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Original Article

Anaesthesia Section

Correlation of Vertebral Column Length and Abdominal Circumference with Subarachnoid Block Characteristics of Hyperbaric Ropivacaine for Infraumbilical Surgeries: A Single-arm Interventional Study

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ABSTRACT

Introduction: Spinal anaesthesia is a neuraxial anaesthesia technique used for lower abdominal and lower limb surgeries. The spread of the intrathecally administered local anaesthetic drug during spinal anaesthesia may be affected by many factors.

Aim: To evaluate the correlation between abdominal girth and vertebral column length with the intrathecal spread of hyperbaric ropivacaine.

Materials and Methods: This prospective single-arm interventional study was conducted in the Department of Anaesthesia at Pt. BDS PGIMS Rohtak, Haryana, India from November 2022 to March 2024. A total of 100 patients of either sex, aged between 20 and 60 years, scheduled for infraumbilical surgeries under Subarachnoid Block (SAB), were included in this single-arm intervention study. Abdominal girth and vertebral column length of the enrolled patients were measured in sitting position. SAB was administered with 3 mL of 0.75% hyperbaric ropivacaine. Sensory and motor block assessments were conducted after the block. The highest sensory block level, time taken to achieve the highest sensory block level and Bromage score of 3, the time taken for two-segment regression and regression to Bromage score of 0 were recorded. Haemodynamic parameters and any complications were noted. Data was compiled and the correlation of vertebral column length and abdominal circumference with sensory and motor block characteristics was analysed at the end of the study. The Pearson's correlation test was used to determine correlation and a p-value of <0.05 was considered statistically significant.

Results: Out of the 100 patients included in the study, 81% were male and 19% were female. The mean age, weight and height of the patients were 36 years, 67 kg and 169 cm, respectively. The mean vertebral column length and abdominal circumference of the patients were 61 cm and 83 cm. Abdominal circumference was significantly correlated with the maximum sensory level (the Pearson's correlation coefficient was 0.680 with a p-value <0.05). However, no significant correlation was found between vertebral column length and the maximum sensory level achieved (the Pearson's correlation coefficient was 0.75 with a p-value of 0.06). The time to achieve maximum sensory and motor levels and the time to regress from the maximum block level were also not correlated with abdominal circumference and vertebral column length (p-value >0.05).

Conclusion: Patients with larger abdominal circumference have more cephalad spread of intrathecal ropivacaine in non obstetric patients undergoing infraumbilical surgeries. However, the present study found no correlation between vertebral column length and any SAB characteristics.

Keywords: Local anaesthetic spread, Motor block, Sensory block

INTRODUCTION

Spinal anaesthesia is a popular and versatile technique primarily used for lower abdomen, perineal, gynaecological and lower limb surgeries. Achieving satisfactory surgical conditions with minimal haemodynamic changes is essential during spinal anaesthesia. However, predicting the spread of local anaesthetic that can produce an adequate block level for surgery with minimal side-effects is challenging. The spread of local anaesthesia in the subarachnoid space is influenced by various factors, including the characteristics of the injected drug, clinical technique and patient characteristics [1]. While drug and technique-related factors can be controlled, the influence of patient characteristics is not fully manageable by clinicians, leading to significant interpatient variability. Even with the same concentration and volume of local anaesthetic, different patients may experience varying degrees of sensory, motor and sympathetic block [2].

Patient factors that can affect intrathecal drug spread include weight, height, age, gender, pregnancy, abdominal circumference, intra-abdominal pressure, spine anatomy and Cerebrospinal Fluid (CSF) properties [3]. Although these factors have been researched in previous studies, the results have varied. Recent literature has noted a correlation between local anaesthetic spread and vertebral column length rather than height [3,4]. Previous studies have also found that CSF volume and pressure are the main determinants of local anaesthetic spread [5-7]. However, measuring these parameters can be inconvenient in clinical settings. Abdominal circumference serves as an easily assessable substitute for lumbosacral CSF volume. Most studies examining the impact of vertebral column length and abdominal circumference on spinal anaesthesia levels have been conducted on obstetric patients [8,9]. There are limited studies assessing the influence of these parameters in non obstetric patients. Furthermore, all these studies have utilised plain or hyperbaric bupivacaine [4,8,10]. No study has investigated the use of other newer and safer local anaesthetics, such as ropivacaine or levobupivacaine. Currently, a hyperbaric solution of ropivacaine 0.75% is commercially available.

In the present study, the authors aimed to assess the correlation between vertebral column length and abdominal circumference with

the intrathecal spread of hyperbaric ropivacaine, another amide local anaesthetic that has a similar mechanism of action but with lesser central nervous system and cardiovascular toxicity [11,12].

The primary objective of the present study was to determine the highest sensory level achieved with hyperbaric ropivacaine (0.75%) in relation to vertebral column length and abdominal circumference. The secondary objective was to evaluate the correlation of both parameters with the time taken to achieve and recede from maximum sensory and motor block levels.

MATERIALS AND METHODS

The present prospective single-arm interventional study was conducted in the Department of Anaesthesia at Pt. BDS PGIMS Rohtak, Haryana, India, from November 2022 to March 2024, after obtaining approval from the local Institutional Ethical Committee (IEC) (EC/NEW/INST/2022/HR/0189) and following Clinical Trials Registry-India (CTRI) registration (CTRI/2023/10/058460). The sample size was based on the standard deviation [11] of the mean abdominal girth of patients from a study conducted by Nigam C et al., [10]. It was calculated with a 95% confidence interval, 80% power and an alpha level of 0.05.

Sample size calculation: The formula used for sample size calculation was:

$N=(Z_{\alpha/2})^2 * s^2/d^2$, where $Z_{\alpha/2}=1.96$ for a 5% level of significance, s=11 and d=2.2.

Thus,

$N=(1.96)^2 * (11)^2 / (2.2)^2=100$.

The sample size was increased to 105 patients to account for potential dropouts. Out of these, 5 patients were excluded for not meeting the inclusion criteria. Consequently, 100 patients were enrolled in the present study after obtaining informed consent.

Inclusion criteria: A total of 100 patients of either sex, aged between 20 and 60 years and belonging to American Society of Anaesthesiologists (ASA) physical status I or II, scheduled for infraumbilical surgeries under spinal anaesthesia (SAB), were included in the study.

Exclusion criteria: Patients with any contraindications for spinal anaesthesia, those under 18 years of age or over 60 years, those at the extremes of weight (less than 40 kg or more than 80 kg) and those at the extremes of height (less than 150 cm or more than 180 cm), as well as pregnant patients, were excluded from the study.

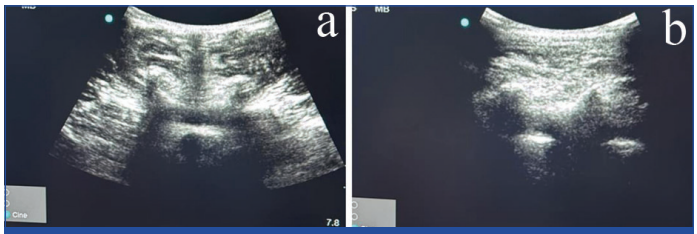
Study Procedure

All patients underwent a preoperative assessment and written informed consent was obtained. The patients' age, sex, height and weight were noted. Prior to the surgical procedure, the patients were kept fasting for six hours and premedicated. Upon arrival in the operating room, standard ASA monitoring, including Heart Rate (HR), mean arterial pressure, Electrocardiography (ECG) and pulse oximetry (SpO_2), was performed. An intravenous line was secured with an 18 G cannula and intravenous fluid was started. Baseline readings of HR, mean arterial pressure and SpO_2 were recorded. Abdominal girth and vertebral column length were measured in a sitting position using measuring tape.

Abdominal Circumference Measurement (AC): It was measured at the level of the superior border of the iliac crest in a horizontal plane at the end of expiration in a sitting position without back flexion, using a measuring tape.

Vertebral Column Length Measurement (VCL): It was measured from the C7 vertebra to the sacral hiatus. Initially, the C7 vertebra and sacral hiatus were located by palpation and then confirmed with Ultrasound (USG). The distance from the C7 vertebra to the sacral hiatus was measured in a sitting position using a measuring tape [10].

The location of the L3-L4 interspace was confirmed by ultrasound [Table/Fig-1a,b]. Spinal anaesthesia was then performed aseptically at the L3-L4 interspace in the sitting position using a midline approach with a 23-gauge Quincke needle. When free flow of cerebrospinal fluid was obtained, 3 mL of 0.75% hyperbaric ropivacaine was injected intrathecally. Immediately after the Spinal Anaesthesia Block (SAB), patients were placed in a supine position without any tilt of the operating table. The sensory level of the SAB was assessed by the loss of pinprick sensation in the bilateral midclavicular lines at two-minute intervals initially. Thereafter, sensory block assessment continued every five minutes until the maximum sensory block was achieved. The motor block was assessed using the modified Bromage scale [13]. Surgery was started once the sufficient spinal block level was reached. If the adequate effect required for the surgery was not achieved, general anaesthesia was administered.



[Table/Fig-1]: USG-guided assessment of L3-L4 space. a) Transverse view of lumbar spine; b) Sagittal view of lumbar spine.

The following observations were taken:

- Demographic data (age, height, weight)
- Abdominal circumference and vertebral column length
- Maximum sensory block level
- Time taken to achieve maximum sensory level and the time taken for two-segment regression from the maximum sensory block level
- Time taken to achieve Bromage score 3 and the time taken to regress to Bromage score 0
- Routine haemodynamic monitoring was performed and any complications (hypotension, bradycardia, nausea, vomiting) were noted.

STATISTICAL ANALYSIS

Upon completion of the study, data were compiled and analysed. The analysis was performed using IBM SPSS (SPSS Inc., IBM Corporation, NY, USA) Statistics Version 25 for Windows software program. A pearson's correlation test was used to determine the correlation between vertebral column length and abdominal circumference with various sensory block characteristics. A p-value of less than 0.05 was considered to indicate a significant difference.

RESULTS

Initially, 105 patients were assessed for the study. Out of these, five patients were excluded for not meeting the inclusion criteria (one patient had a height >180 cm and four patients had a weight >80 kg). Finally, 100 patients were included in the study. The demographic data of the patients, including mean age, weight, height and gender distribution, are depicted in [Table/Fig-2]. The mean vertebral column length and abdominal circumference, along with their ranges, are shown in [Table/Fig-3]. The time to achieve and regress from the maximum sensory and motor block levels was noted in [Table/Fig-4]. Haemodynamic monitoring during surgery is depicted in [Table/Fig-5].

One of the key parameters of the study was to observe the maximum sensory level achieved after administering hyperbaric ropivacaine. In most cases, the sensory level achieved was T6 (45%) and T8 (47%) [Table/Fig-6]. The motor level achieved was assessed using the Modified Bromage scale. In 95% of cases, a Bromage 3 motor

level was achieved, as shown in [Table/Fig-7]. Patients who attained the maximum T6 sensory level had a vertebral column length of 62.83±4.71 cm (mean±SD), while patients with the T8 sensory level had a vertebral column length of 59.55±4.68 cm. Patients with a mean abdominal circumference of 86.33±11.79 cm and 78.62±11.57 cm achieved T6 and T8 sensory levels, respectively [Table/Fig-8].

Demographic parameters	Values
Mean age	36.13±12.31 years
Gender distribution	
Male	81%
Female	19%
Mean weight	67.71±11.65 kg
Mean height	169.29±5.52 cm

[Table/Fig-2]: Demographic data of patients.
Mean values are presented as mean±SD, gender distribution as number (%)

Parameters	Mean±SD	Minimum	Maximum
VCL	61.39±5.42	51	81
AC	83.23±12.62	60	115

[Table/Fig-3]: Vertebral column length and abdominal circumference of patients.
Values are presented as number of patients N, minimum and maximum values of VCL and AC in centimetres, mean values as mean±SD
VCL: Vertebral column length, AC: Abdominal circumference

Parameters	Mean±SD	Minimum	Maximum
Time to achieve maxim sensory level	8.19±2.17	2.00	15.00
Time to achieve bromage 3	10.23±2.669	1	15
Time to recede to bromage 0	171.34±39.49	72	240
Time taken for two segment regression of maxim sensory block	68.48±17.66	30	94

[Table/Fig-4]: Various time periods recorded.

Time	Heart rate (Beats/minute) Mean±SD	Mean arterial pressure (mmHg) Mean±SD	Mean SpO_2 (%) Mean±SD
Baseline	77.80±11.361	84.39±8.060	98.95±0.57
5 min	76.22±11.212	91.18±7.125	98.83±0.667
10 min	76.12±10.280	91.14±8.143	98.82±0.947
15 min	76.24±10.723	90.46±8.361	98.71±0.977
20 min	76.58±10.098	91.44±8.049	98.96±0.852
25 min	76.78±10.576	92.85±7.123	99.01±0.689
30 min	77.03±10.521	91.94±7.089	98.91±0.621
35 min	77.01±9.676	91.77±6.841	98.79±0.671
40 min	77.64±9.584	92.10±7.686	98.84±0.662
45 min	77.61±9.402	92.04±7.497	98.79±0.640
50 min	77.94±9.597	92.45±7.350	98.73±0.529
55 min	77.89±9.198	92.67±7.087	98.89±0.424
60 min	78.19±8.593	92.69±6.791	98.76±0.429

[Table/Fig-5]: Haemodynamic monitoring.

Maximum sensory level achieved	n (%)
Effect not achieved	1 (1%)
T10	3 (3%)
T12	2 (2%)
T4	2 (2%)
T6	45 (45%)
T8	47 (47%)
Total	100 (100%)

[Table/Fig-6]: Maximum sensory level achieved after giving intrathecal ropivacaine.

Motor level achieved	n (%)
Bromage 0	1 (1%)
Bromage 2	4 (4%)
Bromage 3	95 (95%)
Total	100 (100%)

[Table/Fig-7]: Motor level achieved after giving intrathecal ropivacaine.
Values are presented as number and percentage of patients achieving different levels of motor block

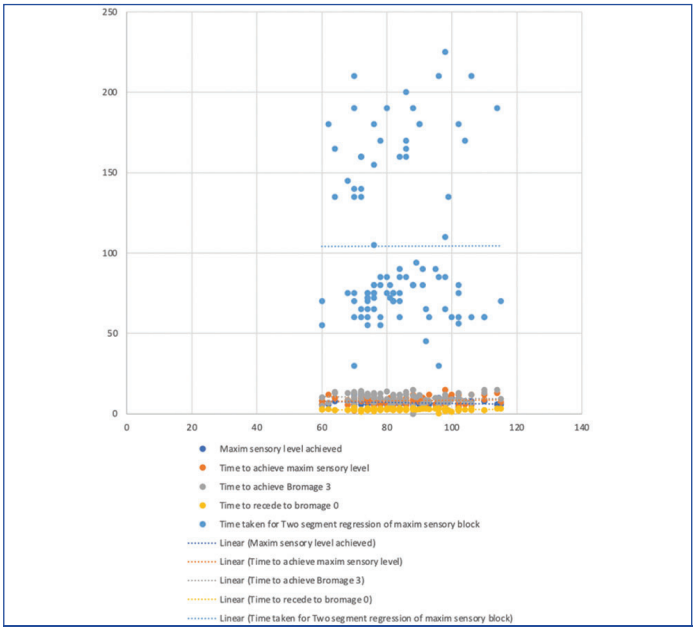
Maximum sensory level	VCL (Mean±SD)	AC (Mean±SD)
Effect not achieved	67.000	102.00
T10	65.167±13.8954	98.33±2.082
T12	61.000±11.3137	71.00±1.414
T4	64.250±8.1317	102.00±.000
T6	62.833±4.7158	86.33±11.786
T8	59.553±4.6779	78.62±11.573
Total	61.395±5.4204	83.23±12.616

[Table/Fig-8]: Mean VCL and AC of patients achieving different sensory levels.
Mean VCL and AC values of patients achieving a particular maximum sensory level are depicted as mean±SD, VCL: Vertebral column length; AC: Abdominal circumference

Pearson's correlation coefficients were used to determine the correlation of Vertebral Column Length (VCL) and Abdominal Circumference (AC) with various sensory and motor block parameters achieved after administering hyperbaric ropivacaine. Abdominal circumference was significantly correlated with the maximum sensory level achieved (p-value <0.001) [Table/Fig-9,10].

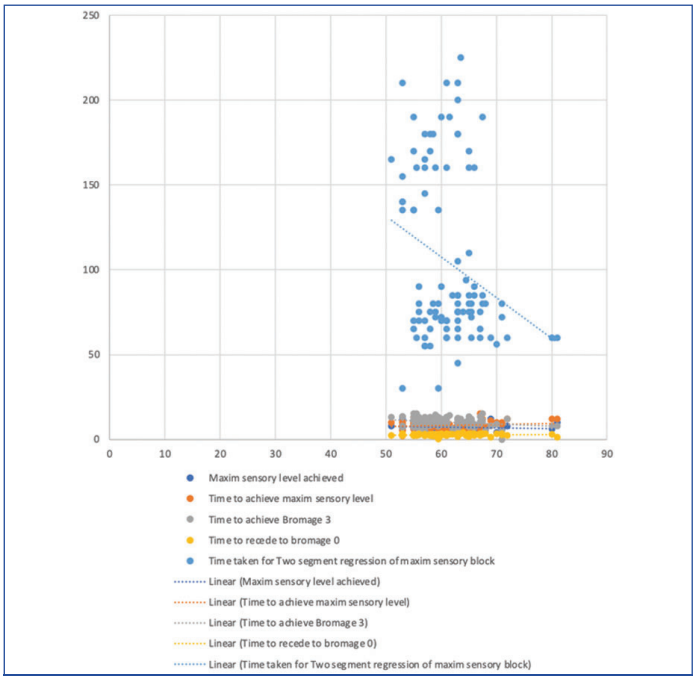
Various time periods		VCL	AC
Maximum sensory level achieved	Pearson's correlation	0.75*	0.680*
	p-value	0.06	p<0.001**
Time to achieve maximum sensory level	Pearson's correlation	0.184*	0.161*
	p-value	0.066	0.110
Time taken for two segment regression of maximum sensory block	Pearson's correlation	0.0380*	-0.029*
	p-value	0.763	0.822
Time to achieve Bromage 3	Pearson's correlation	0.56*	0.045*
	p-value	0.49	0.660
Time to recede Bromage 0	Pearson's correlation	0.17*	0.13*
	p-value	0.22	0.306

[Table/Fig-9]: Correlation of VCL and AC with various Subarachnoid Block (SAB) characteristics.
Correlation of various block parameters with VCL and AC, VCL: Vertebral column length, AC: Abdominal circumference; *Pearson's Correlation, **significant



[Table/Fig-10]: Correlation of abdominal circumference with various block characteristics.

This exhibited a strong positive correlation (Pearson's correlation coefficient of 0.680). However, no significant correlation was found between vertebral column length and the maximum sensory level achieved [Table/Fig-9,11]. The time to achieve the maximum sensory level and the two-segment regression from the maximum sensory level were also not correlated with AC and VCL [Table/Fig-9-11]. Additionally, there was no significant correlation of vertebral column length and abdominal circumference with the time to achieve Bromage 3 or regress to Bromage 0, as shown in [Table/Fig-9-11]. In the present study, 5 patients out of 100 developed hypotension (5%) after receiving hyperbaric ropivacaine. These cases were managed conservatively. No patient experienced bradycardia, nausea, or vomiting.



[Table/Fig-11]: Correlation of vertebral column length with various block characteristics.

DISCUSSION

Spinal anaesthesia is a commonly used anaesthetic procedure that has fewer complications and postoperative morbidity than general anaesthesia. However, unlike general anaesthesia, the effect of intrathecally administered drugs is unpredictable in terms of extent and duration and it is influenced by many modifiable and non modifiable factors. Various studies have been conducted to identify the most important factors that affect the spread of local anaesthetic drugs administered intrathecally [5-8]. Previous studies primarily focused on the relationship between patient characteristics and the sensory level achieved after SAB, but adequate anaesthesia for a particular surgery is not solely dependent on the initial sensory level achieved. Other aspects of block characteristics, such as motor block and the time to achieve and regress sensory and motor block, should also be considered while finding correlations between patient characteristics and block characteristics [4,8-10]. Therefore, the authors took into account the influence of Vertebral Column Length (VCL) and Abdominal Circumference (AC) on all parameters of SAB characteristics, including maximum sensory and motor block, as well as the time to achieve and regress from those levels.

A total of 100 patients aged 18 to 60 years who were planned for infraumbilical surgery under spinal anaesthesia were enrolled in the present prospective study. The mean age of the patients was 36 years and it turned out to be a male-predominant study (81%). Pregnant patients were excluded from the study. A similar study was conducted by Nigam C et al., which included 60 male patients aged 16 to 65 years [10]. Zhou QH et al., enrolled 114 patients aged 19 to 55 years, consisting of 84 males and 30 females [3]. Thus, both of these studies were male-predominant and included a similar age group, consistent with the present study [10,13].

The mean height of patients in the present study was 169.29±5.52 cm. The mean heights of patients in the studies conducted by Nigam C et al., and Zhou QH et al., were 167.9±7.8 cm and 166.7±7.7 cm, respectively [3,10]. Wei CN et al., also conducted a similar study in which the mean height was 158.6±4.5 cm, which was lower than that in the present study [9].

In the present study, the abdominal circumference and vertebral column length of the study patients were measured prior to SAB. The mean vertebral column length and abdominal circumference of the patients were 61.39±5.42 cm (range 51-81 cm) and 83.23±12.62 cm (range 60-115 cm), respectively. Nigam C et al., observed a mean vertebral column length of 60.9±3.2 cm (range 51.0-67.0 cm) and a mean abdominal circumference of 78.4±11.0 cm (range 61-106 cm) in their study patients. Thus, there was a wider range of vertebral column length and abdominal circumference in the present study compared to that of Nigam C et al., [10]. In the study conducted by Zhou QH et al., the mean abdominal circumference of patients was 78.2±12.3 cm, while the vertebral column length was 63.5±5.5 cm [3].

The authors evaluated the effect of Vertebral Column Length (VCL) and Abdominal Circumference (AC) on sensory and motor block characteristics in SAB for lower limb and lower abdominal surgeries. The present study revealed a strong positive correlation between AC and the maximum sensory level achieved after administering hyperbaric ropivacaine. However, the study did not find any correlation between VCL and the maximum sensory level. Other parameters of sensory and motor block were not affected by VCL and AC.

The study demonstrated a strong positive correlation between the maximum sensory level achieved and AC. This suggests that patients with a larger AC had a higher sensory block level compared to patients with a lower AC. A possible explanation for this might be increased abdominal compression in patients with greater AC, leading to increased abdominal pressure, especially in the supine position. This increase in abdominal pressure may cause the displacement of foraminal contents inwards, resulting in a higher sensory block level [5,6]. The present study findings are in concordance with the study conducted by Zhou QH et al., [3]. However, they used plain bupivacaine intrathecally instead of a hyperbaric drug. Similar results were also observed by Yahya M et al., [14], who found that the ratio of truncal length to the square of abdominal circumference correlates with spinal anaesthesia sensory block height. Gunkaya M et al., also observed that the maximum upper dermatomal block level increased with waist circumference and Body Mass Index (BMI) [15]. Similar results were also observed by Wei CN et al., and Lee YH et al., [9,16]. However, in these studies, the participants were pregnant patients. In parturients, in addition to increased abdominal pressure, other factors such as compression of the dural sac by the dilation of the venous plexus and increased sensitivity to local anaesthetics also contribute to higher sensory block levels [9,16].

The present study results were in contrast to the study conducted by Nigam C et al., [10]. The mean AC was higher in the present study compared to the study by Nigam C et al., Additionally, the present study exhibited a wider range of abdominal circumference, from 60 to 115 cm, which may have influenced the results. Aside from the maximum sensory

level achieved, other characteristics of the block, such as the onset and regression of sensory and motor block, were not affected by AC. These findings contrast with those of the study conducted by Gunkaya M et al., [15], which observed that the time needed for the block to reach the T10 sensory level and a Bromage score of 3 was shorter in patients with larger waist circumference.

The present study demonstrated no correlation between VCL and sensory block characteristics. These results are in contrast to the studies conducted by Zhou QH et al., Wei CN et al., and Ni TT et al., [4,9,17]. However, the present study findings align with those of Nigam C et al., and Pargger H et al., [10,18]. Similar to the study by Nigam C et al., the VCL to height ratio was lower in the present study compared to the studies conducted by Zhou QH et al., Wei CN et al., and Ni TT et al., [4,9,17]. This discrepancy may be attributed to differences in the ethnicity of the patient populations. A lower VCL to height ratio might have reduced the contribution of VCL to the total height of the patient, which could explain the lack of correlation between VCL and sensory block characteristics in the present study.

Similar to abdominal circumference, there was no correlation between VCL and the time to achieve or recede from maximum sensory and motor levels in the present study. Bhiwal AK et al., observed a significant positive correlation between the ratio of VCL to AC squared and the time to reach the maximum sensory level [19]. However, their study population differed from the present study, as they enrolled pregnant patients. There is a scarcity of studies comparing VCL and AC with the times to achieve and recede sensory and motor block levels. Further research is needed to draw any definitive conclusions.

The authors used hyperbaric ropivacaine for the present study. To the authors knowledge, most studies comparing the effects of VCL and AC on SAB characteristics have utilised intrathecal bupivacaine. Ahad B et al., used intrathecal isobaric ropivacaine in pregnant patients to assess the spread of local anaesthetic [20]. It was found that intrathecal ropivacaine had similar efficacy with better haemodynamic stability but shorter motor and sensory blockage compared to intrathecal bupivacaine when both were used in identical doses, as demonstrated in studies conducted by McNamee DA et al., and Dar FA et al., [21,22]. However, when these drugs were used in a 1:1.5 dose ratio, their block characteristics were found to be comparable, as shown in a study by Gautier PE et al., [23]. With this background, the authors decided to use a higher concentrated dose of hyperbaric ropivacaine, specifically 3 mL of 0.75% ropivacaine, compared to the commonly used dose of hyperbaric bupivacaine, which is 3 mL of 0.5% bupivacaine, for lower limb surgeries. With this dose, except for a few cases, the rest of the study patients were able to undergo the desired surgery comfortably, as the surgery duration was shorter.

Limitation(s)

There were a few limitations to the present study, such as the use of a fixed dose of local anaesthetic. Individual dosing, rather than a fixed dose, would predict spinal anaesthesia characteristics more accurately. Additionally, there were fewer variations in vertebral column length due to the male-dominant study population. Further studies are needed with different patient strata.

CONCLUSION(S)

The present study concluded that abdominal circumference has significant predictive value for the maximum sensory block level achieved with hyperbaric ropivacaine in non obstetric patients undergoing infraumbilical surgeries. Patients with larger abdominal circumferences experience more cephalad spread of SAB. However, abdominal circumference was not correlated with the time to achieve or recede from maximum sensory and motor block levels. Additionally, the authors found that there was no significant correlation between vertebral column length and any characteristics of SAB.

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