Ultrasound guidancvrsus loss-of-resistance technique during epidural epidural cather placement in children

Thesis
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Abstract

Current techniques of epidural anesthesia are blind, and the technique can be frustrating and time consuming. Ultrasound-guided epidural catheter insertion is performed with multi-frequency scanning probes (5-12 MHz) to identify the epidural space and guide the epidural catheter advancement to target space before injection of the local anesthetic. This technique is compared with the use of traditional loss of resistance technique in pediatric surgical patients.

Key words:

Ultrasound, Epidural catheter, Epidural space, Pediatric.

CONTENTS

List of figures

List of tables

Table no. ***Title*** ***page***

Epidural blockade in children, particularly neonates and infants, is challenging. Neuraxial analgesia for abdominal surgery is known to offer compelling advantages in both adults and in children. In children, these advantages include improved hemodynamic stability, reduced need for postoperative ventilatory support, improved analgesia without the risk of opiate-induced respiratory depression and lower perioperative stress levels.

Despite these advantages the routine use of epidural analgesia, particularly in newborns (preterm or term) is limited to a few centres. The most popular method for detecting the epidural space is the loss-of-resistance (LOR) technique, and is usually performed with the child under anesthesia. The LOR approach has been associated with complications and adverse outcomes. These include dural puncture or more significantly neurological deficits as a result of unintentional spinal cord trauma.[5] The LOR techniques rely on tactile sensation and are performed more or less 'blind', leaving the task of determining the position of the epidural cannula either to the physician's individual ability or radiographic studies.

The first report on the use of ultrasound in visualization of the epidural space dates back to 1980 [1], but until recently ultrasound was not used in inserting and visualizing epidural catheter. Technical improvements in ultrasound enable digital depiction at high resolution, which makes its clinical use feasible.

The last 10 years have seen great progress in the generation and resolution of ultrasound images, allowing not only the visualization of the vessels, but also of nerve roots, peripheral nerves, dura mater, pleura, and fascias [2]. The technological evolution of ultrasound equipment made possible the reduction in the size of the equipment and the production of portable machines with high quality image, decreased cost, and greater versatility. Thus, the use of the ultrasound is increasingly more frequent in regional anesthesia.

Ultrasonography has been shown to improve the success rate and safety of the neuroaxial regional anaesthesia technique in children. This is because of direct visualization of the anatomy of the neuroaxial structures as well as the spread of the local anesthetic in the epidural space. This helps to achieve a more effective blockade, with decreased dependency of anatomic landmarks, reduced volume of local anesthetics, and increased safety. Therefore, the use of ultrasound in regional anesthesia is capable of offering several potential advantages when compared to the "blind" techniques.

Aim of work

The aim of this work is to set a comparison between the use of ultrasound guided epidural catheter insertion and the loss of resistance technique in pediatric surgical patients in order to emphasize the feasibility and the benefits of using ultrasonograghy over the traditional blind technique. Hence, we can introduce this new technique and establish it as a standard technique for neuroaxial regional block in pediatrics.

Embryological Background

The nervous system and the spinal cord are not fully developed at birth, and several morphologic abnormalities must be considered. During embryonic life, the spinal cord fills the spinal canal, but from the fetal period onward, the growth of the osseous structures exceeds that of neural structures; consequently, the termination of the cord and the dural sac occur at progressively higher levels **(Table I-1)**. Due to lower terminations of these essential structures, lower intervertebral approaches to the epidural and subarachnoid spaces are recommended in infants to avoid any neurological damage[3].

Table (I-1)

Changes in the Termination of the spinal Cord and the Dural Sac during growth[1]

	Embryonic Period	Fetal Period	Birth	Adult Level (9-12 Months)
Horsetail projection	Co2-3	S1-L5	L3	L1
Dural sac ending	Co2-3	S3-S4	S3-S4	S1-S2

Nerve fibres envelopes are not differentiated at birth. The myelinization process begins in cervical neuromeres during the fetal period and progressively extends downwards and upwards, but not achieved until the 12^{th} year of life [4]. Lack of myelin favors penetration of local anesthetics, a process enhanced further by the reduced size of the nerve fibres and shorter distance between successive nodes of Ranvier. These peculiarities explain why the nerve block occurs so quickly and is so complete even with the use of diluted solutions of local anesthetics in infants and young children. Additionally, nerve envelopes (epineurium, perineurium) are loosely attached to underlying nerve structures which favors the spread of local anesthetics along the nerve and roots, another condition improving nerve blockade in young children.

The spine undergoes significant morphological and structural changes throughout childhood and adolescence. At birth it displays a single regular flexure: approaching the epidural space at different levels (lumbar and thoracic) requires the same orientation of the needle. With the infant ability to sustain the head, the cervical flexure appears by the 3 to 6 months of age; later (by 8 to 9 months of age), with the infants ability to maintain sitting position, the lumbar lordosis developes [4].

Ossification of the vertebrae is a progressive phenomenon. During infancy and early childhood (up to the 6th year), the vertebrae remains cartilaginous and are thus easily traversed by sharp needles. The ossification nucleus can be damaged by improper epidural block technique. The sacrum is made of distinct vertebral bones, the osseous fusion of which is not achieved before the 25th year of life; this particularity permits intervertebral epidural approach to be performed at all sacral levels throughout childhood. The main particularities of infants and children are shown in the **table I-2**

Table (I-2)

Main Features of the Pediatric Period and Their Implications Regarding Regional Anesthesia [3]

Features of Infants and Young Children.	Clinical Consequences and specific Dangers.	Regional Anesthesia Implications.
Incomplete myelination of nerve fibers	Easier penetration of LA	Diluted solution more effective, reduced latency
Enzyme immaturity	Delayed metabolism of aminoamides	Decreased reinjection dose
Lower termination of spinal cord and dural sac	Danger of spinal damage	Approach epidural space below L4
Incomplete ossification of vertebrae	Danger of lesion of ossification nuclei and crossing of cartilaginous bone	Use short and short-beveled needles; avoid use of too thin needles
Sacral vertebrae not fused	Existence of sacral interspaces	Posterior sacral epidural possible
Delayed development of spinal curves	Cervical lordosis (3-6months) Lumbar lordosis (8-9months)	Change orientation of epidural needle as needed
Change of axial orientation of coccyx, no growth of sacral hiatus	Identification of sacral hiatus becomes more difficult with age	Caudal approaches more difficult above 6-8 years of age
Epidural fat becomes progressively less fluid	Reduced spread of local anesthetic above 6 years of age	Caudal anesthesia less effective above 6-8 years of age
Loose attachment of perineural sheathes	Increased spread of LA along nerve paths with danger of distant nerve blocks	Less volumes required for peripheral nerve blocks but larger doses for central blocks (leaking along spinal roots

The epidural space in children is divided into sacral, lumbar, thoracic, and cervical levels. The caudal block enters at the sacral level. A lumbar epidural needle/catheter is typically placed at the L3-4 interspace, which in older children is found in the midline of a line that may be drawn between the two iliac crests. Although these landmarks are accurate in older children, the intercrestal line may actually cross the L5-S1 interspace in neonates and the L4-5 interspace in infants up to a year of age because of the lag of the growth of the spinal cord.

The epidural space is a 'potential space' that contains fatty tissue and blood vessels. It is located between the bony vertebral canal and the outer surface of the dura matter. The epidural space is the outer space of the spinal canal. It surrounds the spinal cord and the meninges and extends from the foramen magnum to the sacral hiatus. It communicates the paravertebral space and the perineural space surrounding the spinal roots and nerves. Near the spinal ganglia, arachnoid granulations protrude through the dura mater, allowing crossing of local anesthetics and intimate relationships with the subarachnoid space in the so called dural cuff region. It has the same contents as the caudal space, loose areolar connective tissue and fluid fat in infants, becoming enriched with connective fibres and more densely packed above 6 to 8 years of age [5].

The epidural space contains many valveless epidural veins which create an intricate and plexiform network. This is connected both to the azygous system and inferior vena cava.

The inner limit of the epidural space is the dura matter, which surrounds the conus terminalis, cauda equine, and nerve roots only below L2 but the spinal cord itself at thoracic levels, where the spinal cord additionally occupies almost the entirely spinal canal, thus pushing the dura mater closer to the ligamentum flavum and reducing the safety margin of any epidural approach at thoracic levels.

Anatomy of the sacral region

The sacral hiatus is a V-shaped orifice located just above the sacrococcygeal joint, corresponding to the lack of dorsal closure of the vertebral arches of the fifth and usually the fourth sacral vertebrae. It is limited by two easily palpable bony crests, the sacral cornua. It is covered by the sacrococcygeal membrane, which is the sacral continuation of the ligamentum flavum. The sacral hiatus gives immediate and easy access to the sacral epidural space at a level where most roots of the cauda equina are no longer inside the sacral canal, below the termination of the dural sac, as shown in **figure (I-1)**. The distance between the upper margin of the sacrococcygeal membrane and the dural sac can be estimated by the following formula [6] : **Distance (mm) = 13 + (15 × Body surface area)**. Caudal blocks should be performed only with short-length, short-bevel needles to avoid the risks of dural puncture. As the child grows up, the axis of the sacrum compared with that of the lumbar spine changes, and the sacral hiatus becomes more difficult to locate and may even close. [7]

In infants, the sacral canal is filled with fluid fat and loose areolar connective tissue, which allows easy spread of anesthetic solutions up to the age of 6 or 7 years, when the epidural fat becomes more densely packed,