Ultrasound assessment of cranial spread during caudal blockade in children: Effect of different volumes of local anesthetic

ABSTRACT

Background: Ultrasound-guided caudal block injection is a simple, safe, and effective method of anesthesia/analgesia in pediatric patients. The volume of caudal drug required has always been a matter of debate.

Materials and Methods: This present prospective, randomized, double-blinded study aimed to measure extent of the cranial spread of caudally administered levobupivacaine in Indian children by means of real-time ultrasonography. Ninety American Society of Anesthesiologists I/II children scheduled for urogenital surgeries were enrolled in this trial. Anesthesia and caudal analgesia were administered in a standardized manner in the patients. The patients received 0.5 ml/kg or 1 ml/kg or 1.25 ml/kg of 0.125% levobupivacaine according to the group allocated. Cranial spread of local anesthetic was noted using ultrasound.

Results: There was no difference in the spread when related to age, sex, weight, or body mass index. A significant difference of ultrasound-assessed cranial spread of the local anesthetic was found between Group 1 (0.5 ml/kg) with both Group 2 (1 ml/kg) (P = 0.001) and with Group 3 (1.125 ml/kg) (P < 0.001) but there is no significant difference between Group 2 and Group 3 (P = 0.451) revealing that spinal level spread is only different between 0.5 ml/kg and 1 ml/kg of local anesthetic.

Conclusion: In conclusion, the ultrasound assessment of local anesthetic spread after a caudal block showed that cranial spread of the block is dependent on the volume injected into the caudal space. Since there was no difference between 1 ml/kg and 1.25 ml/kg, to achieve a dermatomal blockade up to thoracic level, we might have to increase the dose beyond 1.25 ml/kg, keeping the toxic dose in mind.

Key words: Caudal block; cranial spread; ultrasound; volume

Introduction

Ultrasound-guided caudal block injection is a simple, safe, and effective method of anesthesia/analgesia in pediatric patients. Ultrasound provides real-time visualization of the needle and cranial spread of drug. Hence, it helps in the titration of the volume of drug according to the level of dermatomal blockade required for surgery. The volume of caudal drug required has always been a matter of debate with literature mentioning fluoroscopy and static X-ray to see the spread.[1] With the advent of ultrasound, it is now

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possible to see the exact spread of the drug in the caudal epidural space. Few studies have been conducted till date to determine the factors affecting the spread of the drug in the epidural space during caudal blockade in infants and children. No such study has been done in Indian population. Thus, this present prospective, randomized, double-blinded study aimed to measure extent of the cranial spread of caudally administered levobupivacaine in Indian children by means of real-time ultrasonography, with emphasis on comparing three different volumes keeping the speed constant.

**Materials and Methods**

This randomized double-blinded study was done over a period of 1 year in AIIMS, Patna. Independent Ethics Committee clearance and Clinical Trials Registry-India (CTRI) registration (CTRI/2016/04/006850) was done. Ninety American Society of Anesthesiologists (ASA) I/II pediatric patients in the age group 1–6 years were included in the study. All these patients were posted for urogenital surgeries. The exclusion criteria included patients with known coagulopathy, allergy to drugs, infection at puncture site, preexisting neurological disease, and whose parents refused to give consent.

**Anesthesia technique**

Premedication in the form of pedicloryl 100 mg/kg was administered orally 4 h before the surgery. Intravenous access of all the patients was secured in the preoperative holding area and maintenance fluid started. Once the child was shifted to operating room, monitors including electrocardiography, noninvasive arterial pressure, pulse oximetry, carbon dioxide, and gas analyzer were applied during induction and maintenance of anesthesia. Anesthesia was induced with 3 mg/kg of propofol and 1 μg/kg fentanyl. The airway was established using appropriately sized laryngeal mask airway, and depth of anesthesia was adjusted accordingly with a goal of 1 minimum alveolar concentration. Soon after that, the patient was put in the lateral position and ultrasound-guided caudal block given. After a period of 15 min, surgery was started. The caudal block was considered a failure if anyone of the following was noted: (i) movement of the limbs in association with skin incision, (ii) an increase in heart rate and/or non invasive blood pressure of >15% compared to base line in association with skin incision, and (iii) intra operative need for supplemental administration of fentanyl (1 mcg/kg), as judged by the attending anesthetist.

Spontaneous breathing was maintained during surgery. After completion of surgery, the laryngeal mask airway was removed, and the child was sent to a postanesthetic care unit once awake.

**Ultrasound-guided caudal block**

On placing the patient in the left lateral decubitus position, 12th rib was identified which was tracked medially to identify and mark the 12th vertebral body. Sonosite Turbo M and high-frequency hockey stick probe were used to identify the dura mater, the epidural space, and the conus medullaris. The levels of the T12 spinous process and the conus medullaris were marked on the skin. Under all aseptic precautions, the sacral cornua and sacrococcygeal ligament were identified using the ultrasound. The 5 cm short beveled 22-gauge needle was introduced to reach the sacral epidural space and drug injected after negative aspiration. According to a computer-generated random list, the children were randomized to receive a total volume of:

- Group I: 0.5 ml/kg of levobupivacaine 0.125%
- Group II: 1 ml/kg of levobupivacaine 0.125%
- Group III: 1.25 ml/kg levobupivacaine 0.125%, according to the group selected.

The speed of the drug injection was kept constant at 0.5 ml/s. This was done using a syringe infusion pump (Perfusor M). During the drug injection, the probe was moved paramedially in the cephalad direction tracking the drug spread. After completing the injection, the highest level achieved with local anesthetic was tracked sonographically [Figure 1]. The corresponding spinous process was marked and level determined by counting the spinous process from previously mentioned T12 level. The level reached by local anesthetic relative to the conus medullaris (“+ mm” local anesthetic cranial to the conus medullaris and “− mm” local anesthetic caudal to the conus medullaris) was determined by measuring the distance between the skin mark of the conus medullaris and the skin mark representing the cranial extension of the local anesthetic using a regular measuring tape.
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Blinding
The pharmacist not involved in the collection or analysis of the data loaded the drug according to the group assigned. The syringe was attached to the infusion pump with a constant speed adjusted. The first and second author performed the caudal block along with the sonographic assessment and measurement. Both the first and second authors were blinded to the volume of local anesthetic injected. The caudal needle was attached to a pressure monitoring line and to the infusion syringe.

Statistical analysis
Sample size calculation was based on detecting a two vertebral level difference between incremental volumes with an 80% power and a significance level of 0.05%. There was a 25% difference for incremental volumes between groups based on which the sample size was calculated to be 76. Thus, an increased sample of ninety children with ASA Grades 1 and 2 who were scheduled for urogenital surgeries were included in the study.

Descriptive analysis of the sample was performed to find out the basic details of the study population. For comparison of patient characteristics and of the differences in the spread of local anesthetics in the epidural space, testing for normal distribution of the data was performed, followed by an ANOVA. $P < 0.05$ was considered significant. Pearson correlation coefficient was used to correlate the cranial spread of the local anesthetic relative to the body weight, body height, and body mass index (BMI). Differences in the cranial spread of local anesthetic and the spread of local anesthetic relative to the conus segmental medullaris between these groups were analyzed using the post hoc Tukey’s test with ANOVA, and the results were plotted on the box plots.

Results
A total of ninety children were included in the study. Relevant patient data are shown in Table 1.

Demography
There was no significant difference in between the three groups statistically with respect to age, weight, height, or BMI [Table 1].

Caudal spread
The distribution of the local anesthetic inside the caudal–epidural space could be seen by ultrasound in all cases, thus, generating an upper level of cranial spread for all patients. All caudal blocks were considered successful as all the surgical procedures could be completed without any indications of insufficient analgesia as outlined in the methods section. There was no correlation between the spread and the variables such as weight, height, BMI, and age.

A significant difference of ultrasound-assessed cranial spread of the local anesthetic was found between Group 1 (0.5 ml/kg) with both Group 2 (1 ml/kg) ($P = 0.001$) and with Group 3 (1.25 ml/kg) ($P < 0.001$) but there is no significant difference between Group 2 and Group 3 ($P = 0.451$) revealing that spinal level spread is only different between 0.5 ml/kg and 1 ml/kg of local anesthetic.

The distance of the cranial spread of the local anesthetic relative to the conus medullaris is illustrated in Table 2 showing a significant difference between groups 0.5 and 1.0 ($P = 0.006$) and group 1.25 ($P = 0.000$) respectively. However, no difference in spread relative to the conus medullaris could be observed between groups 1.0 and 1.25 ($P = 0.121$).

Spread with measurements relative to T12 is illustrated in Table 2; it also showed the same trend with significant difference between Groups 1 and 2 ($P = 0.000$) and Groups 1 and 3 ($P = 0.000$) and no significant difference between 2 and 3 ($P = 0.150$). Thus, Table 2 summarizes that characteristics of spread of local anesthetic differ significantly only when the doses are widely different like between 0.5 and 1 ml/kg, but they remain the same when the doses are close like 1 ml/kg and 1.25 ml/kg. The maximal level of cranial spread observed was T10.

Box and whisker plot [Figure 2] shows that the median spinal level of local anesthetic in Group 1 is between L2 and L3 and for both Group 2 and 3 is L1–L2. The 2nd group which was administered local anesthetic of 1 ml/kg dose had a varying response in almost all children receiving it, so the 25th and

### Table 1: Demographic characteristics

| Variables   | Group 1       | Group 2       | Group 3       |
|-------------|---------------|---------------|---------------|
| Age (years) | 3.20±1.58     | 2.84±1.68     | 2.76±1.33     |
| Weight (kg) | 13.26±3.93    | 11.73±3.78    | 12.41±3.30    |
| Height (cm) | 89.46±16.85   | 88.38±20.48   | 83.13±16.16   |
| BMI (kg/m²) | 16.70±3.48    | 15.84±5.97    | 18.51±4.50    |

BMI: Body mass index

### Table 2: Characteristics of spread of local anesthetic

| Variables            | Group 1       | Group 2       | Group 3       |
|----------------------|---------------|---------------|---------------|
| Spread of local anesthetic (cm) | 5.00±0.871    | 3.93±1.202    | 3.60±1.102    |
| Spread relative to conus (mm)     | −23.41±14.83  | −12.01±16.17  | −4.90±9.68    |
| Spread relative to T12 (mm)        | −31.66±15.27  | −14.66±13.06  | −8.23±11.03   |
75th percentile could not be computed for it and a clear and definite box-and-whiskers plot could not be obtained. The maximal level of cranial spread observed was T10.

Figure 3 shows the median spread relative to conus medullaris on injection of local anesthetic. It can be seen that the distance from conus reduces as the amount of anesthetic agent administered increases as the median spread comes near to 0 mm from conus medullaris in Group 3. Figure 4 shows that the distance of spread of the local anesthetic from T12 vertebra also reduces sequentially as the dose of the anesthetic agent is increased from 0.5–1 to 1.125 ml/kg.

Discussion

There have been few studies done to see the spread of local anesthetic in the caudal space. Earlier authors have used clinical cutaneous testing methods (e.g., pinprick or skin pinching), performed under halothane anesthesia about 15–20 min after the injection of local anesthetics.[2,3] Soon after this, radiological methods were used wherein local anesthetic was mixed with radiopaque dye and the spread was seen in caudal space.[1]

Kapral et al. used ultrasound to see the real-time spread of local anesthetics in peripheral nerve blocks.[4] Soon, ultrasound found its use in visualizing the Dural sag in pediatric caudal blocks.[5] In our present study, we have also used ultrasound to determine the cranial spread of caudally administered local anesthetics in children and to assess the effect of various volumes on the cranial spread of the drug.

There is obvious difference between the levels as assessed by cutaneous testing and objective radiographic visualization (X-ray/ultrasound). This has been attributed to various factors. First, cutaneous testing was done under light halothane anesthesia without end-tidal measurements of volatile agents. This could have led to partially anesthetized dermatomes to be classified as completely blocked dermatomes leading to wrong assessment. Radiographic assessment was performed immediately while cutaneous testing was performed after 15–20 min after the block procedure. Hence, radiographic assessment took only primary spread into account while cutaneous assessment also took secondary spread into account. Visual assessment and pain response are different dimensions and hence cannot be compared.[6]

We have been using an age-old formula based on weight to calculate the volume of local anesthetic in caudal blocks. However, in our clinical practice, we have seen that this formula might not be accurate in patients posted for upper abdominal surgeries. Various studies have shown that factors such as weight, age, and height predict the correct volume. In a study done by Satoyas et al., they used a simple formula to calculate the volume of local anesthetic, \( V = D - 13 \), where \( V = \) volume in ml, \( D = \) the distance from C7 to the sacral hiatus (D in cm). This calculation yielded fairly good results in children between the age group 1 month to 11 years undergoing abdominal surgeries.[7] They did not take weight into calculation, as many patients were underweight for their height.
Koo et al. in 2010, studied spread of local anesthetic in the caudal space fluoroscopically using a weight-based formula.[1] They concluded that the injectate volume is the key determinant of the height of the block. Younger patients had a significantly larger spread when the same weight-based dosage was administered.

Thomas et al. in 2010, studied the effect of volume of local anesthetic on the anatomic spread of caudal block in children aged 1–7 years. They found that increasing the volume of injectate between 0.5 and 1.0 results in a modest increase in the spread of the caudal solution. They also concluded that volume <1 ml will not reach a level greater than L2.[8]

Brenner et al. concluded that numerically small correlation exists between the injected volume of the local anesthetic and the cranial spread of caudally administered local anesthetics as assessed by ultrasound.[9]

However, in our present study, increasing the dose from 0.5 ml/kg to 1 ml/kg increased the spread of the local anesthetic cranially. An increase in the volume to 1.25 ml/kg did not increase the cephalad spread further. This was also confirmed with the spread in relation to conus medullaris and T12 vertebra. Hence, according to us, achieving a level of blockade till thoracic dermatomes is not possible with this dose.

Lundblad et al. in 2011, studied segmental distribution of caudal anesthesia (1.5 ml/kg) in neonates, infants, and toddlers as assessed by ultrasonography. They found an inverse relationship between age and the number of segments covered by a caudal injection of 1.5 ml/kg of local anesthetic in children 0–4 years of age.[3]

Later in 2012, Lundblad et al. stated that there are two separate patterns of secondary spread of caudal block: horizontal intrasegmental redistribution and longitudinal cranial spread. The compression and the reexpansion of the dural sac force the local anesthetic to travel further cranially leading to secondary spread.[9] We did not study secondary spread, as our main aim was just to see the primary spread sonographically. Furthermore, with the huge turnover of the cases, it was difficult to wait for us to study secondary spread.

Triffterer et al. studied the effect of the speed of injection of the local anesthetic in the primary spread of the drug.[10] Although their study did not yield any significant effect, we tried to keep the speed constant using an infusion pump.

Conclusion

The ultrasound assessment of local anesthetic spread after a caudal block showed that cranial spread of the block is dependent on the volume injected into the caudal space. Depending on required dermotomal level of blockade as per surgical incision, we can adjust volume of local anesthetic under real-time ultrasound. The dermatomal difference in cranial spread between 0.5 ml/kg and 1 ml/kg or 1.25 ml/kg was significant, but it was not significant between 1 ml/kg and 1.25 ml/kg. Hence, to achieve a higher thoracic level, we might have to increase the dose further keeping the toxic dose in mind. Hence, this could be used as a pilot study with a larger sample size required to validate the findings of this study.

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Conflicts of interest

There are no conflicts of interest.

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