The extent of cranio-caudal spread within the erector spinae fascial plane using computed tomography scanning in a neonatal cadaver

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S Govender: The conception and design of the study, acquisition of data, analysis and interpretation of data, drafting the article, revising it critically for important intellectual content, final approval of the version to be submitted; D Mohr: Acquisition of data and revising it critically for important intellectual content; AN Van Schoor: The conception and design of the study, revising it critically for important intellectual content and final approval of the version to be submitted. Prof AT Bosenberg. The concept and design of the study, revising it critically for important intellectual content and final approval of the version to be submitted.

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Conflicts of interests

None to declare.

What is known about the topic?

The Erector Spinae plane block (ESP) is an interfascial block, in which local anesthetic travels deep to the erector spinae muscle targeting the ventral and dorsal rami of spinal nerves.

What new information this study adds:

The route of access for an ESP block follows a paravertebral spread into the paravertebral space covering 3-4 vertebral levels, suggesting an approximate volume of 0.5-0.6ml per dermatome.

Abstract

Background: The Erector Spinae Plane block (ESP) is a novel approach for blockade of the spinal nerves in infants, children and adults. Until recently the gold standard for truncal procedures include the paravertebral and epidural blocks. However, the exact mechanism by which this blockade is achieved is subject to debate.

Methods: 2.3ml (1ml.kg) of iodinated contrast dye was injected bilaterally into the erector spinae fascial plane of a fresh unembalmed preterm neonatal cadaver (weighing 2.3kg), to replicate the erector spinae plane block and to track the cranio-caudal spread of the contrast dye using computed tomography. The "block" was performed at vertebral level T8 on the right-hand side and at vertebral level T10 on the left-hand side.

Results: Contrast dye was spread over three dermatomal levels from T6 to T9 on the right-hand side, while on the left-hand side, the spread was seen over four dermatomal levels from T9 to T11/12. Contrast dye also spread over the costotransverse ligament, into the paravertebral space and further lateral from the lateral border of the erector spinae muscle into the intercostal space. However, no spread was seen in the epidural space.

Conclusion: The erector spinae plane block is a versatile technique that can be part of the multimodal postoperative analgesic strategy for truncal surgery. In this study, contrast material dye was tracked over four vertebral levels in the paravertebral space (suggesting an approximate volume of 0.5-0.6ml per dermatome).

Key words: cranio-caudal, dermatomal spread, erector spinae plane block, neonates, paravertebral spread.

Introduction

Erector spinae plane (ESP) block is a novel approach to blockade of the spinal nerves in infants, children and adults. Until recently the gold standard for truncal procedures include the paravertebral and epidural blocks.[1,2] The ESP block serves as a "paravertebral by proxy" and is an alternative approach, targeting similar nerves as the paravertebral and epidural blocks.[3] The exact mechanism by which the ESP blockade is achieved is subject to debate.

The mechanism of analgesia is thought to result from blockade of the ventral and dorsal rami of spinal nerves.[4] The ESP block is performed with deposition of local anesthetic deep to the erector spinae muscle, yet superficial and lateral to the tip of the transverse process. Authors have suggested the ESP block is safer than epidural blocks as the local anesthetic is administered distant from the neuraxial structures within a fascial plane.[5–8]

The objective of this report is to determine the degree of cranio-caudal spread of contrast medium while replicating the ESP block in a fresh neonatal cadaver. Contrast material was injected into the erector spinae fascial plane with the aim of tracking the cranio-caudal spread within the fascial plane. The spread was confirmed using computed tomography (CT).

Materials and method

The study was approved by the PhD and Research Ethics Committee (94/2019), University of Pretoria, Gauteng, South Africa. Permission was also obtained from the Radiology Department, Steve Biko Academic Hospital to utilize their CT scanning equipment. A fresh unembalmed preterm neonatal cadaver (weighing 2.3kg) subject to cryopreservation was obtained through the National Tissue Bank from the University of Pretoria under the regulations specified in the South African National Health Act 61 of 2003. Iodinated contrast dye was injected into the erector spinae fascial plane space by an experienced anaesthesiologist to replicate the ESP block and to determine the cranio-caudal spread of the contrast using computed tomography.

Prior to placing the ESP block test injections were done on the lower limb to determine the concentration of the contrast material that could be used. This depended on the amount of scatter – a combination of dark and light streaks between objects such as bone – on the Philips CT machine (parameters: 100 Kvp, 75 mAs, 7.2 scan time). Two millilitres of pure concentrated contrast dye was injected into the right leg, while two millilitres of diluted contrast

dye was injected into the left leg. Upon scanning, the right side was difficult to interpret as the quality of the image was distorted by scatter artifacts. Therefore, we decided to use 30ml of 30% urografin (cot 85588036) diluted in 200ml of 0.9% sodium chloride (cot 9030801) as the contrast medium.

With the cadaver in a prone position, the procedure began by palpating the spinous process of the seventh cervical vertebra. This was further confirmed under ultrasound guidance by using an Edge^{TM} ultrasound system machine (ref: P15000-11, SN-03P55Z) with a high frequency (6 - 13MHz) linear array transducer (footprint size of 2.5cm) covered with a protective plastic sheath. Once the seventh cervical vertebra level was confirmed, the spinous process and the corresponding transverse process of vertebrae T8 and T10 were identified by counting inferiorly from the seventh cervical vertebrae. The transducer was placed perpendicular to the transverse process of T8, 1cm lateral to the spinous process (on the right-hand side), to obtain a short axis view of the bony landmarks and the surrounding musculoskeletal structures. The transducer was then rotated 90 degrees into a longitudinal parasagittal orientation, to establish a long axis view for the same structures. A 16mm 21g needle was then inserted in a cranio-caudal direction towards the lateral tip of the transverse process using the in-plane approach. Once contact was made with the transverse process, 2.3ml (1ml/kg) of contrast dye material was injected into the erector spinae fascial plane between the transverse process and the erector spinae muscle. As the contrast dye was injected, the erector spinae muscle was hydro dissected away from the underlying bony landmarks. The procedure was then repeated on the left-hand side at vertebral level T10. The dye was allowed to spread for 20 minutes prior to turning the cadaver in a supine position for CT scanning. The images were reconstructed to provide a three-dimensional (3D) view of the trunk in an attempt to fully delineate the spread of the contrast dye.

Results

Using the multi-slice CT and 3D volume rendering function on radiant DICOM viewer, we were able to determine the cranio-caudal spread over multiple vertebral levels. On the right-hand side, spread over three dermatomal levels from T6 to T9 was seen, while on the left-hand side, there was spread over four dermatomal levels from T9 to T11/12. (Figure 1). The contrast dye was observed over the costotransverse ligament and further lateral from the lateral border of the erector spinae muscle into the intercostal space. Contrast dye spread was also seen in the

paravertebral space, however, no spread was seen in the epidural space. Additionally, contrast dye was seen anterior to the erector spinae muscle from vertebral levels T6 to T11/12, yet posterior to the muscle from vertebral levels T9 to T11/12 (Figure 1).

Figure 1: Lateral view of a three-dimensional volume rendered CT reconstruction of contrast injectate spread in a fresh neonate. Green arrows – represent the cranio-caudal spread within the erector spinae fascial plane space at vertebral level T8. Yellow arrows – represents the cranio-caudal spread within the erector spinae fascial plane space and posterior to the erector spinae muscle at vertebral level T10.

Discussion

Since its inception, the indications and clinical use of the ESP block for various surgical strategies have been increasing.[9] The ESP block is a novel regional technique that could be used as an alternative to neuraxial blocks for truncal surgery.[9–11] The aim of this report was to determine the cranio-caudal spread of contrast material within the fascial plane space and subsequently infer the dermatomal coverage when replicating the procedure in a fresh neonatal cadaver.

The mechanism of spread for the ESP block is attributed to the anterior perforations in the sheath of the erector spinae muscle and the soft tissue gaps.[12,13] It is hypothesised that the ESP block targets the ventral and dorsal rami of spinal nerves as the local anesthetic penetrates into the paravertebral and epidural spaces.[14,15] However, this was not entirely the case in this study. Contrast dye was seen over the posterior aspect of the lamina, the posterior aspect of the transverse process, the costotransverse ligament and in the paravertebral space. Anatomically, based on this study and various other supporting studies the ESP block could be a possible alternative to a paravertebral block as the spread of local anesthetic solution is similar.[6,16,17]

The lack of spread to the epidural space could be a result of in-vivo factors such as: intrathoracic pressure changes, as well as absence of muscle tone and tissue tension that may effect the spread of the contrast material in a cadaver.[18,19] Volume may also be a factor and using larger volumes may have led to epidural spread. In this study 1ml/kg was used, as the focus was on the spread of contrast rather than procedure simulation.

Various studies using alternative imaging techniques reported results similar to this study. Adhikary and colleagues, as well as Schwartzmann and co-worker used magnetic resonance imaging to display diffusion into paravertebral and epidural space, after performing an ESP block.[20,21] Jadon and others, reported cranio-caudal spread to the dorsal rami, ventral rami and lateral cutaneous branches of the intercostal nerves after an ESP block was placed under fluoroscopic guidance.[22] Although these studies show more favourable results, including an epidural spread, it is important to note that certain imaging techniques offer a higher spatial resolution than others. Furthermore, the type of contrast material used may also result in discrepancies in the spread between soft tissue gaps.[23] Contrast also has different physicochemical properties to local anesthetic agents

De Cassai and colleagues demonstrated that the median volume to cover one dermatome is equivalent 3.4ml when performing the ESP block.[24] However, this is only applicable to adults. The volume to dermatome ratio in infants and children is yet to be determined. Several authors hypothesis that the a volume of 0.3-0.5ml/kg should be enough to provide adequate spread in children.[9,13,25] In this cadaver, we noted the contrast material spread approximately one dermatome cranially and two to three dermatomes caudally.

ESP block has been used as an alternative to neuraxial blocks for a wide range of procedures.[5,6,8,17,25–32] Further investigations are needed to be performed in a larger sample size to determine whether 0.3-0.5ml/kg provides adequate dermatomal spread in infants and children; whether 'in-plane' or 'out-of-plane' improves spread; or whether needle insertion over the lateral tip of the transverse process affects the cranio-caudal spread as opposed to needle placement deep to the erector spinae muscle between the transverse processes.

Conclusion

The ESP block is a versatile technique that can be part of the multimodal postoperative analgesic strategy for truncal surgery. ESP block has become popular because of the ease of placement and potential safety as compared to other neuraxial techniques. In this study, a single cadaver, contrast dye spread over 3-4 vertebral levels in the paravertebral space (suggesting a volume of 0.5ml-0.6ml per dermatome level).

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