ORIGINAL ARTICLE

Effects of Preemptive Analgesia by Caudal Route using Spinal Column Height Based Formula for Dose Calculation in Paediatric Patients Undergoing Infra Umbilical Surgery

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Abstract

Background: Caudal analgesia is a widely used technique for providing perioperative pain relief in pediatric patients undergoing infraumbilical surgeries. However, determining the appropriate dosage of local anesthetic agents can be challenging due to variations in pediatric anatomy and body habitus. Various formulae have been used for dose calculation based on body weight, spinal column height, age of patient, rate of injection etc. It is not possible to address all these factors while constructing these formulae. This study aims to explore that use of spinal column height-based formulae for dose calculation aiming to optimize analgesia while minimizing the risk of adverse effects other than body weight-based formulae.

Methods: This Quasi experimental study was carried out between June 2022 to November 2023 at Dhaka Medical College and Hospital. 50 patients belonging to ASA I and II of either sexes (25 patients in each group) were randomly allocated into two groups equally; Group A (Study group) received 0.25% plain bupivacaine according to spinal column height based modified Spiegel formulae and Group B (Control group) received 0.25% plain bupivacaine according to body weight based Armitage formulae. Drug volume was calculated according to respective formulae in both groups. Respiratory rate, Oxygen saturation and haemodynamic parameters (HR, MAP) were recorded at different time level. In the Post Anaesthesia Care Unit (PACU), level of sensory block and pain intensity were assessed by pin prick method and Wong Baker FACES pain scores respectively, at 5, 10, 15, 20, 30, 60 and 120 minutes then hourly upto 6 hours. Level of motor block was also assessed by modified Bromage scale during this period.

Results: The mean number of spinal segments blocked was significantly different among groups ($p< 0.001$) with patients in group A (4.11±0.22) showing significantly lower number of spinal segments blocked as compared to that in group B (4.40±0.21; $p< 0.001$). The mean volume of 0.25% bupivacaine used in group A was significantly lower ($p< 0.001$) than that in group B.

Conclusion: Caudal analgesia utilizing a spinal column height-based formula for dose calculation offers a reliable and precise approach for pain management in pediatric patients undergoing infraumbilical surgery while minimizing the risk of adverse events.

Key words: Caudal epidural analgesia, Modified Spiegel formula, Armitage formula, Postoperative pain, Infra umbilical surgery

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Introduction

Pain is an unpleasant subjective sensation that can be better felt than expressed. One of the most feared symptoms of diseases is pain, which a human being is always trying to alleviate and conquer since ages[1]. In most cases pain remains untreated in children because of the myths that children and infants do not feel pain, they do not remember painful episodes and there are no untoward consequences of experiencing pain in children[2]. Many factors contribute to inadequate pain relief in children such as: lack of training and experience regarding pediatric analgesia, difficulties in quantifying pain, inadequate use of pain scales and low expectations with respect to postoperative analgesia. Elsewhere, inter-patient variability in pain perception and analgesic requirements, differences in pharmacodynamics and pharmacokinetics, age-restricted drug licensing and a relative paucity of studies examining pediatric analgesia have also been proposed as contributing factors[3].

But appropriate pain management is a key factor in patient's early physical fitness and most importantly patient's satisfaction[4]. Quality of recovery, good surgical outcome, reduced hospitalization, and reduced convalescence along with parental satisfaction is dependent on adequate postoperative analgesia[5]. On the other hand, severe pain in children has significant long-term effects, sometimes even more than an adult[1]. Postsurgical pain can not only be agonizing for the child but may also result in harmful adverse physiologic response such as alteration in behavioral responses, change in baseline sensory function, enhanced responses to future pain, functional disability, depression, effects on family members and economic impact[6].

The ease of performance and the safety of caudal block make it a very popular method of pain relief in young children undergoing infraumbilical surgeries[7]. The caudal block was first described for anesthetic use in children by Campbell in 1933, and it is likely the most common regional anesthesia technique performed in children[8]. Caudal epidural analgesia in the pediatric age group is a popularly used regional technique nowadays due to its high success rate, good safety profile and long standing familiarity[9]. It significantly decreases the postoperative pain and systemic analgesic requirements. Caudal route is one of the simplest, reliable and safest techniques in pediatric surgery, with a high success rate[10]. It reduces the requirement of inhaled and intravenous (IV) anaesthetic agents, attenuates the stress response to surgery, facilitates a rapid and smooth recovery and provides satisfactory postoperative analgesia.

However, it is wise to utilize the lowest effective dose of local anesthetic solution that produces a predictable degree of neuraxial blockade, avoids an unwanted high level of blockade, and offers a larger margin of safety in the event of accidental intravascular injection. Numerous researchers have tried to develop formulas that would specify the ideal volume of local anesthetic needed to generate a predictable dermatomal level of neuraxial block in caudal epidural block. Some researchers have derived formulae using spinal height[11] while others have done so using body weight of the patient[12]. Other researchers also have developed their own formulae for dose calculation according to their research. The distribution of local anesthetics in caudal epidural block is influenced by a number of variables such as posture of the patient, height and age[13]. Other factors may also include dose (volume x concentration), place of injection along the neuraxis, rate of injection, body weight[14]. Considering all of these variables while constructing these calculations might not be practically possible.

Various scientific literatures lack direct comparisons of these formulae. In this study effects of preemptive analgesia by caudal route were assessed using spinal column height based modified Spiegel formula for dose calculation compared to body weight based Armitage formula in patients aged 4-8 years undergoing infra umbilical surgery.

Methods

This Quasi-experimental study was carried out between June 2022 to November 2023 in the Department of Anaesthesia, Pain, Palliative and Intensive Care, Dhaka Medical College and Hospital, Dhaka. Patients of age range 04-08 years, American Society of Anesthesiologists (ASA) physical status I, II and undergoing infra umbilical surgery were included in this study. Patients with history of allergy or adverse effects with local or regional anesthetics,

local infection at the site of injection, bleeding diathesis, spinal deformities, Body Mass Index (BMI) more than 30 Kg/m^2 and total dose of 0.25% bupivacaine exceeding 2.5mg/kg were excluded from this study.

After obtaining approval from the Ethical Review Committee, DMCH, a total of 50 patients were selected and randomized into two groups (Group A: Spinal column height based modified Spiegel formula and Group B: Body weight based Armitage formula). All the subjects received caudal epidural block with 0.25% bupivacaine after induction of general anaesthesia with dose calculated as per designated formula.

Study procedures

Spinal column height and body weight were measured in all subjects. Spinal column height was measured from cervical 7 (C7) vertebrae to sacral hiatus and expressed in centimeters. Location of C7 vertebrae was confirmed by bony prominence of the C7 vertebral spine and marked with a marker. Location of sacral hiatus was confirmed by feeling of a depression or dimple in between two sacral cornu and also marked with a marker. Distance between these two points was then measured by a measuring tape keeping the patient in erect posture. All patient's height and weight was also measured at that point. All patients' weight was measured by the same weight machine. Drug volume was calculated as per group allocation. All subjects received 0.25% bupivacaine for caudal analgesia at the beginning of surgery with dose calculated as per designated formula. Total volume of drugs did not exceed 30 ml according to age and BMI. In group A, spinal column height based Modified Spiegel formula was used for thoracic 10 (T10) level block. In group B, body weight-based Armitage formula was used for lower thoracic level.

Standard fasting period was maintained in all patients. All patients were cannulated with appropriately sized intravenous cannula before the procedure. A multiparameter patient monitor was attached to every patient. Baseline parameters (MAP, HR) were recorded at that point. General Anaesthesia (GA) with spontaneous respiration and caudal block was performed to all patients. General anesthesia was induced with propofol 2 mg/kg with fentanyl 2 µ gm/kg. Airway was maintained with an appropriately sized Laryngeal Mask Airway (LMA) with 50% nitrous in oxygen and 1% halothane. Muscle relaxants were not used as caudal block provided satisfactory muscle relaxation. Then the patients were prepared for caudal injection. For that they were positioned laterally with their hip flexed.

After proper exposure skin disinfection was done with povidone iodine solution. Location of sacral hiatus was again confirmed by bony landmark process and a 23G hypodermic needle was introduced within the sacral hiatus. The needle was oriented 60° in relation to the back plane with the bevel end directed ventrally. After crossing the sacro-coccygeal ligament perceptible by characteristic 'pop' when crossed the needle was redirected 30° to the skin surface, and then advanced a few millimeters into the sacral canal. Needle placement was confirmed by loss of resistance and unintentional placement into the intrathecal and epidural vessels was excluded by absence of spontaneous reflux of cerebrospinal fluid or blood. Then a calculated volume of 0.25% bupivacaine was administered after induction.

Heart rate (HR), Oxygen Saturation (SpO_2) and MAP were monitored during the perioperative period. After the completion of surgery, in the post anesthesia care unit (PACU), level of sensory block and pain intensity were assessed by pin prick method and FACES scale (Wong-Baker faces pain scale) respectively, at 5,10,15,20,30,60 and 120 minutes then hourly up to 6 hours. Motor blocks by modified Bromage scale were also assessed postoperatively. Investigator himself collected the data in the post anaesthesia care unit (PACU) in the postoperative period. The children were transferred from PACU at least after six hours, provided all other discharge criteria from the recovery room were fulfilled.

Intravenous fentanyl (0.5µg/kg) was planned as rescue analgesic whenever FACES pain score is >4 and will be repeated every 10 minutes until FACES score becomes <4. Total dose of intravenous fentanyl should not exceed 2µg/kg. However, adequate facilities with emergency drugs and equipment were available if the patient had experienced any adverse effects related to opioid administration (apnoea, hypotension, hypoventilation etc). The duration of analgesia was defined as the time from administration

of caudal block till the need for first rescue analgesic dose in postoperative period. Hypotension (fall in MAP by more than 20% of the baseline), motor weakness (modified Bromage score ≥1) after 2 hours or need for urinary catheterization (assessed every 2 hours based on clinical evidence of distension of urinary bladder or no passage of urine for 4 hours after the procedure) were recorded as adverse events. Data collection was done up to six hours after completion of surgery in the PACU.

Study measures

Armitage Formula[12]: This formula was described by Armitage on 1979. He used the formula for lower thoracic (up to thoracic 10) level of block which is the following: V= 1 ml per kilogram body weight. Here, V is the volume of drugs used in milliliter (ml)

Modified Spiegel Formula[11]: It is the formula used to block up to thoracic 10 level of dermatome.
Volume for T10 block (ml) V= {4+(D−15)/2}×13/20
Here, V is the volume of drugs in milliliter (ml), D is the distance between cervical 7 (C7) vertebrae to sacral hiatus in centimeters (cm). Remaining portion of this formula derived through empirical equations.

Wong-Baker FACES pain scale[15]: It is a visual pain assessment tool primarily used for children and individuals who may have difficulty communicating their pain. The scale shows a series of faces ranging from a happy face at 0, or "no hurt", to a crying face at 10, which represents "hurts like the worst pain imaginable".

Figure 1: Wong-Baker FACES pain rating scale

Statistical analysis

All data are presented in suitable table or graph according to their affinity. A description of each table is given to understand them clearly. All statistical analysis was performed using the SPSS 22.0 for windows (SPSS Inc., Chicago, IL, USA). Numerical data such as HR, MAP, sensory level and volume of drug at different points are expressed as mean ±SD. They were analyzed by student's t test. Categorical data is expressed as frequency and percentage. They were analyzed with chi-square test. The significance of the results as determined in 95.0% confidence interval and value of $p<0.05$ are considered statistically significant.

Results

This quasi experimental trial was carried out in a tertiary level hospital (DMCH) in Dhaka city. Total 50 patients aged 4-8 years coming for infra umbilical surgery were enrolled in this study by inclusion and exclusion criteria & they were randomly divided into two groups (group A and B); 25 patients in each group. In Group A, Spinal column height based modified Spiegel formula was used for dose calculation and in Group B, body weight-based Armitage formula was used for dose calculation. The baseline characteristics of the study participants are presented in table I. No statistically significant difference were found in case of demographic variables and clinical status.

Table I: Distribution of study subjects according to baseline characteristics

Characteristics	Group A (n=25)	Group B (n=25)	p value
Age in years	5.20±1.30	4.90±1.33	0.427
Sex			
Male	18(72%)	21(84%)	0.306
Female	7(28%)	4(16%)	
Spinal height	36.56±4.47	36.16±3.59	0.729
Duration of surgery	75.56±2.86	71.82±3.34	0.021
Body weight	15.92±2.19	15.20±1.93	0.225
Number of surgery			
Hemiotomy	16(64%)	19(76%)	
Circumcision	7(28%)	5(20%)	
Orchidopexy	2(8%)	1(4%)	

Values are expressed as Mean±SD and within parenthesis percentage (%) over column in total.

Considering HR and MAP in the peri-operative period, there were no significant statistical differences observed among the two groups.

In Group A, mean volume used (8.76 ml ± 0.96) was significantly lower than that used in Group B (13.2 ml ± 1.4; $p < 0.001$). There are also statistically significant differences in blocked number of spinal segments (14.40±1.04 in group A Vs 16.80±1.04 in group B), and used volume of drugs per segment between the groups (table II).

Table II: Level of sensory blockade and volume of the study subject

Sensory level to pinprick	Group A (n=25)	Group B (n=25)	p value
Volume used (ml)	8.76±0.96	13.20±1.40	0.001
Volume used (ml/kg)	0.66±0.06	1±0	0.001
Number of spinal segments blocked	14.40±1.04	16.80±1.14	0.001
Volume per segment	0.63±0.04	0.75±0.09	0.001

Values are expressed as Mean±SD

Sensory level to pinprick of the study subject was statistically significant at regular time intervals (at 5, 30, 60 mins and then hourly up to 6 hours). Higher number of dermatomal levels was seen to be achieved in Group B compared to Group A (table III).

Table III: Distribution of study subjects according to Sensory level to pinprick

Sensory level to pinprick test	Group A (n=25)	Group B (n=25)	p value
After 5 minute	14.40±1.04	16.80±1.04	0.001
After 30 minute	13.60±0.83	15.60±0.82	0.001
After 60 minute	13.47±0.83	14.80±0.82	0.002
After 120 minute	12.80±1.19	14.80±1.13	0.002
After 180 minute	12.75±0.90	14.20±1.00	0.001
After 240 minute	12.20±1.00	13.80±1.20	0.003
After 300 minute	11.80±1.30	13.80±1.34	0.002
After 360 minute	11.40±1.38	13.46±1.41	0.001

Values are expressed as Mean±SD

The mean duration of analgesia in group A 4.1 hours, whereas in group B it is about 4.40 hours. This means that group B has got extended duration of analgesia when compared with group A. This duration of analgesia is also statistically significant as detected by student 'T' test, in which the probability value is 0.001.

Table IV: Distribution of patients by Wong-Baker FACES pain score ≥ 4 at different points of time

Time	Group A (n=25)	Group B (n=25)
30 min	0	0
1 hour	0	0
2 hour	2(8%)	1(4%)
3 hour	4(16%)	3(12%)
4 hour	18(72%)	6(24%)
5 hour	9(36%)	16(64%)
6 hour	11(44%)	8(32%)

Values are expressed as absolute number, within parenthesis percentage (%) over the column in total.

Table IV demonstrates the distribution of patients by Wong-Baker FACES pain score ≥ 4 at different points of time. At 4 hours maximum patients (72%) in group-A had pain sore ≥ 4 and required rescue analgesia. Then at 6 hours higher number of patients in group-A (44%) had pain score ≥4. At these time points they needed rescue analgesic. Whereas 32% patients at group-B showing score ≥4 at 6 hours. Maximum patients in group-B required rescue analgesic at 5 hours as 64% of patients in group B achieved pain score ≥ 4.

Discussion

Being reliable, safe and easy-to-perform, caudal block is one of the most popular and commonly used regional blocks with general anaesthesia in paediatric practice. This study was conducted to evaluate the effects of preemptive analgesia by caudal route using spinal column height based modified Spiegel formulae for dose calculation compared to body weight-based Armitage formulae in pediatric patients.

In this study, no statistical difference was found in aspect of age, gender, body weight of the patients and the mean duration of surgery (min) ($p > 0.05$) between two groups (group-A & group-B). According to the current study it has been observed that heart rate and MAP at different points of time in perioperative period were close to the baseline value in both groups. In this study, the volume calculated using weight-based Armitage formulae turned out to be higher than the volume calculated using spinal column height based modified Spiegel formula and hence, consistently led to a higher level of neuraxial blockade. Sensory level blockade corresponding to T10 level was uniformly achieved in both the study groups.

Different studies have shown that the injectate volume is a key determinant of the height of block and that the spread is higher when weight-based dosage administration is used in younger individuals. Sinha C et al (2017) assessed the local anesthetic spread by ultrasound after a caudal block and showed that cranial spread of the block is dependent on the volume injected into the caudal space[16]. Similarly, Verghese ST et al. (2002) suggested that in children undergoing orchidopexy, a caudal block with a larger volume of dilute bupivacaine is more effective than

the smaller volume of the more concentrated solution in blocking the peritoneal stimulation during spermatic cord traction, without compromising the quality of postoperative analgesia[17]. However, in a study by Thomas et al. (2010) where they compared different volumes (0.5, 0.75, and 1 mlkg-1 of local anaesthetic solutions containing radio-opaque contrast, a modest increase in spread of injectate with increasing volume was observed[18].

In this current study, the mean (±SD) number of spinal segments blocked in group A is 14.40(±1.04) and group B is 16.80(±1.04), which are consistent with these above-mentioned studies. But the use of the minimal yet adequate volume for achieving the sensory blockade of target dermatomes is imperative to avoid complications associated with higher volumes such as local anaesthetic systemic toxicity (LAST), decreased cerebral flow and haemodynamic instability; which is also our primary aim of the study. In this regard, Lundbald et al (2014) observed a decline in mean cerebral blood flow (CBF) velocity and oxygenation after using higher volume (1.5 $ml.kg^{-1}$) in caudal block in infants with unaffected systemic haemodynamic parameters and advised caution while using higher volumes in patients with intracranial pathology[19]. However, in another study, Lundbald et al (2012) recognised the secondary cranial spread of local anaesthetic that, resulted in higher cutaneous median levels on testing at 15 min (T4) compared to ultrasonographic assessment at 0 min (T10) and after 15 min (T8)[20]. In our study, we used the pin-prick method for checking the cutaneous sensations at 5, 10, 15 and 30 min, therefore it is unlikely that this delayed cranial spread would be missed out in our observations.

In our study, the volume of local anesthetics used (ml/kg) was 0.66±0.06 in Group A and 1ml /kg in Group B, which was statistically significant ($p < 0.05$). There were also statistically significant differences in blocked number of spinal segments between the groups ($p < 0.05$). These findings correlated with the study by Kaushal et al., (2020)[21]. In this double-blind randomized study, children aged between 1 and 6 years and planned for infra-umbilical surgery were randomly allocated to receive caudal epidural block (targeting T10 level block) with 0.25% bupivacaine, using a volume calculated by modified Spiegel formula (group I), Takasaki formula (group II), and Armitage formula (group III). The authors demonstrated that dose calculation as per spinal column height-based modified Spiegel formula was more precise than body weight-based Takasaki and Armitage formulae for calculation of the volume of 0.25% bupivacaine for achieving T10 blockade in caudal epidural analgesia. As newer observations said that larger volumes of local anaesthetic reduce CBF and may cause LAST, use of the precise and smaller volumes of local anaesthetic appears more prudent. Our study shows that, spinal column height-based modified Spiegel formula is more precise than body weight-based Armitage formulae for calculation of the volume of 0.25% bupivacaine for achieving T10 blockade in caudal epidural analgesia for post-operative pain relief in paediatric population undergoing infra-umbilical surgeries. In that regard we can say the height of spinal segments (column) might be more significant than the body weight, which often varies grossly even among children with the same height.

On the contrary, McGown (1982) found weight to be a more accurate predictor of the dose per segment, and also found that the concentration of local anaesthetic did not seem to be important in determining the level of neural blockade, whereas the volume of local anaesthetic did[22]. However, the majority of children in his study did not receive general anaesthesia as a supplement to the caudal block, and this makes comparisons with other studies difficult.

Use of a smaller volume is often considered a compromise of longer duration of analgesia. Silvani et al. (2006) compared the post-operative duration of analgesia and motor blockade using low volume high concentration (ropivacaine 0.375% at 0.5 $ml.kg^{-1}$) with high volume low concentration (ropivacaine 0.1% at 1.8 $ml.kg^{-1}$) in caudal blockade and observed that the ‘’high volume, low concentration’’ regimen produced prolonged analgesia compared to the ‘’low volume, high concentration’’ regimen[7].

The difference of volume (0.5 ml vs $1.8ml.kg^{-1}$) is greater compared to our study (0.66 ml to 1.0 $ml.kg^{-1}$). Since our patients received 0.25% bupivacaine comparison of the duration of analgesia in this perspective would not have been rational. None of the patients in both groups of our study experienced haemodynamic

compromise or needed urinary catheterisation in the post-operative period.

Conclusion

Both formulae can be used for dose calculation in case of caudal block in paediatric patients undergoing infra umbilical surgery. In one hand, the Armitage formula which is based on body weight, is a commonly used and easily remembered method for calculating dosages in pediatric patients undergoing infraumbilical surgery. However, the modified Spiegel formula, which relies on spinal column height, emerges as a more precise alternative for preemptive analgesia administered via the caudal route. Moreover, the modified Spiegel formula offers an added layer of safety, providing a wider margin in the event of inadvertent intravenous drug administration. This distinction positions it as a preferred choice for enhancing patient care in such surgical scenarios.

Declaration

Ethics approval:

The study was approved by the Ethical Review Committee of DMCH (Memo No. ERC-DMC/EC-C/2022/202).

Author contributions

Conception and development of the idea RA
Writing RA
Data analysis RA, RMR, MMH
Data collection RA, MIA, MSA, AKMNK,TA
Review and Editing RA, MMK

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