantage, the high prevalence of comorbidities in elderly patients increases the risk of perioperative morbidity and mortality [3,4].

The urinary bladder is innervated by both sympathetic and parasympathetic nerves. Sympathetic fibers (T11-L2) carry pain signals caused by bladder distension, while parasympathetic fibers (S2-S4) transmit stretch sensations. For procedures involving the bladder, a sensory block up to the T10 level is adequate. However, raising the block above T10 can obscure signs of capsular perforation and may lead to hypotension, which can be detrimental to patient health, particularly in the elderly [3]. Inguinal hernia is also a common condition, and open inguinal hernia repair is one of the most frequently performed surgeries. The inguinal canal is supplied by the ilioinguinal (L1) and genitofemoral (L1-L2) nerves, while the iliohypogastric nerve (L1) provides sensation to the overlying skin. The spermatic cord is innervated by the cremasteric nerve (L1-L2), sympathetic fibers (T10-L1), and parasympathetic fibers (S2-S4). A sensory block up to T10 is sufficient for performing hernia repair [5].

Hypotension is the most common complication following SAB, particularly in elderly patients with age-related comorbidities, where a 25% reduction in systemic vascular resistance can significantly impair vital organ function. Therefore, optimising the dosage of local anesthetics for subarachnoid block is essential to minimise this risk [6]. For TURP surgery, achieving an optimal intrathecal anesthetic dosage ensures sufficient sensory blockade, preventing the bladder traction response while reducing the incidence of hypotension and bradycardia caused by an excessive thoracic block. In elderly patients, a sensory block limited to the T10 level is typically sufficient to provide effective anaesthesia while reducing the risk of haemodynamic disturbances. The extent of local anesthetic spread in the subarachnoid space is largely determined by its concentration and volume, underscoring the importance of precise dose optimisation. Administering only the minimum dose necessary to achieve the desired block level is essential, as spinal anaesthesia-induced hypotension in this population is primarily attributed to a decrease in stroke volume [7]. Subarachnoid Block (SAB) poses unique challenges in the elderly due to age-related anatomical and physiological changes. These include structural abnormalities like spinal canal stenosis, foramen stenosis, etc., and functional changes such as a decline in neuronal density, which become more pronounced with advancing age [3].

In geriatric patients, the prevalence of lumbar central canal stenosis is notably higher [8], often resulting from degenerative processes such as spondylolysis, spondylolisthesis, and age-related changes in the vertebral bodies and intervertebral discs [9,10]. As a result, the DSCSA has become a valuable and sensitive metric for evaluating the severity of lumbar spinal canal stenosis. It is measured using ultrasound imaging by calculating the distance between the sagittal anterior complex and the posterior complex of the dura [11,12]. A reduction of >30% in the DSCSA has been reported in previous studies [3,13,14]. It is important to anticipate that local anesthetics may spread more cephalad due to the reduced space within the spinal canal. Experienced anesthesiologists often tailor the dosage of intrathecal anesthetics to the patient's age, comorbidities, and procedure requirements to avoid excessive blockade and minimise haemodynamic instability and associated complications [15]. We hypothesised that DSCSA is an effective parameter for modifying the dosage of spinal anaesthesia to achieve a T10 sensory blockade in geriatric patients undergoing TURP and inguinal hernia repair. Given the increasing adoption of advanced imaging techniques like ultrasound and MRI, we noted a lack of sufficient studies exploring this approach [3,6]. Therefore, further research in this area is crucial to optimise spinal anaesthesia practices in geriatric patients. The aim of our study was to determine the minimum required dose of local anesthetic in spinal anaesthesia, tailored to the DSCSA, to achieve a T10 blockade in elderly patients. The primary objectives were to compare the sensory level, motor block duration, and two-segment regression time between groups. The secondary objective was to compare intraoperative MAP and Heart Rate (HR) between the ultrasound (U) group and the control (C) group.

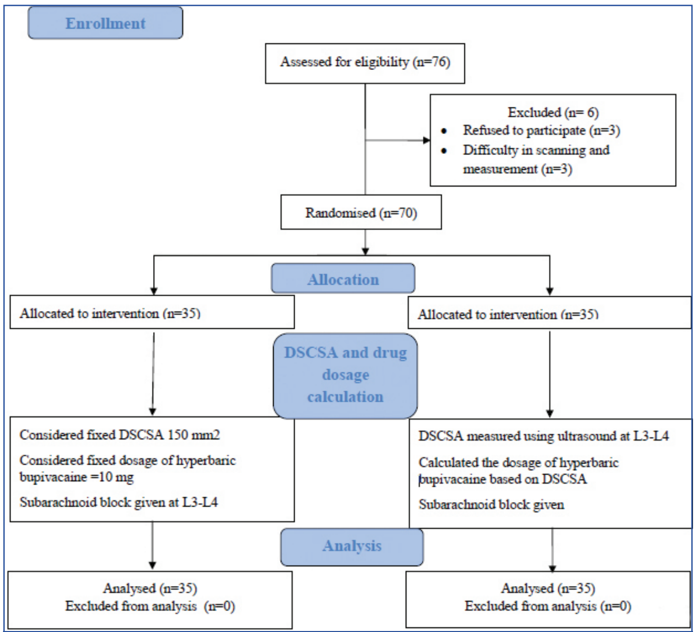
MATERIALS AND METHODS

This was a randomised controlled study conducted at Dr. DY Patil Medical College and Research Centre, Pune, Maharashtra, India, which is a tertiary care centre, over a six-month period from July to November 2024. The study was conducted after obtaining approval from the Institutional Ethics Committee (research protocol no. IESC/FP/81/2023), followed by CTRI approval (registration no. CTRI/2024/06/068376). The procedure was explained to the patients, and written consent was obtained.

Sample size calculation: According to a study conducted by Pula R et al., the required sample size for this study was N=70 (35 in each group) with respect to an error probability of 0.05 and 0.8 power, and an error probability of 7% [6]. The sample size was calculated using G*Power V 3.1.9.4.

Inclusion and Exclusion criteria: The inclusion criteria were age >60 years, and ASA I and II patients were included. The exclusion criteria were: patient refusal for enrollment, infection at the site of injection, patients on anticoagulant therapy, patients with raised intracranial pressure, and ASA IV patients. A total of 76 patients were assessed for eligibility (n=76), out of which six were excluded (n=6).

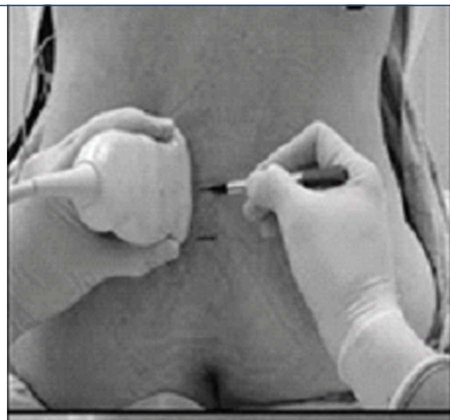
Out of the 76 patients who were undergoing surgical procedures considered for our study, three patients declined to participate, and scanning was difficult, making it impossible to measure DSCSA in two patients. Ultimately, the study was conducted on 70 patients who were randomly assigned to the ultrasound group and the control group, with 35 patients in each group. Patients were divided into two groups by computer-generated simple balanced randomisation using WINPEPI software version 11.65 [Table/Fig-1].



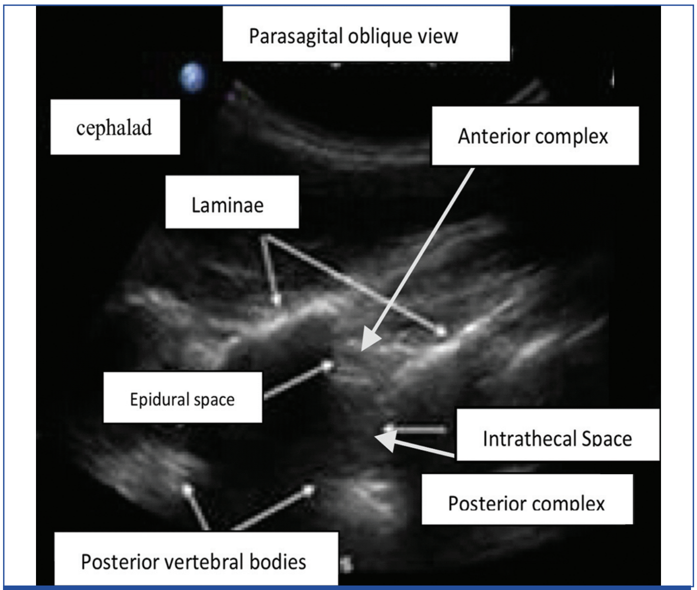
[Table/Fig-1]: Study flowchart.

Study Procedure

All relevant investigations were performed. All patients were secured with an 18 G intravenous (i.v.) cannula and preloaded with 500 ml of Ringer's Lactate (RL). All required monitors were attached to the patients. In group U (USG), the sagittal anteroposterior diameter of the dural sac was measured at the L3-L4 space in a sitting position by ultrasound before spinal anaesthesia [Table/Fig-2,3]. For the control group, a baseline dose of 10 mg of hyperbaric bupivacaine was used, assuming the DSCSA to be 150 mm^2. The dosage of hyperbaric bupivacaine was optimised in group U according to the DSCSA measured using the formula $A=\varpi\times r^2$ (or) $\varpi\times(D/2)^2$ [1]. (A=Area of the dural sac cross-sectional area, r=radius of dural sac, D=diameter of dural sac). A reduction in the dose of



[Table/Fig-2]: Measuring sagittal anteroposterior diameter of the dural sac at L3-L4 space in sitting position by ultrasound



[Table/Fig-3]: Ultrasound image showing anterior complex and posterior complex.

hyperbaric bupivacaine was calculated mathematically based on the proportionate reduction in area (for example, if we are using 10 mg for a 150 mm^2 area, the drug dosage for a calculated area of 'A' mm^2 is 'X'. Then X=A (in mm^2)×10/150). Ultrasound imaging was performed using the HITACHI ARIETTA 570 model by an operator with 10 years of experience in regional anaesthesia and neuraxial ultrasound techniques.

Using a 26 G Quincke Babcock spinal needle, a subarachnoid block was given at the L3-L4 intervertebral space with Injection Bupivacaine 0.5% heavy (10 mg for control group patients and the calculated amount of drug for the ultrasound group) in a sitting position under all aseptic precautions.

The Modified Bromage scale was used every 2.5 minutes after spinal anaesthesia to measure the motor block until fixation of the level (1- complete block; 2- almost complete block; 3- partial block; 4- detectable weakness of hip flexion; 5- no weakness at hip flexion; 6- normal ability to perform knee flexion). Sensory blockade levels for the patients were measured every 2.5 minutes up to 30 minutes, and every 15 minutes until the end of surgery. MAP and HR were measured every 2.5 minutes for up to 20 minutes, then every five minutes until 30 minutes, and were measured every 15 minutes until the end of surgery or until two-level regression.

The surgeon was requested to commence the surgical procedure once the sensory block had extended to the T10 level. If the patient began to complain of pain, fentanyl 1 μg/kg was administered intravenously.

STATISTICAL ANALYSIS

Data normality was checked using the Shapiro-Wilk test. The comparison of quantitative variables was analysed using the Independent t-test. The comparison of qualitative variables was analysed using the Chi-square test. If any cell had an expected value of less than 5, Fisher's exact test was used. For statistical significance, a p-value of less than 0.05 was considered statistically significant. Data entry was performed in Microsoft Excel, and the final analysis was conducted using the Statistical Package for Social Sciences (SPSS) software, IBM manufacturer, Chicago, USA, version 25.0.

RESULTS

Age, height, weight, ASA grading, and duration of surgery were compared between the control (C) group and the ultrasound (U) group [Table/Fig-4]. The mean dural sac cross-sectional area in the ultrasound group was 120.03±12 mm^2 (p<0.0001), and the calculated mean dose of bupivacaine was 7.99±0.77, which was significantly lower compared to the control group with a constant area of 150 mm^2 and a dose of 10±0 mg, with a p-value <0.0001 [Table/Fig-5]. The highest level of sensory blockade (T4) was observed in group C. The proportion of patients with the maximum sensory level blocked at T4 and T6 was significantly lower in group U compared to group C (T4: 0% vs. 8.57%, T6: 0% vs. 11.43%) (p-value=0.004). However, group U had a significantly higher proportion of patients with the maximum sensory level blocked at T8 (37.14% vs. 11.43%) [Table/Fig-6]. The time taken for the maximum sensory level block was 11.7±1.82 minutes in group U and 13.07±1.7 minutes in group C, with a p-value of 0.866. The time taken for complete motor block (Bromage score=1) in the control group was 5±2.5 minutes, and in the ultrasound group, it was 7±2.5 minutes. The time taken for complete motor block was significantly faster in the control group compared to the ultrasound group, with a p-value=0.001 [Table/Fig-7]. The time taken for a two-level regression in group U was 52.5±13.44 minutes, and in group C, it was 62.64±14.49 minutes, with a significant difference between them (p-value=0.003). The time taken for motor block recovery was 157.23±11.92 minutes in group U, which was significantly lower compared to 199±21.86 minutes in group C (p-value <0.0001) [Table/Fig-8].

Parameter	Control group	Ultrasound group	p-value
Age (years) [Independent t-test, Fisher's exact test]	70.23±6.19	72.03±6.13	0.226
Height (cm) [Independent t-test]	161.57±9	162.49±9.48	0.68
Weight (kg) [Independent t-test]	68.89±11.96	66.46±9.27	0.346
ASA [Chi-square test]	1.54±0.5 ASA I-16 Patients ASA II-19 Patients	1.43±0.0.5 ASA I-20 Patients ASA II-15 Patients	0.36
Duration of surgery (minutes) [Independent t-test]	58.43±13.76	62.89±17.95	0.248

[Table/Fig-4]: Comparison of parameters.
Values presented as mean±SD; Independent t-test, Fisher's-exact test, Chi-square test.

Variables	Control group	Ultrasound group	p-value
Dural cross-sectional area (mm^2)	150±0.0	120.03±12.0	<0.0001
Dose of the drug (mg)	10±0	7.99±0.77	<0.0001

[Table/Fig-5]: Comparison of DSCSA and dosage.
Independent t-test

Max sensory level blocked	Group U (n=35)	Group C (n=35)	Total	p-value
T4	0 (0%)	3 (8.57%)	3 (4.29%)	
T6	0 (0%)	4 (11.43%)	4 (5.71%)	
T8	13 (37.14%)	4 (11.43%)	17 (24.29%)	0.004*
T10	22 (62.86%)	24 (68.57%)	46 (65.71%)	
Total	35 (100%)	35 (100%)	70 (100%)	

[Table/Fig-6]: Comparison of max sensory level blocked between group U and C (Fisher's-exact test).

Variables	Control group	Ultrasound group	p-value
Highest sensory level block	T4 (T4-T10)	T8 (T8-T10)	0.004
Time taken for highest sensory block (min)	13.07±1.7	11.7±1.82	0.866
Time taken for motor block (bromage score=1) (min)	5+2.5	7+2.5	0.001

[Table/Fig-7]: Comparison of motor and sensory block.
Values presented as mean±SD; Fisher's-exact test

Variables	Control group	Ultrasound group	p-value
Two level regression time of sensory block (min)	62.64±14.49	52.5±13.44	0.003
Motor recovery time (min)	199±21.86	157.23±11.92	<0.0001

[Table/Fig-8]: Comparison 2 level regression and motor recovery.
Values presented as mean±SD

The analysis of heart rate showed no significant difference between both groups (p-value=0.092), whereas a greater decrease in MAP was observed in the control group compared with the ultrasound group (p-value <0.0001) [Table/Fig-9,10].

Variables	Control group	Ultrasound group	p-value
Baseline heart rate (per min)	75.94±12.1	71.14±11.42	0.092
Highest heart rate recorded (per min)	87.97±10.76	81.26±10.44	0.01
Baseline blood pressure (mmHg)	96.74±13.05	101.2±11.06	0.128
Lowest blood pressure recorded (mmHg)	73.43±13.75	90±11.2	<0.0001
No.of patients received Phenylephrine (%)	31.43%	5.71%	0.012

[Table/Fig-9]: Haemodynamics parameters.
Values presented as mean±SD

cephalad spread of anaesthesia is associated with an increased risk of complications such as bradycardia and hypotension, and it can complicate the identification of capsular rupture during TURP. Therefore, it is essential for anaesthesiologists to consider the patient's age when adjusting the local anaesthetic dose to ensure adequate anaesthesia without causing such complications [16].

Lim YS et al., conducted a study on Lumbar Central Canal Spinal Stenosis (LCCSS) and concluded that narrowing of the DSCSA and Spinal Canal Cross-Sectional Area (SCCSA) are major contributors to LCCSS [14]. However, their findings demonstrated that while both DSCSA and SCCSA were significantly associated with LCCSS, DSCSA was a more sensitive parameter for its assessment. Based on this evidence, we selected DSCSA as the criterion for modifying the dosage of local anaesthetic drugs in our study. Wang WB conducted a study on the use of DSCSA as an effective parameter for spinal anaesthesia in geriatric patients undergoing TURP with isobaric bupivacaine [3]. In their study, the mean DSCSA in the ultrasound group was 102.5±7.6 mm^2, and the calculated drug dosage was 6.7±1.6 mg. The onset time for maximal sensory block was 26.3±12.2 min, and the two-segment regression time was 156.1±42.3 min. In our study, the results were 120.03±12.0 mm^2 and 7.99±0.77 mg in the ultrasound group. The difference in onset time and two-segment regression time may be due to the use of isobaric bupivacaine in their study, whereas we used hyperbaric bupivacaine.

Interval	Mean Arterial Pressure (MAP) (mmHg)			Heart rate (per minute)		
	Group U (n=35)	Group C (n=35)	p-value	Group U (n=35)	Group C (n=35)	p-value
0 minute	101.2±11.06	96.6±13.15	0.118	71.14±11.42	76.89±11.87	0.043
2.5 minutes	94.63±12.11	86.69±13.74	0.013	75.83±10.01	80.54±11.42	0.071
5 minutes	93.63±12.23	81.17±15.56	0.0004	76.74±10.05	81.6±11.71	0.067
10 minutes	95.06±10.74	79.14±14.28	<0.0001	75.74±10.78	80.54±13.32	0.102
12.5 minutes	96.6±10.87	81.8±12.91	<0.0001	75.26±11.87	77.94±13.17	0.373
15 minutes	97.43±10.07	82.54±14.03	<0.0001	73.23±11.99	78.26±12.37	0.089
17.5 minutes	97.54±9.48	83.51±12.6	<0.0001	73.86±12.36	77.6±12.06	0.204
20 minutes	97.91±9.76	83.4±13.17	<0.0001	73.94±11.5	77.54±12.1	0.206
25 minutes	98.17±9.44	82.51±14.47	<0.0001	73.57±10.99	77.29±12.45	0.19
30 minutes	97.51±9.16	83.11±13.46	<0.0001	73.6±10.28	77.54±11.77	0.14
45 minutes	96.37±8.97	85.06±12.25	<0.0001	74.09±10.32	78.2±11.2	0.115
1 hour	97.8±9.48	84.37±11.31	<0.0001	74.94±10	78.54±10.52	0.147

[Table/Fig-10]: Comparison of Mean Arterial Pressure (MAP) and heart rate between group U and C (Independent t-test).
Values presented as mean±SD

DISCUSSION

The aim of the present study was to determine the minimum required dose of local anaesthetic in spinal anaesthesia based on the DSCSA to achieve a T10 sensory blockade in geriatric patients. The statistical analysis of the study data confirmed our hypothesis that a modified drug dosage, determined using a formula based on the DSCSA, decreased the likelihood of a higher-level blockade while maintaining stable haemodynamics. In contrast, larger doses of local anaesthetics were associated with significant haemodynamic changes, likely due to excessive cephalad spread of the drug.

The study compared a control group receiving a fixed 10 mg dose of hyperbaric bupivacaine with an ultrasound-guided group where the dosage was adjusted based on DSCSA. The ultrasound group received a significantly lower mean dose of 7.99±0.77 mg, with a corresponding reduction in the cephalad spread of sensory block (maximum T8 vs. T4 in controls, p=0.004), shorter motor block duration (157.23±11.92 min vs. 199±21.86 min, p<0.0001), and faster two-segment regression time (52.5±13.44 min vs. 62.64±14.49 min, p=0.003). Haemodynamically, the ultrasound group maintained more stable MAP (p<0.0001) and had significantly lower vasopressor requirements.

The study findings revealed that the maximum cephalad spread of the anaesthetic reached T4 in the control group, compared to T8 in the ultrasound-guided group. This demonstrates the effectiveness of tailoring the anaesthetic dose based on DSCSA to minimise complications and improve outcomes. It has been noted that the DSCSA is reduced by approximately 30% in elderly patients compared to younger individuals. In our study, the average DSCSA in the ultrasound-guided group was 120.03±12.0 mm^2. A higher

The time taken to reach the maximum sensory level block was 11.7±1.82 minutes in the ultrasound (U) group and 13.07±1.7 minutes in the control (C) group, with no significant difference between the groups (p=0.866). However, there was a notable difference in the maximum sensory block level, with the C group reaching T4 and the U group reaching T8. This suggests that the sensory block ascended more rapidly in the control group compared to the ultrasound group. In the comparison of haemodynamics, heart rate showed no significant difference in both groups (p-value=0.092), whereas a more pronounced fall in MAP was observed in the control group compared to the ultrasound group (p-value <0.0001).

Pula R performed a similar study to modify the dosage of hyperbaric bupivacaine for spinal anaesthesia in elderly patients undergoing TURP, using ultrasound-guided DSCSA measurements [6]. They concluded that adjusting the dosage based on DSCSA significantly reduced the maximal decrease in MAP (p=0.041) and led to earlier two-segment regression time, with no significant changes in heart rate. Our study corroborates these findings, showing a significant maximal decrease in MAP (p<0.0001) and earlier two-level regression time, while a notable difference in the increase in heart rate (p=0.01) was observed. These results further validate the utility of DSCSA in optimising anesthetic management for elderly patients.

In the current study, the ultrasound (U) group experienced a smaller change in MAP from baseline than the control (C) group. The greater dosage of bupivacaine and increased cephalad spread of the sensory block in the control group likely contributed to the larger change in MAP, which required the administration of phenylephrine to elevate MAP.

Limitation(s)

The current study has several limitations. The study did not explore the correlation between height, DSCSA, and anesthetic dosage, which could provide valuable insights for future studies. The speed of spinal anesthetic injection was not accounted for, which may introduce a confounding factor. Furthermore, DSCSA was measured only at the L3-L4 level, and additional studies should include measurements at the L2-L3 and L4-L5 levels for a more comprehensive analysis.

CONCLUSION(S)

This study demonstrated that adjusting intrathecal bupivacaine dosage based on DSCSA significantly reduces the cephalad spread of anaesthesia and minimises haemodynamic fluctuations in geriatric patients. The ultrasound-guided group achieved an adequate T10 sensory blockade with a lower anesthetic dose and experienced a reduced incidence of hypotension as well as shorter motor block duration. These findings emphasise the clinical value of individualising spinal anaesthesia dosing to patient-specific anatomical parameters. The use of ultrasound for DSCSA measurement is a practical and non-invasive tool that enhances patient safety. Incorporating this technique into routine practice can improve anesthetic outcomes, especially in elderly populations. Further large-scale studies are warranted to validate and standardise this approach across broader patient groups.

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