Ultrasound in Med. & Biol., Vol. 40, No. 11, pp. 2630–2636, 2014

0301-5629/$ - see front matter

http://dx.doi.org/10.1016/j.ultrasmedbio.2014.06.020

● *Original Contribution*

ULTRASOUND VISIBILITY OF SPINAL STRUCTURES AND LOCAL ANESTHETIC SPREAD IN CHILDREN UNDERGOING CAUDAL BLOCK

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(*Received* 9 *January* 2014; *revised* 14 *May* 2014; *in final form* 30 *June* 2014)

Abstract—This study assessed ultrasound visibility of spinal structures in children and observed the extent of local anesthetic spread within the epidural space during caudal block. Spinal structures were evaluated with ultrasound from the sacral area to the thoracic area in 80 children, and drug spread levels were observed after caudal injection of 0.5, 1.0, 1.25 and 1.5 mL/kg local anesthetic. The conus medullaris, dural sac and dura mater were easily identified with ultrasound in most children. However, ligamentum flavum visibility declined with increasing vertebral level and markedly decreased at the thoracic level in children older than 7 mo or heavier than 8.5 kg. Drug spread was higher with increasing volume ($p < 0.001$) and in children ≤12 mo more than children >12 mo ($p < 0.001$); drug spread was significantly correlated with age ($R^2 = 0.534$). Spread levels assessed with ultrasound were roughly two to three segments lower than those in previous radiologic studies. (E-mail: hkkil@yuhs.ac)

Key Words: **Ultrasound, Spinal structures, Caudal block, Children.**

INTRODUCTION

Several formulas have been introduced to predict cranial spread of local anesthetics after single-shot caudal block in children (Armitage 1979; Busoni and Andreuccetti 1986; Schulte-Steinberg and Rahlfs 1977; Takasaki et al. 1977). Recently, a low-concentration, high-volume (1.5 mg/kg) local anesthetic regimen for prolonged postoperative analgesia has gained popularity (Lundblad et al. 2011, 2012; Silvani et al. 2006). However, the relationship between volume of anesthetic and block level was unreliable, and there was a large discrepancy in predicted levels between formulas, especially at high volumes. A radiographic study that used 1.5 mL/kg 0.15% ropivacaine for caudal blockade reported the median (range) drug spread level to be T6 (T3–T11) in 37 infants and small children (Hong et al. 2009).

As an alternative method to assess local anesthetic spread during caudal block in children, real-time ultrasound has garnered much interest (Brenner et al. 2011; Thomas et al. 2010; Triffterer et al. 2012). In a recent ultrasound study, cranial spread beyond T12 after caudal injection of 1.5 mg/kg local anesthetic was observed in only 25% of 32 infants and toddlers (Lundblad et al. 2011). Another study reported the median drug spread level to be as high as T8 (T4–T11) after caudal injection of the same volume of local anesthetic in 16 infants (Lundblad et al. 2012). This relatively large discrepancy between studies may be due to the difference in local anesthetic spread with patient age and the possible detection bias caused by ultrasound visibility of spinal structures. The local anesthetic within the epidural space is detected as a highly hypo-echoic pattern, and injected local anesthetics widen the epidural space, which displaces the dura mater anteriorly. Therefore, the accuracy and reliability of estimating local anesthetic spread with ultrasound can be said to be dependent on the visibility of spinal structures (Brenner et al. 2011; Lundblad et al. 2011; Marhofer et al. 2005; Tsui and Suresh 2010).

We performed this prospective study in 80 small children between 2 and 54 mo of age, to assess ultrasound visibility of spinal structures that may affect the detection of local anesthetic spread within the epidural space during caudal block. The extent of cranial drug spread at different predetermined volumes was also observed with real-time ultrasound.

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METHODS

Patients

After approval was obtained from the institutional review board of Yonsei University Health System and the study was registered at www.ClinicalTrials.gov (NCT01340313, Principal investigator: Hae Keum Kil, registered on April 19, 2010), 80 American Society of Anesthesiologists physical status I children, aged 2 to 54 mo, undergoing ambulatory urologic surgery were enrolled in this study. Written informed consent was obtained from the parents of all patients. Children with local infections on their back, coagulation disorders, pre-existing neurologic diseases or spinal anomalies were excluded. On the basis of previous pharmacokinetic studies, children weighing more than 18 kg were also excluded from this study to avoid systemic complications resulting from a large dose of local anesthetic (Kil et al. 2007; Roberts et al. 2005).

Anesthesia protocol

No premedication was given. Standard monitoring (electrocardiography, non-invasive arterial blood pressure, pulse oximetry and end-tidal carbon dioxide tension) was employed, and anesthesia was induced through inhalation of 6%–7% sevoflurane in oxygen as in previous studies (Hong et al. 2009; Kim et al. 2014). After securing intravenous access was secured, tracheal intubation was performed without neuromuscular blockers, and mechanical ventilation was started to maintain an end-tidal carbon dioxide level of 35 ± 5 mm Hg.

Ultrasound examination and caudal block

After induction of anesthesia, the patient was placed in the lateral position with both hips in full flexion, and ultrasonography (LOGIQe, GE Healthcare, Wauwatosa, WI, USA) was performed using a linear probe (8–13 MHz) to evaluate spinal structures. Optimal images including the dura mater and ligamentum flavum were obtained in the median or paramedian (60°–80° angle) longitudinal view with the manipulation of probe position, beam frequency and depth. The dura mater and ligamentum flavum are identified as two highly hyperechogenic lines, with the underlying spinal cord appearing as a largely hypo-echoic structure. Images of three vertebral levels (lower lumbar, L4–5; upper lumbar, L1–2; lower thoracic, T10–11) were saved for later assessment. The spinous process levels of L5 and T12 were marked on the skin for easy identification of the spinal level during caudal injection. Corresponding vertebral levels of the dural sac and conus medullaris were evaluated. All ultrasound examinations were performed by a single, highly experienced investigator familiar with the technique.

After sterilization of the skin, caudal puncture was performed using a 22G short-beveled needle with the loss of resistance technique. Successful puncture was confirmed with ultrasound. The probe was placed in the predetermined position to visualize local anesthetic movement within the epidural space. Then, 1.5 mL/kg of 0.15% ropivacaine (Naropin, Astra Zeneca, Wedel, Germany) was injected at a rate of approximately 1 mL/3 s using a 10-mL syringe connected to a 45-cm extension tube. The dose and concentration of ropivacaine were chosen on the basis of our previous study (Hong et al. 2009). At the same time, the probe was moved cranially to follow the bulk movement of the local anesthetic with dural displacement (Fig. 1). The local anesthetic is identified as an anechoic area above the dura mater causing an expansion within the epidural space. Marks were made on the skin corresponding to the observed leading edge of the local anesthetic when

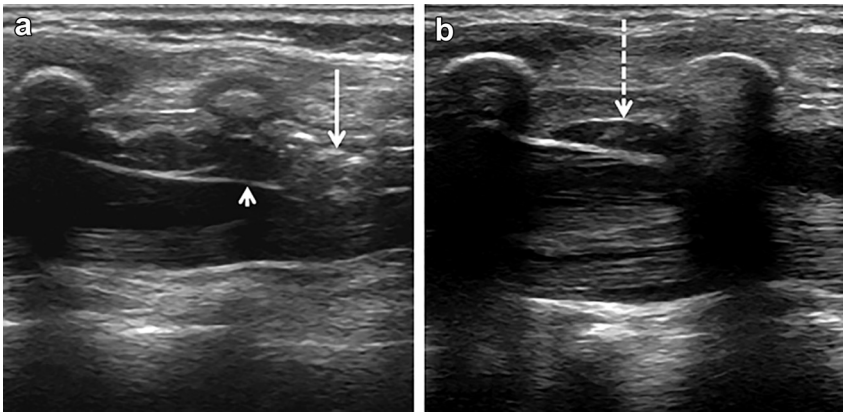

Fig. 1. Drug movement within the epidural space observed by ultrasound in a 20-mo-old toddler (height = 79 cm, weight = 11 kg). (a) The solid arrow indicates the turbulent leading edge of the injected drug while the arrowhead indicates ventral displacement of the dura mater caused by drug movement. (b) Dotted arrow indicates the bulk movement of injected drug within the epidural space.