Hemodynamic Effects of Caudal Blocks in Different Age Group of Children: A Prospective Observational Pilot Study using USCOM

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Objective: *To compare changes in hemodynamic parameters including systemic vascular resistance (SVR), cardiac output (CO), blood pressure (BP) and heart rate (HR) after caudal block in different age groups of children.*
Material and Method: *This single-center observational pilot study was conducted in ASA 1 to 2 children, less than 8 years of age who underwent surgeries under combined GA and caudal block from December 2013 to December 2014. Patients were divided into 3 groups (Group 1 = 0 to 1 years old, Group 2 = 1 to 3 years old, Group 3 = 3 to 8 years old). Hemodynamic parameters were measured with USCOM and compared at baseline and at 5, 10, and 15 minutes after caudal block with 1 mL/kg 0.25% bupivacaine.*
Results: *Total of 42 participants enrolled in this study (Group 1 = 11, Group 2 = 15, Group 3 = 16). CO, mean arterial blood pressure (MAP), and HR decreased after caudal block. HR and CO reductions were more pronounced in Group 3. MAP reduction was highest in Group 2. There was no reduction in SVR after caudal block in all groups.*
Conclusion: *No evidence of SVR reduction after caudal block in children less than 8 years old, which reflects immature sympathetic nervous system of this patient group. There were reductions in CO, MAP, and HR in these patients, especially in 3 to 8 years old. Future study with more participants is required to make conclusion.*

Keywords: *Caudal block, Pediatrics, Hemodynamic changes, USCOM*

J Med Assoc Thai 2017; 100 (Suppl. 7): S36-S43
Full text. e-Journal: *http://www.jmatonline.com*

Caudal block is one of the most common regional blocks in infants and children. It is easy to be performed by anesthesiologist. When combined with general anesthesia, it provides intraoperative and postoperative analgesia for lower extremities; perineal; lower abdominal; upper abdominal; or even lower thoracic surgeries. Caudal block can also be performed in ambulatory surgery setting. This technique can reduce the incidence of postoperative apnea in preterm infants and postoperative opioid consumption(1).

In adult studies, the hemodynamic changes after caudal blocks usually caused by sympathetic blockade.Venodilatation and vasodilation will occur and may cause hypotension in some patients. Venodilatation in lower part of the body leads to venous pooling in lower extremities and reduction in venous return to the heart and cardiac output (CO) respectively. Vasodilation effect also produces reduction in systemic vascular resistance (SVR). When local anesthetics spread to T1-T4 levels, the cardiac accelerator fiber will be inhibited causing bradycardia by unopposed parasympathetic function[2,3].

Caudal blocks in pediatric population, especially less than 8 years of age[4-6], cause less hemodynamic disturbances than in adult. This was explained by less blood pooling in their legs and immature sympathetic nervous system (SNS) function[4]. However, there was no clear cut on the age of children when their maturity of SNS reached the adult's. Hemodynamic parameters, especially systemic vascular resistance (SVR) changes after caudal block may reflect the capabilities of SNS function in children. We would like to conduct a study in order to identify specific pediatric age group that the SNS is mature and causes reduction in SVR after caudal blocks.

Transesophageal echocardiography (TEE) was reported as a measuring tool to evaluate hemodynamic parameters in several studies[7,8]. TEE is

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reliable, but considered as an invasive monitoring and need expertise, especially in pediatric patients. Bedside cardiac output (CO) measurement using pulmonary artery catheter (PAC)[9] was invasive and less applicable for children and unsuitable for neonate.

Ultrasonic cardiac output monitoring (USCOM, Sydney, Australia) is a noninvasive CO monitor based on continuous-wave Doppler ultrasound to measure the velocity of blood flow through the aortic or pulmonary valve. It was introduced for clinical use in 2001, providing a rapid interpretation of CO. It has been used to measure hemodynamic parameters in adults and children[10-12]. USCOM has been validated in adult and pediatric patients comparing it to CO pulmonary artery catheter (CO PAC) thermodilution technique[13-16]. USCOM is an FDA approved device for using in children with evidence of good inter-rater reliability[17] and ease of use[18]. The study by Day I et al in physicians who had no experience in using USCOM, they can be trained to develop reliable hemodynamic measuring skills by the 20th measurement[18].

Since there was little information on the hemodynamic changes after caudal block in pediatric population, therefore we would like to study the effect of caudal block on hemodynamic changes in different age groups of patients under 8 years of age using USCOM. The objective was to study effects of caudal block on hemodynamic (SVR, CO, blood pressure, heart rate) changes in different age groups of patients less than 8 years of age using USCOM.

Material and Method

The single-center prospective observational study was approved by International Review Board (Si 184/2014). Written informed consent was obtained from the parents.

Participants

Pediatric patients, ASA 1-2, aged between 0 to 8 years who were scheduled for elective lower abdominal surgeries, lower extremities, or surgeries in groin/perineum region from December, 2013 to December, 2014 were enrolled in the study. They were divided into 3 groups of 15 patients each: Group 1 = 0 to 1 year, Group 2 = more than 1 year to 3 years, Group 3 = more than 3 years to 8 years. Patients who had 1) contraindication to caudal block/general inhalational anesthesia, 2) known structural heart disease, or 3) short stature, abnormal growth development or diagnosis of failure to thrive were excluded.

Anesthetic protocol

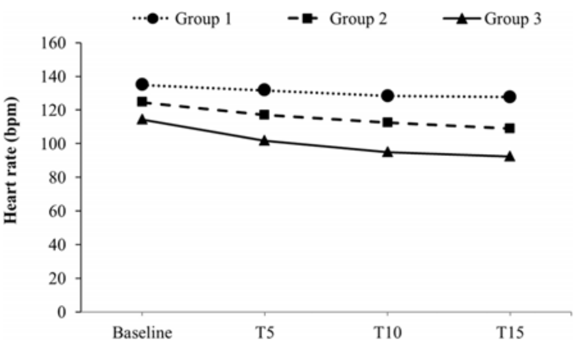
On operative day, patient would be attached to the monitor per American Society of Anesthesiologist standard of care including noninvasive blood pressure, electrocardiography, end-tidal carbon dioxide and temperature. Then induction of general anesthesia was initiated. Patients who already had IV line in place would receive either 5 mg/kg of thiopental IV or 2 to 2.5 mg/kg of propofol IV per in-charge anesthesiologist decision. Ones who had no IV placed would receive inhalation induction with sevoflurane in oxygen and nitrous oxide. Muscle relaxants (atracurium or cis-atracurium) would be given to facilitate tracheal intubation. Five to 10 minutes after the endotracheal tube intubation or until patient was in steady state, the first scan by USCOM at suprasternal area was performed and hemodynamic parameters were recorded as patient's baseline condition. Then patient would be placed in lateral position in order to perform caudal block. After loss of resistance was identified, 0.25% bupivacaine 1 mL/kg was delivered in caudal space and completed in 20 to 30 seconds in every case by the first or second investigator of this study. The hemodynamic parameters recorded at each USCOM evaluation were systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), heart rate (HR), CO, and SVR. Then the same hemodynamic parameters were measured at 5, 10 and 15 minutes after completion of caudal block. Either the 1st or the 2nd investigator of this study performed USCOM measurements in all patients. Only one investigator throughout the study period examined each patient. During study period, all patients were maintained with 1 MAC of inhalational anesthetic agents and received fentanyl not more than 1 mcg/kg IV. After completion of study, additional opioids and muscle relaxant can be subsequently given and depth of anesthesia can be adjusted per attending anesthesiologist's decision. In case of hypotension (SBP less than 5th percentile of age), crystalloid fluid bolus would be given and total fluid amount were recorded. Other possible causes of hypotension would be identified and treated.

Data collection

The record form consisted of 1) Patient demographic (age, gender, body weight, height, ASA physical status, comorbidity, surgical diagnosis, preoperative fasting time preoperative fluid received 2) Hemodynamic parameters (SBP, DBP, MAP, HR, CO, SVR) at baseline, and 5, 10 and 15 minutes after caudal block and 3) Anesthetic data (anesthetic agents, volume of 0.25% bupivacaine, duration of anesthesia, and complications). Since there was no previous study regarding the SVR changes in different age groups of pediatric patients after caudal block, we would like to perform this pilot study and aim to get 15 patients in each age group.

Statistical analysis

Data were prepared and analyzed using PASW Statistics for Windows, 18.0 Chicago: SPSS Inc. Continuous variables were expressed as mean ± standard deviation (SD) or median and range as appropriate. Number and percentage were described for categorical variables. Independent sample t-test or Mann-Whitney U test, as appropriate, was used to compare continuous variables between children less than 3 years old and children 3 to 8 years old. Categorical variables between groups were compared with Chi-square test or Fisher's exact test. One-way ANOVA followed by Bonferroni's post-hoc pair wise comparisons tests or Kruskal-Wallis test followed by Tukey post-hoc pair wise comparison was used to compare continuous variables among 3 age groups. All tests of significance were two tailed, $p<0.05$ was considered statistical significance.



T5 = 5 minutes after caudal block, T10 = 10 minutes after caudal block, T15 = 15 minutes after caudal block, Group 1 = 0 to 1 year, Group 2 = >1 to 3 year; Group 3 = >3 to 8 year.

Fig. 1 Heart rate (HR) changes at 5, 10 and 15 minutes after caudal block in 3 groups of patients.

Results

There were total of 42 participants enrolled in this study (Group 1 = 11, Group 2 = 15, Group 3 = 16). Patient characteristics of 3 groups were presented in Table 1. Hemodynamic changes after caudal block in each group were presented in Fig. 1 (HR), Fig. 2 (MAP), Fig. 3 (CO) and Fig. 4 (SVR).

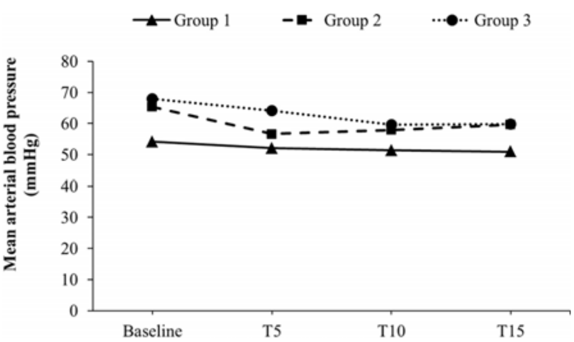


Fig. 2 Mean arterial pressure (MAP) changes at 5, 10 and 15 minutes after caudal block in 3 groups of patients.

Table 1. Demographic data of patients at different age groups

Factors	Group 1 (n = 11)	Group 2 (n = 15)	Group 3 (n = 16)	*p*-value
Mean age (yr)	0.5±0.3	1.7±0.6	5.2±1.5	<0.01
Gender: Male	7 (63.6)	14 (93.3)	13 (81.3)	0.16
Body weight (kg)	6.5±2.9	11.5±2.8	17.5±3.4	<0.01
Height (cm)	63.8±13.5	83.0±9.1	105.8±9.9	<0.01
ASA I	7 (63.6)	13(86.7)	13 (81.3)	0.35
ASA II	4 (36.4)	2(13.3)	3 (18.8)	0.35
Type of operation				0.17
Lower abdomen	4 (36.4)	1 (6.7)	1 (6.3)	
Groin/perineum	7 (63.6)	13 (86.6)	14 (87.5)	
Lower extremity	0 (0)	1 (6.7)	1 (6.3)	
Preoperative fasting (hr)	7.6±1.3	8.5±1.5	8.4±1.8	0.29
Total intravenous fluid (mL)	29.1 (2.9, 58.8)	36.4 (7.6, 50.5)	31.3 (0,39.5)	0.11

Data presented as mean SD, median (min, max) or n (%)

After caudal block, mean changes of each hemodynamic parameter (HR, MAP, CO, SVR) were presented in Table 2. CO, MAP, and HR were decreased over time after caudal block. Compared with baseline, HR and CO changes in 3 to 8 years old patients were more pronounced than those of younger patients. Reduction of MAP after caudal block was highest in Group 2. Maximum degrees of hemodynamic changes were identified at 10 minutes after caudal block. Overall, there was no reduction in SVR after caudal block in every group and there was an increasing in SVR after caudal block in Group 3 patients. Subgroup analysis in Group 3 was subsequently performed and unable to identify the cut of point of age that had significant SVR reduction after caudal block.

Discussion

According to our study objective, we would like to study the hemodynamic effect of caudal block in the 'immature SNS' population. Age group that had reduction in SVR after caudal block should reflect

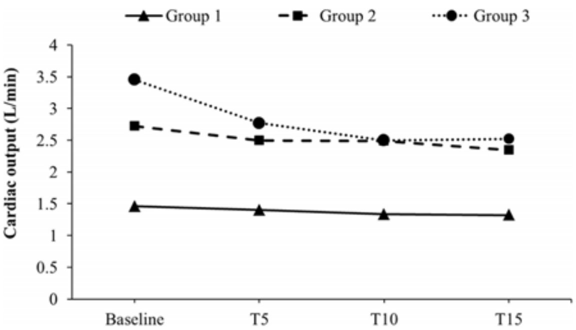


Fig. 3 Cardiac output (CO) changes at 5, 10 and 15 minutes after caudal block in 3 groups of patients.

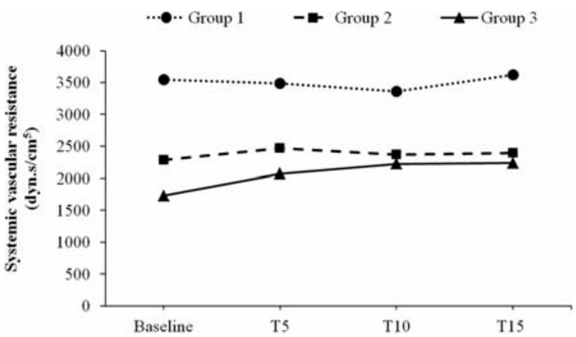


Fig. 4 Systemic Vascular resistance (SVR) changes at 5, 10 and 15 minutes after caudal block in 3 groups of patients.

Table 2. Mean changes in HR, MAP, CO, and SVR, compared with baseline, in 3 groups after caudal block over time (at 5, 10, 15 minutes after block)

Parameters	Group 1 (n = 11)	Group 2 (n = 15)	Group 3 (n = 16)	*p*-value
Mean heart rate change (bpm)				
T5	3.5	7.7	12.4	0.15
T10	6.5	12.2	19.3	0.03
T15	7.1	15.7	21.9	<0.01
Mean MAP change (mmHg)				
T5	2.0	8.8	3.8	0.04
T10	2.7	7.5	8.3	0.21
T15	3.2	9.6	8.1	0.09
Mean cardiac output change (L/min)				
T5	0.1	0.2	0.7	<0.01
T10	0.1	0.2	1.0	<0.01
T15	0.1	0.4	0.9	<0.01
Mean systemic vascular resistance change (dyn.s/cm^5)				
T5	64.2	-180.3	-340.0	0.42
T10	185.0	-85.3	-492.0	0.04
T15	-75.0	-109.0	-503.2	0.19

The minus data representschanges in parameters that had pre-caudal block value lower than post-caudal block value.
T5 = 5 minutes after caudal block; T10 = 10 minutes after caudal block; T15 = 15 minutes after caudal block; Group 1 = 0 to 1 year; Group 2 = >1 to 3 year; Group 3 = >3 to 8 year

that their SNS was mature enough to be affected by local anesthetics. The result of this pilot study could not identify the specific 'cut-of-point' of pediatric age that identifies maturity status of SNS. This result was similar to the previous studies[4-6].

Previously, there was little information on the effect of caudal block on CO, MAP, and HR. In this study, there were significant reduction in CO, MAP, and HR in all groups of children. Therefore, caudal block in pediatric population can produce hemodynamic disturbances via other mechanisms than reduction of SVR.

Bradycardia after lumbar epidural block without cardiac accelerator fiber blockade (sensory level checked) was reported in adult and pediatric population[4,19-21]. The explanation in adult setting was reduction of venous return from venous pooling will increase vagal activity by cardiopulmonary-mediated reflex[19]. However, this cannot be used to explain the same phenomenon in pediatric setting because there was an echocardiography evidence demonstrated no reduction in venous return in pediatric population after epidural block[20]. The reduction of heart rate in young children after caudal block was also demonstrated in another study[21]. The effect only elicited in children who received plain local anesthetics.

Effect of caudal block on CO was inconclusive. From our study, CO was decreased after caudal block. There was a report of increasing of blood volume in descending aorta from 1.92 to 1.14 L/min in the study by Larousse E et al. From Monsel et al's study detected hemodynamic changes after epidural block in children weighed less than 10 kg by a transesophageal Doppler. They reported no significant reduction of CO after epidural block, which increased stroke volume and decreased HR, SBP, DBP, and SVR. These findings were also matched with Group 1 of our study participants. However, all studies used different intervals to define their age groups of pediatric patients and the numbers of participants were small, so the result of hemodynamic effects after caudal block may be varied.

The SVR value of this USCOM study was calculated from the formula. SVR = 80 (MAP-MVP)/CO, where MAP = mean arterial pressure; MVP = mean venous pressure; CO = cardiac output. We did not measure MVP directly in the study. The MVP value used for calculation was a 'normal' value for age that was recommended by the machine. The reported SVR values may not represent the correct ones. However, the error should not be a major effect because 1) there were total of 4 examinations in one patient, and 2) all studies were performed before surgeries started, so the volume status should be maintained throughout.

Depth of anesthesia of each patient in this study may be different. We attempted to keep all patients at the same depth of anesthesia by maintaining end-tidal anesthetic agent concentration at 1 MAC for age. But we did not use BIS monitor to assess depth of anesthesia. Isoflurane can produce increase in HR. We did not control the type of anesthetic agent. There were more patients who received sevoflurane than isoflurane. Although the higher proportion of isoflurane patients were group 3 patients, they also found to have reduction in HR after caudal block.

Level of local anesthetics spreading reflects dermatomal area of sympathetic block, as well as degree of hemodynamic disturbances. Although all patient in our study received equal volume of 0.25% bupivacaine per kg body weight, but the distribution of bupivacaine in each age group were different. Previous studies of the average maximal level of local anesthetic spreading in children who received the same dosage was at T10 level (6 to 58 months old)[22], T11 level (1 to 5 years old)[23], and L2 level (1 to 7 years old)[24].

There was an observation of further reduction in SBP in some cases beyond 15 minutes after caudal block. However, no information on other hemodynamic parameter was reported because no further USCOM measure was performed. During sevoflurane anesthesia, onset of caudal bupivacaine was 3.1 minutes[25]. However, there was no information about when it reached maximal effect. One study in infants who received 1.5 mL/kg of local anesthetics found to have secondary spreading of local anesthetics from T10 to T8 level at 15 minutes after injection. Since there was information of secondary spreading in this 1 mL/kg dose, we could not make a conclusion about the cause of further reduction of SBP beyond 15 minutes after caudal block in our study.

This study did not compare the patient in the same age group who received only general anesthesia without caudal block. So, we cannot exclude the effect of inhalational agent on hemodynamic changes. Lastly, this study was only a pilot study. There was not enough information from literature review to calculate sample size. And the number of the patients in each group may not have enough power to detect significant difference between groups.

More participants in each group will be required to get enough power to detect difference between groups. Age groups should be classified with the same interval of age ranges. Level of local anesthetic spreading should be identified, if possible. Number of examinations for each patient should be increased until all studied parameters are at steady state. Studies to compare hemodynamic parameter changes from caudal block by using different noninvasive tools can also be an interesting subject.

Conclusion

From this pilot study, there was no SVR reduction after caudal block in pediatric patients younger than 8 years of age.This may reflect that SNS of this patient group were still immature. However, there were reductions in CO, MAP, and HR in these patients, especially in 3 to 8 years old group. Future study with more participants is required to make conclusion.

What is already known on this topic?

Sympathetic nervous system (SNS) in children is not mature. Hemodynamic changes after caudal block in children were less pronounced than the adults'. There was no clear cut of children's age when SNS is well developed.

What this study adds?

There was no SVR reduction after caudal block in pediatric patient younger than 8 years old, which support previous finding. However, caudal block with 1 mL/kg dose of 0.25% bupivacaine should be done with caution because reductions in HR, MAP, and CO were identified in all age group.

Acknowledgements

Authors would like to thank Dr. Sasima Tongsai for contributing on statistical analysis and Ms. Nipaporn Sangarunakul for organizing this study.

Trial registration

Clinicaltrials.in.th: TCTR20170526045.

Potential conflicts of interest

None.

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การเปลี่ยนแปลงของระบบไหลเวียนเลือดหลังจากการฉีดยาเข้าช่องเหนือเยื่อหุ้มไขสันหลังระดับ caudal ในผู้ป่วยเด็ก; การศึกษานำร่องแบบไปข้างหน้าโดยการตรวจวัดด้วยเครื่อง USCOM

ภารดี ศิริบูรณ์, พิชยา ไวทยะวิญญู, สุวรรณี สุรเศรณีวงศ์

วัตถุประสงค์: *เพื่อเปรียบเทียบการเปลี่ยนแปลงของค่าระบบไหลเวียนเลือดคือ SVR, CO, MAP, HR ภายหลังจากการฉีดยาเข้าช่องเหนือเยื่อหุ้มไขสันหลังระดับ caudal*

วัสดุและวิธีการ: *การศึกษานี้เป็นการศึกษานำร่องแบบไปข้างหน้าในผู้ป่วยเด็กอายุน้อยกว่า 8 ปี ที่มาเข้ารับการผ่าตัด ภายใต้การระงับความรู้สึกแบบทั่วไปร่วมกับการฉีดยาเข้าช่องเหนือเยื่อหุ้มไขสันหลังระดับ caudal ที่โรงพยาบาลศิริราช ระหว่างเดือนธันวาคม พ.ศ. 2557 ถึง เดือนธันวาคม พ.ศ. 2558 โดยแบ่งผู้ป่วยออกเป็น 3 กลุ่มคือ กลุ่มที่ 1: อายุ 0 ถึง 1 ปี กลุ่มที่ 2: อายุมากกว่า 1 ปีถึง 3 ปี กลุ่มที่ 3: อายุมากกว่า 3 ปีถึง 8 ปี และใช้เครื่อง USCOM ในการตรวจวัดค่าระบบไหลเวียนเลือดดังกล่าวเปรียบเทียบค่าก่อนฉีดยา 0.25% bupivacaine 1 มล./กก. เข้าช่องเหนือเยื่อหุ้มไขสันหลังระดับ caudal และหลังฉีดยาที่ 5, 10, และ 15 นาที*

ผลการศึกษา: *มีผู้ป่วยทั้งหมด 42 คนที่เข้าร่วมการศึกษา (กลุ่มที่ 1 = 11, กลุ่มที่ 2 = 15, กลุ่มที่ 3 = 16) พบว่าค่า CO, MAP และ HR ลดลงภายหลังจากการฉีดยาเข้าช่องเหนือเยื่อหุ้มไขสันหลังระดับ caudal ในทุกช่วงอายุ โดยผู้ป่วยกลุ่มที่ 3 มีการเปลี่ยนแปลงของค่า HR และ CO มากที่สุด และผู้ป่วยกลุ่มที่ 2 มีการเปลี่ยนแปลงของ MAP มากที่สุด และไม่พบว่ามีการลดลงของค่า SVR ในทุกกลุ่มอายุ*

สรุป: *ไม่พบการเปลี่ยนแปลงลดลงของค่า SVR ภายหลังจากการฉีดยาเข้าช่องเหนือเยื่อหุ้มไขสันหลังระดับ caudal ในผู้ป่วยเด็กอายุน้อยกว่า 8 ปี แต่พบการเปลี่ยนแปลงลดลงของ CO, MAP, และ HR ในทุกกลุ่มอายุโดยเฉพาะกลุ่ม อายุ 3 ปีขึ้นไปถึงไม่เกิน 8 ปี ควรมีการศึกษาในอนาคตในกลุ่มตัวอย่างขนาดใหญ่ขึ้นเพื่อให้ได้ข้อสรุปที่ชัดเจนยิ่งขึ้น*