INTRODUCTION

It's considered that Post- operative pain management in children is essential as it reduce the pain as well as anxiety of the parents regarding post-operative pain. There are some options which are found and being used currently by pediatric anesthetists. However there is no consensus over a single best method.

Post- operative pain management had always been a major concern of parents as well as pediatric anesthetists. Contrary to the ancient notion that children don't feel pain, many studies have focused on the importance of good pain management in children.

According to the studies, children in surgical ward feel more pain than children in medical ward and prevalence was found to be 44% and 13% respectively ***(Groenewald et al., 2012)***. And it was found that about 64% of pediatric patients after surgery experience moderate to severe pain while 29% experience mild pain ***(Romsing and Walther-Larsen, 1996)***.

Studies have suggested that painful experiences and events during childhood even during infancy, may lead to long term psychological effects. Therefore pediatric anesthetists, surgeons and pharmacologists had been in a continuous search to locate a safe and effective analgesic for children ***(Larsson, 2001)***.

Regarding Nalbuphine, it is a synthetic opioid agonist-antagonist analgesic derivative of the phenanthrene group, and its structure is similar to those of oxymorphone and naloxone. It acts as an agonist of mu opioid receptors (MORs) and kappa opioid receptors (KORs), thus providing sedation as well as analgesia and it protects against receptor blockade-dependent respiratory failure. Nalbuphine is used for managing mild and moderate pain. It characterized by ceiling effect, once its maximum plasma concentration has been reached, incremental doses do not potentiate its analgesic effects or increase the risk of respiratory failure ***(Camagay et al., 1982)***.

Nalbuphine had been used by adult as well as pediatric anesthetists for post-operative pain control from a long time as it has offered excellent post-operative pain control ***(Moyao-Garcia et al., 2009)***. However in children, it is certainly associated with some side effects, the most dangerous being respiratory depression. This side effect limits its usage in pediatric age group ***(Schnabel et al., 2014)***. In day care procedures, like hernia repair in children, even caudal block may be used as it can reduce the pain of the pediatric patient in an effective way ***(Cheon et al., 2011; Wang et al., 2013)***.

In pediatric patients, caudal anesthesia is an effective and safe method of anesthesia. It can be used alone as an anesthetic agent or combined with general anesthesia to reduce both intraoperative and postoperative anesthetic need for additional analgesia.

AIM OF THE WORK

The aim of this prospective, observational study is to compare pain scores in patients undergoing inguinal herniotomy after caudal block and intravenous nalbuphine.

Chapter 1

CAUDAL CANAL BLOCK

For many years, caudal anesthesia has been used as it is the easiest and safest approach to the epidural space. When correctly performed there is little danger of either the spinal cord or dura being damaged.

Although caudal technique was reported earlier than lumbar technique, the first technique lost much of its clinical utility. This was because of inconsistent results secondary to inadequate understanding of anatomy. Now Caudal or sacral block is gaining wider publicity because of proven efficacy in pediatric patient pain management, acute & chronic pain management, spinal endoscopy & epidural adhesiolysis ***(Chen et al., 2004)***.

Applied Anatomy

The caudal (sacral) canal extends from the upper border of sacral bone (in relation to lumbar epidural space) to the sacral hiatus. Whole of this canal is enclosed in sacral bone.

Sacrum

The five sacral vertebrae unite to form sacrum. The sacrum articulates with fifth lumbar vertebra superiorly, coccyx inferiorly & iliac bones laterally. The anterior surface of sacrum has four paired openings for the exit of anterior rami of sacral nerves ***(Figure 1).***

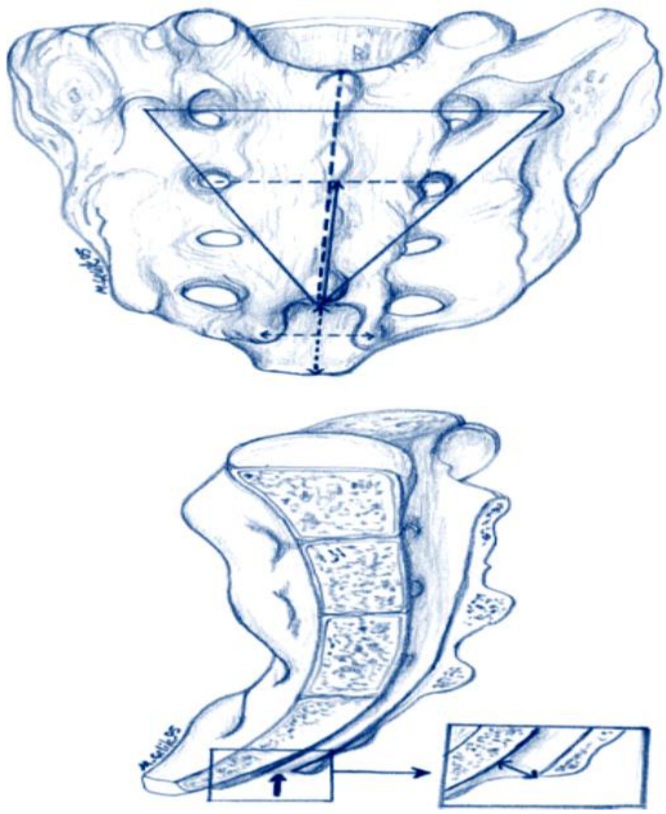

Figure (1): Anatomy of the sacrum, anterior and lateral view ***(Larsson, 2001)***.

The posterior surface is convex & rough in nature because of fusion of vertebral elements. Median sacral crest runs over the posterior surface (thick crest represents the fused portions of sacral spinous process). The posterior surface has four pairs of foramina for escape of posterior rami of sacral nerves. These foramina are smaller when compared to anterior foramina. The laminae of fifth sacral vertebra (sometimes fourth also) fails to fuse; the resultant gap is called the sacral hiatus. On either side of sacral hiatus are the remnants of the inferior articular processes of the fifth sacral vertebra which are called the sacral cornua.

The sacral hiatus is covered by sacrococcygeal membrane which is an extension of the ligamentum flavum and is pierced by coccygeal & fifth sacral nerves. Medial to sacral foramina intermediate sacral crest can be appreciated. They are formed by fusion of transverse process of sacral vertebrae. These crests end at sacral cornua, which are also nothing but remnants of articular process of fifth sacral vertebra ***(Chen et al., 2004)***.

The sacrum of children is also more narrow and flat compared to the adult population ***(Raux et al., 2010)***.

Coccyx

Coccyx, otherwise called tail bone gets attached superiorly to sacrum & inferiorly to anococcygeal ligament. Coccyx is actually made up of 3 to 5 vestigeal remnants of vertebrae. The inferior portion of coccyx is mobile & prone for fractures. Coccyx curves anteriorly & superiorly. Ganglion impar is situated at the junction of sacrum & coccyx ***(Chen et al., 2004)***.

Sacral (caudal) canal

This canal has a total volume of 30-35ml in adults after the contents have been evacuated (cadaver). The spinal cord ends at the lower border of L_1 vertebra, subsequently the sacral & coccygeal nerves pass to sacral canal as cauda equina. The dura ends at S_2 level & the pia continues as filum terminale to get attached to coccyx.

The sacral nerve roots (upper four) anterior rami exit through anterior sacral openings & posterior rami through posterior sacral openings. As mentioned earlier, the fifth sacral nerve & coccygeal nerves traverse the canal & pierce through sacrococcygeal membrane to come out. The vertebral venous plexus continues into sacral canal, they are more concentrated towards anterior surface. The remainder of the sacral canal is filled with adipose tissue, which is subject to an age-related decrease in its density. This change may be responsible for the transition from the predictable spread of local anesthetics administered for caudal anesthesia in children to the limited and unpredictable segmental spread seen in adults. The sacral hiatus is covered only by skin, a subcutaneous fatty layer and the sacrococcygeal membrane. The most distal portion of the dural sac and the sacral hiatus usually terminates between levels S1 and S3 ***(Uemura et al., 1992) (Figure 2).***

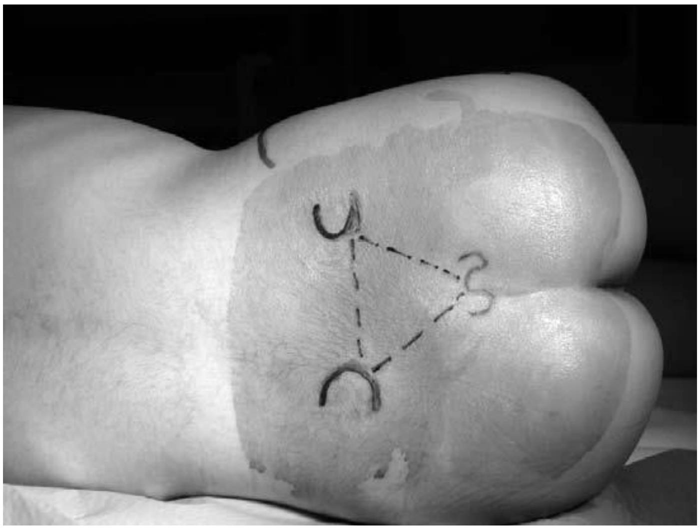

Figure (2): Surface anatomy for sacral hiatus localization ***(Raux et al., 2010)***.

Anomalies in the position of the dural sac reflection can result in unintended dural puncture ***(Uemura et al., 1992)***.

The sacral canal contains:

1. The terminal part of the **dural sac**, ending between S1 and S3.
2. The five sacral nerves and coccygeal nerves making up the **cauda equina**. The sacral epidural veins generally end at S4, but may extend throughout the canal. They are at risk from catheter or needle puncture.
3. The **filum terminale** - the final part of the spinal cord which does not contain nerves. This exits through the sacral hiatus and is attached to the back of the coccyx.
4. **Epidural fat**, the character of which changes from a loose texture in children to a more fibrous close-meshed texture in adults. It is this difference that gives rise to the

predictability of caudal local anesthetic spread in children and its unpredictability in adults.

Even though caudal epidural block (CEB) has a wide range of clinical applications, it is sometimes hard to determine the anatomical location of the sacral hiatus and the caudal epidural space, especially in adults.

The determination of the landmarks by the clinician enables the sacral hiatus to be ascertained and may increase the success rate of CEB ***(Morgan et al., 2002)***.

Indication of caudal block

There are three groups of indications for caudal epidural block in children:

1. Patients requiring sacral block (eg: circumcision, anal surgery and orthopedic surgeries of lower limb)
2. Patients requiring lower thoracic block (inguinal herniorrhaphy)
3. Patients requiring analgesia of the upper thoracic dermatomes (As postoperative analgesia in cholecystectomy).

Technique

A- Position:

Caudal anesthesia may be performed in the prone, lateral or knee-chest position. The lateral position is often used in children, as the landmarks are easier to find than in adults. In the lateral position, the upper leg is flexed at the hip and knee to help spread the gluteal muscles away from the hiatus ***(Morgan et al., 2002)***.

B- Technique:

1. Once the patient is in the appropriate position, the landmarks are identified. The sacral cornu may be easily palpated on the thin patient, lying just above the inter-gluteal crease.
2. The sacral hiatus can be located by first palpating the coccyx, and then sliding the palpating finger in a cephalic direction (towards the head) until a depression in the skin is felt. The sacralcoccygeal membrane forms a soft valley between and just below these peaks. The position is confirmed by drawing the triangle formed by the hiatus and the posterior superior iliac spines; it should be equilateral. The membrane should also be 4-5 cm above the palpable tip of the coccyx ***(Figure 3).*** As there can be a considerable degree of anatomical variation in this region confirmation of bony landmarks is the key to success. The needle can penetrate a number of different structures mimicking the feel of entering the sacral hiatus. It is important to establish the midline of the sacrum as considerable variability occurs in the prominence of the cornua, causing problems unless care is taken ***(Morgan et al., 2002)***.

Figure (3): Caudal block, lateral position ***(Morgan et al., 2002)***.

3. The procedure must be carried out with a strict aseptic technique. The skin should be thoroughly prepared and sterile gloves worn. Any infection in the caudal space is extremely serious ***(Larsson, 2001).***
4. Deep infiltration is done with a 22-gauge short beveled cannula or needle, avoiding excessive distortion of the tissues.
5. The needle is introduced at approximately a 70-degree angle to the skin (perpendicular to the membrane). Firm pressure will allow the needle to penetrate the sacrococcygeal ligament and drop into the caudal canal. The canal here is shallow and vigorous advancement will produce laceration of the periosteum of the anterior wall of the canal ***(Morgan et al., 2002)***.
6. Once in the canal, the hub of the needle is dropped downward toward the gluteal crease so the tip now advances up the center of the canal almost parallel to the long axis of the back itself. The angle of the canal can normally be

expected to be almost flat in relation to the skin in females, but somewhat steeper in males or blacks. If the angle is 50 degrees or greater, intraosseous or transsacral placement should be suspected ***(Figure 4)***.

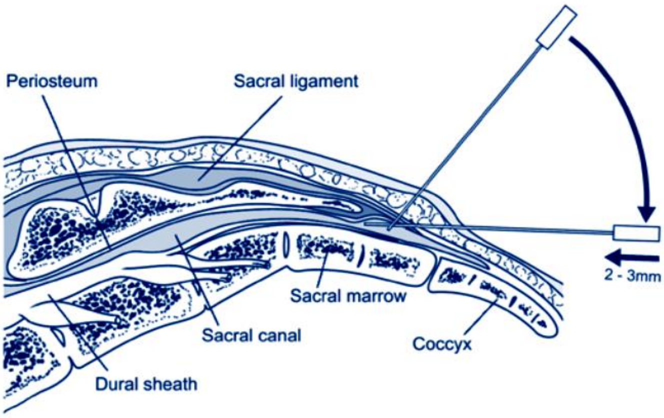

Figure (4): Technique of needle introduction ***(Raux et al., 2010)***.

Care should be taken not to insert the needle too far as the dura lies at or below the S2 level in the child and further advancement will increase the risk of dural puncture ***(Morgan et al., 2002)***.

7. The needle should be aspirated looking for either CSF or blood. A negative aspiration test does not exclude intravascular or intrathecal placement. Care should always be taken to look for signs of acute toxicity during the injection. The injection should never be more than 10ml/30 seconds.

Further tests to confirm the correct position include gently moving the tip of the needle from side to side. The needle will feel firmly held ***(Orme and Berg, 2003)***.

A "whoosh" test has been described for identifying correct needle placement in the caudal canal.

This characteristic sound has been noted during auscultation of the thoracolumbar region during the injection of 2 to 3mL of air into the caudal epidural space. The test has been modified in pediatrics to the "swoosh", where in local anesthetic, and not air injection, is auscultated during the performance of the block ***(Orme and Berg, 2003)***.

Light blood staining is not uncommon and indicates entry into the sacral canal. There should be no local pain during injection. Tingling or a feeling of fullness that extends from the sacrum to the soles of the feet is common during injection ***(Orme and Berg, 2003)***.

8. A small amount of local anesthetic should be injected as a test dose (2-4mls). It should not produce either a lump in the subcutaneous tissues, or a feeling of resistance to the injection, nor any systemic effects such as arrhythmias, peri-oral tingling, numbness or hypotension. If the test dose does not produce any side effects then the rest of the drug is injected, the needle removed and the patient positioned for surgery ***(Orme and Berg, 2003)***.

Spread of the Local Anesthetic Solutions

Unlike in adults, the segmental spread of analgesia following caudal administration is more predictable in children up to about 12 years of age. Studies suggest that the cephalic spread of caudal solutions in children is not hampered by the same anatomic constraints that develop from puberty onward. Before puberty, anatomic impedance at the lumbosacral junction has not yet developed to a marked degree, and caudal solutions can flow freely upward into the higher recesses of the spinal canal. As a consequence, the rostral spread of caudal anesthesia is more extensive and more predictable in children than in adults ***(Orme and Berg, 2003)***.

Assessing the effectiveness of caudal block in pediatrics

- The success of a caudal block in pediatric patients may be predicted from the laxity of the anal sphincter secondary to the reduction in sphincter tone from the local anesthetic block.
- This is fortuitous since most caudal blocks in children are performed while the child is anesthetized, and it is not possible to assess the effectiveness of the block by testing for sensory analgesia levels.
- Also, the ability to decrease the concentration of inhaled anesthetic agent and opioid requirements is another indication of a successful block.

In the post-operative period, motor function must be checked and the patient should not be allowed to try and walk until complete return of motor function is assured. The patient should not be discharged from hospital until he/she has passed urine, as urinary retention is a recognized complication ***(Orme and Berg, 2003)***.

Various regimes have been produced to calculate the appropriate dose of local anesthetic, the doses vary widely:

1. Armitage recommends bupivacaine 0.5ml/kg for a lumbosacral block, 1 ml/kg for a thoraco-lumber block, and 1.25ml/kg for a mid-thoracic block. He recommended the