

Ultrasound guidance versus loss-of-resistance technique during epidural
epidural catheter placement in children

Thesis

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by

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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..... | I |
| List of tables..... | IV |
| INTRODUCTION..... | 1 |
| REVIEW OF LITERATURE | |
| Anatomy of the epidural space..... | 3 |
| Physiology of pain..... | 20 |
| Epidural in Pediatrics..... | 38 |
| Basic Principles of Ultrasound..... | 60 |
| MATERIALS AND METHODS..... | 78 |
| RESULTS..... | 88 |
| DISCUSOIN..... | 97 |
| CONCLUSION..... | 103 |
| SUMMARY..... | 105 |
| REFERENCES..... | 108 |

List of figures

| <i>Figure no.</i> | <i>Title</i> | <i>page</i> |
|-----------------------|--|-------------|
| Figure (I-1) | Anatomy of the sacrum and the sacrococcygeal membrane | 8 |
| Figure (I-2) | Anatomy of lumbar vertebra..... | 9 |
| Figure (I-3) | Arrangement of ligaments from posterior to anterior | 10 |
| Figure (I-4) | Level at which spinal cord ends at birth and difference from adults | 11 |
| Figure (I-5) | Arterial supply of the Spinal cord | 12 |
| Figure (I-6) | Relations of the Epidural Space | 13 |
| Figure (I-7) | Epidural space is triangular in shape in transverse section | 14 |
| Figure (I-8) | Distance from the skin to the Epidural space at different vertebral levels and different body weights..... | 15 |
| Figure(I-9) | Vertebral Venous Plexus and its relation to the Epidural Space | 16 |
| Figure(II-1) | Pain processing pathway | 26 |
| Figure (II-2) | Spinal cord gray matter division by Rexed..... | 28 |
| Figure (II-3) | Spinothalamic and other ascending sensory pathways..... | 31 |
| Figure (III-1) | Commonly used Epidural needles, Tuohy needle with Weiss modification..... | 41 |
| Figure (III-2) | Catheter needle system commonly used in pediatric lumbar regional anesthesia..... | 42 |
| Figure (III-3) | Epidural block procedures: sacral intervertebral approach (1), lumbar approach (2), and thoracic approach (3) | 44 |
| Figure (III-4) | Technique for the Advancement of the Epidural needle..... | 45 |

| | | |
|-----------------------|---|----|
| Figure (III-5) | Catheter advanced through the Epidural needle | 46 |
| Figure (IV-1) | Piezoelectric effect | 62 |
| Figure (IV-2) | Lateral Resolution relation to the beam width..... | 64 |
| Figure (IV-3) | Increased Frequency = Increased Attenuation; Increased Attenuation = Decreased Penetrat..... | 65 |
| Figure (IV-4) | Specular Reflection and Diffuse Reflection (Scattering)..... | 68 |
| Figure (IV-5) | The principle of Doppler shift in ultrasound | 69 |
| Figure (IV-6a) | Ultrasound imaging of the sacral vertebral channel, level S2-3 in a 1 year-old infant. Longitudinal section (paramedian)..... | 73 |
| Figure (IV-6b) | Ultrasound imaging of the sacral vertebral channel, level S2-3 in a 1 year-old infant | 74 |
| Figure (IV-7a) | Ultrasound imaging of the lumbar vertebral channel, level L4-5 in a 1 year-old infant. Longitudinal section (paramedian)..... | 74 |
| Figure (IV-7b) | Ultrasound imaging of the lumbar vertebral channel, level L4-5 in a 1 year-old infant. Transversal section..... | 75 |
| Figure (IV-8) | Probe angle and effect on visualization | 77 |
| Figure (V-1) | The Philips Envisor (Germany) and the multifrequency (12-5MHz) probe..... | 79 |
| Figure (V-2) | Epidural set used in the study Perifix® Paed B Braun, needle 18 G and catheter 20 G..... | 80 |
| Figure (V-3) | Position of the Ultrasound probe (paramedian longitudinal view)..... | 82 |
| Figure (V-4) | Measured distance from the skin to Epidural space | 83 |
| Figure (V-5) | Epidural needle advanced in the midline, medial to the ultrasound probe | 84 |

| | | |
|----------------------|--|----|
| Figure (V-6) | Catheter inserted and fixed in the Epidural space | 85 |
| Figure (VI-1) | Distribution of surgeries done to the group US | 89 |
| Figure (VI-2) | Distribution of surgeries done to the group LOR | 90 |
| Figure (VI-3) | Epidural failure and success rates in both study groups.... | 91 |
| Figure (VI-4) | Incidence of bone Contact in both study groups..... | 92 |
| Figure (VI-5) | Incidence of blood aspiration in both study groups | 93 |
| Figure (VI-6) | Incidence of Dural puncture in both study groups | 94 |
| Figure (VI-7) | Correlation between body weight (kg) and skin to epidural distance (mm) | 96 |

List of tables

| <i>Table no.</i> | <i>Title</i> | <i>page</i> |
|----------------------|---|-------------|
| Table (I-1) | Changes in the Termination of the spinal Cord and the Dural Sac during growth | 3 |
| Table (I-2) | Main Features of the Pediatric Period and Their Implications Regarding Regional Anesthesia..... | 5 |
| Table (III-1) | Recommended Drug dosing for Epidural in Children..... | 49 |
| Table (IV-1) | Speed of sound in different tissues | 61 |
| Table (V-1) | Patient demographic data ($n= 40$) | 89 |
| Table (V-2) | Incidence of Complications in the two study groups | 94 |
| Table (V-3) | Data collected in the US group | 95 |

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 1980¹, 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 ultrasonography 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 damage³.

Table (I-1)

Changes in the Termination of the spinal Cord and the Dural Sac during growth¹

| | 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 12th year of life⁴. 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 develops 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 Anesthesia³

| 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,