Vertebral column length and abdominal girth as predictors for cephalad spread of intrathecal hyperbaric bupivacaine: A prospective observational study

ABSTRACT

Introduction: In recent literature, there is some suggestion of vertebral column length (VCL) and abdominal girth (AG) in determining cephalad spread of spinal anesthetic. Bodily habitus including abdominal fat distribution, AG, and VCL may vary among individuals from different races/ethnicity. We thus aimed to evaluate the role of AG, and VCL measured with the patient in sitting as well as lateral position, in determining the cephalad spread of intrathecal hyperbaric bupivacaine.

Methods: Prospective blinded study conducted in 60 consenting adult male patients of ASA status I or II, undergoing lower limb surgery using standardized combined spinal epidural performed. The cephalad spread of subarachnoid block was assessed using loss of discrimination to pin-prick and cold temperature. The VCL was measured from C7 vertebra to the sacral hiatus in sitting as well lateral decubitus position. The AG was measured at level of umbilicus during end of expiration.

Results: The mean AG and VCL in sitting/lateral positions were: 78.4 ± 11.0, 60.9 ± 3.2, and 59.2 ± 3.2 cm, respectively. VCL in sitting position was significantly longer than in lateral position (P = 0.000). There was no significant correlation between the Smax (pin-prick) and AG (P = 0.138), or VCL in sitting position (P = 0.549), or VCL in lateral position (P = 0.323). Similar lack of correlation was noted with the Smax (cold) as well (P > 0.05).

Conclusions: Contribution of AG or VCL on the extent of intrathecal drug spread is not a consistent finding.

Key words: Abdominal girth, predictors, spinal block, vertebral column length

Introduction

Spinal block is a commonly administered anesthetic technique. Herein, the cephalad spread of the intrathecal local anesthetic and thus the level of sensory block that is achieved depends on several factors. Patient characteristics including age, height, weight, gender, cerebrospinal fluid properties, and volume, as well as pregnancy have long been known to influence the intrathecal drug spread. In recent literature, the greater role of the vertebral column length rather than total height was noted in determining cephalad spread of the intrathecal anesthetic. The patients’ abdominal girth has also been recently evaluated and shown to influence the drug spread. Importance of both these newly evaluated predictors for cephalad spread of intrathecal hyperbaric bupivacaine: A prospective observational study

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How to cite this article: Nigam C, Tyagi A, Bhatt S, Kumar M. Vertebral column length and abdominal girth as predictors for cephalad spread of intrathecal hyperbaric bupivacaine: A prospective observational study. Saudi J Anaesth 2022;16:166-71.
patient characteristics, i.e., vertebral column length and the abdominal girth as determinants of intrathecal block extent has been emphasized in view of their ease of measurement in clinical practice. However, almost all of the studies evaluating the role of these two patients related determinants are confined to a single geographical area.\(^3\)\(^-\)\(^7\) The bodily habitus including abdominal fat distribution, as well as torso to total height ratio, and thus the vertebral column length may vary among individuals from different races. This implies a need to substantiate correlation of both these anthropometric patient variables with the cephalad spread of intrathecal spinal anesthetic in various patient subsets.

One of the commonest nonobstetric surgeries in our routine clinical practice is lower limb orthopaedic procedures. Subarachnoid blocks in these patients are most often carried out with patients in sitting position in our institution. Further, when spinal blocks are performed for patients with lower limb fractures in sitting position, there may be an inability to assume a perfectly straight back due to pain. We postulated that such a change in posture could affect measurement of vertebral column length, which could then affect the correlation with sensory block, if any.\(^8\)\(^-\)\(^10\) This effect of suboptimal posture on vertebral column length can be mitigated once the patient is in lateral decubitus position.

Against the above background, the present study aimed to evaluate the role of vertebral column length measured in sitting as well as lateral position, and the abdominal girth, in determining the cephalad spread of intrathecal hyperbaric bupivacaine, in nonobstetric patients undergoing lower limb surgery.

### Method

This prospective observational study was undertaken after obtaining clearance from the Institutional Ethical Committee (IEC-HR, UCMS) in a meeting held on 10/13/2018. Written informed consent was obtained from all participants.

A total of 60 adult male patients of ASA status I or II, without obvious spinal deformity, scheduled for orthopedic surgery of lower limb using combined spinal epidural block were included. Those with extremes of age (<16 years or >65 years), weight (i.e., <50 kg or >80 kg), or height (i.e., <150 cm or >180 cm) were excluded. Also, patients with failed spinal block (no sensory block achieved/technical failure to perform), any obvious spinal deformity, as well as contraindications to block including history of allergy to local anesthetics, coagulopathy (platelet count < 100,000/mm\(^3\) or INR > 1.5), or infection at site of injection were not included.

The spinal block was performed as part of a combined spinal epidural in all patients using the standardized technique. After shifting the patient to operating room, noninvasive blood pressure, lead II electrocardiography, and pulse oximetry were attached and continuously monitored. Intravenous access was established and Ringer’s lactate solution at 10 mL/kg was infused to the patients as coload. With the patient in sitting position, under all aseptic precautions, a combined spinal epidural anesthesia was performed at L\(_4\) \(\pm\)3 intervertebral space via the midline approach. The needle-through-needle technique was used for the block (Portex\(^®\), Smiths Medical ASD, Inc.; USA). The epidural space was identified with an 18 G Tuohy needle using loss of resistance to air, limiting its volume to less than 2 mL. Subarachnoid space was then identified by using a 27 G pencil point spinal needle, inserted through the Tuohy, and after confirming the free flow of cerebrospinal fluid, 2.5 mL of hyperbaric bupivacaine (0.5%) was injected intrathecally over a period of 10 s with orifice pointing cephalad. The epidural catheter was then inserted 5–6 cm inside space and fixed in-situ, once a lack of blood and cerebrospinal fluid through it was confirmed upon aspiration.

No epidural injection of any drug was made at this time. The patients were then rapidly placed in supine position.

Use of epidural top-ups was allowed if required, once the assessment of sensory level achieved with intrathecal drug spread was completed.

The time of removal of spinal needle was marked as completion of intrathecal block (T\(_s\)). The time of putting patient into supine position (beginning from T\(_s\)) was also noted (Ts).

### Assessment of level of intrathecal drug spread

The cephalad spread of subarachnoid block was assessed using loss of discrimination to pin-prick as well to cold temperature. For loss of perception to cold temperature, ice was applied for approximately 2 s before a negative determination was asked for, while the pin-prick was standardized with a 24 G hypodermic needle. The assessments were made in the midline from anesthetized to unanesthetized segments. Assessment using both sensory modalities was made every 3 min beginning after the patient was put in supine position and continued till there was no further increase in three consecutive observations. This was designated as the maximum sensory level (S\(_{\text{max}}\)) for the corresponding modality, i.e., S\(_{\text{max}}\) (pin-prick) and S\(_{\text{max}}\) (cold). The assessments were continued till S\(_{\text{max}}\) with both modalities was achieved.

The total number of dermatomes/segments between the fifth sacral vertebra and cephalic limit of sensory
block was calculated. This number of dermatomes blocked reflected the cephalic extent of intrathecal local anesthetic spread.

**Measurement of abdominal girth**
Prior to any intervention, the abdominal girth was measured at the level of umbilicus during end of expiration, with patient in supine position (in cm).

**Measurement of vertebral column length**
The vertebral column length was measured from the C7 vertebra to the sacral hiatus in the sitting position, without any flexion of back. Vertebral column length was also measured in lateral decubitus position at the end of surgery.

**Location of C7 vertebra**
Initially, the C7 vertebra was located by palpation, using the assisted flexion-extension method.\[8\] It was then confirmed using portable ultrasound imaging (7.5 Hz frequency probe). The transducer was placed in sagittal axis, to identify the transverse process of C7 as a hyperechoic shadow without continuing to the rib laterally.\[9\]

**Location of sacral hiatus**
The sacral hiatus was initially identified by palpation using the sacral cornua as the traditional landmarks (forming its lateral margins). The hiatus was then confirmed by ultrasonography based on previous descriptions for an ultrasound-guided caudal block.\[10\]

The ultrasound machine available in the department was a portable one with probes of 7.5 and 9.0 MHz frequencies (Bard Site-Rite®). We used the former probe.

All length measurements were made using a measuring tape with least count of 0.1 cm.

**Main observations**
The vertebral column length measured in sitting and lateral decubitus position, abdominal girth in supine position, the Smax (pin-prick), and Smax (cold) were noted for each patient, and the number of dermatomes/segments between the fifth sacral vertebra and cephalic limit of sensory block to pinprick and cold sensation were calculated.

**Other observations**
The time to put patients in supine position after completion of intrathecal block (Ts) and to achieve maximum sensory block to both sensations were also noted [Tmax (pin-prick) and Tmax (cold)]. The Tmax was calculated from completion of intrathecal injection to the first time the dermatomal level of Smax was noted.

Demographic characteristics (including height and weight), presence of previous comorbidity, relevant surgical details, and intraoperative hypotension (defined as fall of >20% in mean arterial blood pressure; or <65 whichever value was higher, up to 30 min after intrathecal injection) were also noted.

Hemodynamic variables (heart rate and mean arterial pressure) were noted every 3 min after supine position till maximum sensory block to both sensations was achieved.

**Statistical analysis**
Data is presented as ratios or percentages as appropriate. For correlation of a sensory block level with vertebral column length (sitting and lateral position) as well as abdominal girth, linear regression was carried out. Multiple regression analysis was not performed since no significant correlations on univariate regression were noted. For evaluating level of sensory block, T1 dermatome was designated as the numerical 1 and onwards with S5 dermatome representing the number 22. Comparison of Smax, Tmax, total dermatomes blocked by pin-prick versus cold sensation, and vertebral column length in both positions was made using the Wilcoxon Signed Ranks test (non-normal distribution). A *P* value < 0.05 was considered statistically significant.

**Sample size**
Three predictors of intrathecal spread were being evaluated in the current study. At power of 80%, alpha error of 5%, and effect size of 0.15,\[4\] using G Power 3.1 software, the minimum required sample size was 55 patients. Adding a dropout rate of 10%, e.g., due to failure of block, 60 patients were enrolled.

**Results**
A total of 75 patients were assessed for inclusion of whom 15 were excluded due to nonfulfillment of inclusion criteria (6 = females; 5 = age >65 years; 2 = age <16 years; 1 = weight <50 kg; 1 = weight >80 kg), and finally 60 were included. Consequent to failure of the spinal block in two patients, data from 58/60 was analyzed [Figure 1].

Baseline characteristics of the included patients are depicted in Table 1. All surgical procedures involved orthopedic procedures due to fracture in lower limb (hip/neck of femur/ lower limb bones).

The mean and range of abdominal girth in supine position and the vertebral column length in sitting as well as lateral positions are depicted in Table 2. The vertebral column length in sitting position was significantly longer than in the lateral position (*P* = 0.000).
Due to an inability of adequate sitting position in three patients, ultrasound-guided determination of sacral hiatus could not be done, and hence the result for sitting-vertebral column length and associated findings are for 55 rather than 58 patients.

There was no significant correlation between the $S_{\text{max}}$ (pin-prick) or the $S_{\text{max}}$ (cold) with abdominal girth, vertebral column length in sitting position, or the vertebral column length in lateral position [Table 2] [Figure 2].

The various characteristics for the sensory block are depicted in Table 3. The $Ts$ ranged from 100 to 219 s.

The $S_{\text{max}}$ was statistically similar whether determined by loss of sensation to pin-prick or to cold temperature. The number of dermatomes/segments between the fifth sacral vertebra and cephalic limit of sensory block to pin-prick and cold sensation were statistically similar with both testing modalities ($P = 0.157$) [Table 3].

### Table 1: Patient characteristics ($n=58$)

| Characteristic                         | Value          |
|---------------------------------------|----------------|
| Age (years)                           | 35.0±14.2 (16-65) |
| Height (cm)                           | 167.9±7.8 (151-180) |
| Weight (Kg)                           | 62.3±9.3 (50-80) |
| ASA physical status (grade 1:grade 2) | 50:8           |
| Preexisting systemic morbidity         | 5/58           |
| Basal heart rate (bpm)                | 86.8±15.5 (52-128) |
| Basal mean arterial pressure (mmHg)   | 96.2±9.7 (77-121) |
| Duration of surgery (min)             | 92.6±37.1 (25-192) |

Values are mean±SD, (range), or number of patients

### Table 2: Relationship between $S_{\text{max}}$ with abdominal girth and vertebral column length

| Characteristic                         | Value          | $S_{\text{max}}$ (pin-prick) | $S_{\text{max}}$ (cold) |
|---------------------------------------|----------------|-------------------------------|-------------------------|
| Abdominal girth (cm)                  | 78.4±11.0 (61-106) | 0.138                         | 0.039                   |
| Sitting-Vertebral column length (cm)   | 60.9±3.2 (51.0-67.0) | 0.549                         | 0.007                   |
| Lateral-Vertebral column length (cm)   | 59.2±3.2 (50.2-66.2) | 0.323                         | 0.017                   |

Values are mean±SD or (range); $P$ value and $R^2$ values are derived from univariate linear regression for each characteristic

Figure 1: STROBE flow diagram

Figure 2: Scatter plots to show the relationship between (a) level of sensory block (pin-prick) with abdominal girth and (b) vertebral column length; (c) level of sensory block (cold) with abdominal girth and (b) vertebral column length
The Tmax (cold) was significantly shorter than Tmax (pin-prick) \( (P = 0.002) \) [Table 3].

The repeated hemodynamic observations noted every 3 mins intraoperatively till Smax (pin-prick) was achieved, as shown in Table 4. The incidence of postspinal hypotension was 4/58 (6.8%).

**Discussion**

The present prospective study aimed to evaluate the role of vertebral column length measured in sitting as well as lateral position and the abdominal girth, in determining the cephalic extent of intrathecal drug spread in nonobstetric patients undergoing lower limb surgery, i.e., the Smax.

The salient findings included lack of any significant correlation between the Smax and vertebral column length measured in sitting/lateral positions or the abdominal girth \( (P > 0.05) \). This was irrespective of the modality chosen for assessment of Smax, i.e., pin-prick or cold temperature.

In contrast, earlier studies evaluating the association of abdominal girth and vertebral column length with Smax showed a significant positive association.\(^3\)\(^7\) These earlier studies have included obstetric\(^4\)\(^6\)\(^11\) as well as nonobstetric patients.\(^3\)\(^7\) One of the reasons for lack of such correlation in our study could be a difference in the contribution of vertebral column length to total height, as compared to the previous two studies in nonobstetric patients.\(^3\)\(^7\) Both the previous studies observed patient height similar to our data (165.9 ± 7.3 and 166.7 ± 7.7; versus 167.9 ± 7.8 cm, respectively). However, the vertebral column length was lesser in our population (59.2 ± 3.2 and 60.9 ± 3.2 cm) as compared to values noted earlier (65.2 ± 4.4 and 63.5 ± 5.5 cm).\(^3\)\(^7\) This could imply that vertebral column length may be a significant contributor of Smax depending on its proportion to the total height.

Another reason for the lack of correlation between abdominal girth or vertebral column length and Smax may be the nature of intrathecal local anesthetic. We used hyperbaric bupivacaine while both earlier non-obstetric studies used plain bupivacaine.\(^3\)\(^7\) It is well known that in the sitting position used during intrathecal injection, a hyperbaric local anesthetic tends to settle down due to gravity and thus may ameliorate effect of other factors. In support of our findings, there is one earlier study, though in obstetric patients, that noted a similar lack of correlation between spinal column length and Smax when the block was administered in sitting position while using intrathecal hyperbaric bupivacaine.\(^11\)

The Smax was tested using both pin-prick and cold sensations and was similar with both modalities \( (P = 0.157) \). Although controversial, there is earlier evidence noting similar Smax (within a dermatome or two) with both these modalities.\(^14\)\(^12\)\(^15\)

The vertebral column length in sitting position was significantly longer than in the lateral position \( (P = 0.000) \). As hypothesized, this could be a result of the compromised, slightly laterally tilted sitting position in patients with affliction and pain on side of surgery. The position for measuring the vertebral column length needs standardization (sitting versus lateral) while studying its correlation with intrathecal block characteristics.

A limitation of the present study is the exclusion of patients with extremes of height and weight. This could have prevented wider variations in abdominal girth and vertebral column length, thus influencing the results. We recommend a further trial to elaborate and validate the role of abdominal girth and vertebral column length at extreme values in determining the Smax.

Based on the observations of this present prospective study, we conclude that there appears to be no significant correlation

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**Table 3: Characteristics related to the sensory block level**

| Characteristic | Value |
|---------------|-------|
| Ts (sec)      | 147.9±23.6 (100-219) |
| Smax (pin-prick) | T 9.2±1.8 (T4-L1) |
| Smax (cold)   | T 9.2±1.8 (T4-L1) |
| Number of dermatomes blocked (pin-prick) | 13.9±1.7 |
| Number of dermatomes blocked (cold) | 14.0±1.7 |
| Tmax (pin-prick) (min) | 9.5±2.8 (2.5-17.5) |
| Tmax (cold) (min) | 8.4±2.6 (2.8-17.5) |

Values are mean±SD, median [IQR] or (range); Ts=time to put patient supine after intrathecal injection, Smax=Maximum level of sensory block (sensory modality), Tmax=time to achieve the Smax after intrathecal injection (sensory modality).

**Table 4: Trend of hemodynamic parameters till attainment of Smax (pin-prick)**

| Time point | Heart rate (bpm) | Mean arterial pressure (mmHg) |
|------------|------------------|-------------------------------|
| Ts         | 85.8±14.9        | 93.1±9.6                      |
| Ts + 3 (min) | 84.1±13.9        | 91.8±8.8                      |
| Ts + 6 (min) | 83.1±14.1        | 91.2±8.6                      |
| Ts + 9 (min) | 83.2±15.4        | 89.9±8.1                      |
| Ts + 12 (min) | 82.2±14.4        | 88.6±8.2                      |
| Ts + 15 (min) | 80.9±13.2        | 86.1±8.8                      |
| Ts + 18 (min) | 82.8±13.1        | 84.1±8.7                      |
| Ts + 21 (min) | 80.0±11.3        | 74.5±0.7                      |

Values are mean±SD; Ts=time to put patient supine after intrathecal injection, Smax=Maximum level of sensory block (sensory modality).
of the Smax with the vertebral column length (measured in sitting or lateral position) or the abdominal girth in nonobstetric patients undergoing orthopedic lower-limb surgeries.

Declaration of patient consent
The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity but anonymity cannot be guaranteed.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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