CAUDAL EPIDURAL ANESTHESIA FOR PEDIATRIC PATIENTS: A SAFE, RELIABLE AND EFFECTIVE METHOD IN DEVELOPING COUNTRIES

Alice Edler MD, MA (Education), Assistant Professor of Clinical Anesthesiology, Vinit G.Wellis, MD, Assistant Professor of Anesthesiology, Department of Anesthesiology, Section of Pediatric Anesthesiology, Stanford University School of Medicine, 3300 Pasteur Dr., Rm. H3580, Stanford Ca. 94305 USA

Introduction

In all areas of anesthesia, safety and efficiency are valued goals, and in developing countries additional challenges due to shortages of anesthetic drugs, supplies and monitoring equipment may be present. Caudal epidural anesthesia in developing countries, can in combination with general anesthesia or alone provide safe, reliable and efficient analgesia and / or anesthesia for both high risk and general pediatric surgical patients.

These techniques can be easily learnt and may be modified to extend analgesia into the postoperative period (with the addition of opioids or continuous techniques) or replace general anesthesia in circumstances where either the equipment or general anesthetic techniques are not available. The following manuscript will describe the pharmacological and physiologic basis of caudal epidural anesthesia, techniques for administration, monitoring, and specific modifying techniques of caudal epidural anesthesia and a discussion of complications and contraindications to caudal epidural anesthesia in pediatric patients.

History

Although spinal anesthesia was used in pediatric anesthesia as early as the 1940's, reports of successful pediatric caudal epidural anesthetics initially came from developing countries and in 1967, Fortuna reported a series of 170 patients between the ages of 1-10 years who received caudal epidural anesthesia for surgical procedures of the lower abdomen and lower extremities. These results showed that caudal anesthesia either alone or in combination with general anesthesia was well tolerated with little in the way of respiratory depression or cardiovascular changes.

A further series from Zimbabwe reported 500 pediatric caudal epidural anesthetics. The reported success rate was high (close to 90%), again being well tolerated by the patients, with little in the way of respiratory or cardiovascular problems, but with major failures due to incomplete block or restlessness during surgery. As these patients were only sedated, not anesthetized this could have accounted for some of the technical difficulties in positioning the caudal epidural needle and the restlessness during the surgery.

Today pediatric caudal epidural anesthesia is a well-accepted technique commonly used in combination with general anesthesia or occasionally as the sole anesthetic in high-risk patients.

Indications

Caudal epidural anesthesia in children can be used in:

- **Lower abdominal surgery**: (incision below the umbilicus -T10 sensory level) especially perineal, genitourinary or ilioinginual surgery.
- **Lower extremity surgery (hip, leg and foot)**: though at times it is difficult to achieve a satisfactory block to the distal 1/3 of the foot.
- **Newborn and premature infants**: If used as the sole anesthetic, caudal epidural anesthesia reduces the risk of respiratory depression from residual neuromuscular blockade (pancuronium) and inhalation anesthetics. Post-operative apnea associated with general anesthesia, is reduced with caudal anesthesia but not abolished.
- **Neuromuscular disease such as muscular dystrophy**. There is a high incidence of postoperative respiratory failure due to a combination of general anesthesia and muscle weakness. Caudal epidural anesthesia indicated for lower extremity surgery (very common in these patients).
- **Malignant hyperthermia**: it is generally accepted that all local anesthetic agents are considered safe.

Contraindications

The contraindications for caudal epidural anesthesia are similar to those for spinal or lumbar epidural anesthesia.

- **Coagulation disorders**: Bleeding abnormalities are an absolute contraindication to caudal epidural anesthesia. These abnormalities can be due to disorders of coagulation factor activity (such as Hemophilia, ITP, tumors, or DIC from sepsis) or from the administration of anticoagulants such as heparin or Warfarin. If there are any questions about the coagulation status, the anesthetist should perform a bleeding time test and confirm

Table 1: Formulas to calculate drug volumes (mls) for single shot caudal epidural block (see also table 3)

Local Anesthetic*	Dose (mls)	Estimated Sensory Level
1 % Lignocaine	0.06ml/segment	Mid-Thoracic (T8)
0.25% Bupivicaine	1ml/kg	Mid-Thoracic (T8)
0.175% Bupivicaine	1.25 ml/kg	Mid Thoracic (T8)

* All solutions are containing epinephrine 1:200,000

Table 2 Maximum Recommended Doses of Local Anesthetics for Regional Anesthesia

Drug	Mg/kg (with epinephrine)	Duration (minutes)
Lignocaine	4 (7)	45 -180
Bupivicaine	2 (3)	180-600
Tetracaine	1.5	180-600
2 Chloroprocaine	8 (10)	30-60
Procaine	8 (10)	60-90

that the bleeding time is normal. Bleeding time is a simple laboratory procedure that can be done at the bedside and gives results within 5 minutes. Another laboratory test to consider is INR. This is a more sophisticated test and may not be available at all hospitals.

- **Infection**: Caudal epidural anesthesia should not be used if there is an active infection at the site of injection either at the skin surface or below. This includes active cellulitis, pilonidal/ perirectal abscess, and meningitis. Even in the absence of localized infection, the caudal region has a higher bacterial count than the lumbar epidural space.
- Unstable blood pressure and/or heart rate
- Patient or parent refusal
- Congenital anatomic anomalies of the spinal cord or vertebral bodies - in cases of Spina Bifida, caudal epidural anesthesia should not be attempted as the spinal cord may be tethered within the spinal canal.
- Scoliosis is not an absolute contraindication to caudal epidural anesthesia though scolisis may make caudal epidural anesthesia technically more difficult to achieve.
- The dose of bupivicaine must be carefully controlled in patients with decreased cardiac function, as is often the case of patients with muscular dystrophy.

Anatomy and technique of caudal anaesthesia

The sacral hiatus (SH) in an infant or young child is easily identified because the landmarks are more superficial. The sacral hiatus is formed by failure of fusion of the fifth sacral vertebral arch. The remnants of the arch are known as the sacral cornu, and are located on either side of the hiatus. (See figure 1) The coccyx lies caudal to/lower than the sacral hiatus. Drawing an equilateral triangle by connecting the two posterior superior iliac spines (PSIS) usually locates the sacral hiatus at the apex. Palpation of the sacral hiatus at the apex of this inverted triangle should identify the puncture site. Alternatively, the anesthetist can palpate the convexity of the coccyx and then move cephalad to palpate the concave sacral hiatus to identify the puncture site. (See figure 2).

In young children, the epidural space can be easily reached by the caudal epidural approach with less risk of dural puncture than with thoracic or lumbar epidural approaches. There is minimal risk of cord injury at the level of the sacrococcygeal ligament so general anesthesia or heavy sedation is not often required to prevent the child from moving. However, the dural sac can extend to the level of third or fourth sacral vertebrae in the newborn and therefore care must be taken to avoid an inadvertent intrathecal injection. The sacrococcygeal ligament binds the sacral hiatus posteriorly, superiorly by the sacral cornu and the fused arch of the sacrum. There is considerable variation in the anatomy of the sacral hiatus, which may account for the small percentage of caudal epidural block failures. In addition, there is considerable variation in the angle of the sacral canal. Adult patients of African descent, have a steeper angle of entry into the sacral canal, therefore making the angle of initial needle place different than non-African women. (See figures 4 and 5).

Technique

Caudal epidural block can be performed in the prone or lateral decubitus position. The first step is to identify the sacral hiatus. It is essential that the skin over the caudal area is cleaned with an iodine or alcohol (70%) containing solution, which is allowed to dry. Then, using sterile technique, the caudal epidural space is entered using a short 23-gauge needle or a 22-gauge IV catheter. (See figure 3). The needle is inserted at a 60-degree angle and the needle is advanced until a "pop" is felt. (See figure 4) The needle is then lowered to a 20-degree angle and advanced an additional 2-3 mm to make sure the bevel is in the caudal epidural space, (See figure 5) if using a cannula withdraw the stylet and advance the cannula into the caudal space. Do not advance the needle or cannula any more than is necessary.

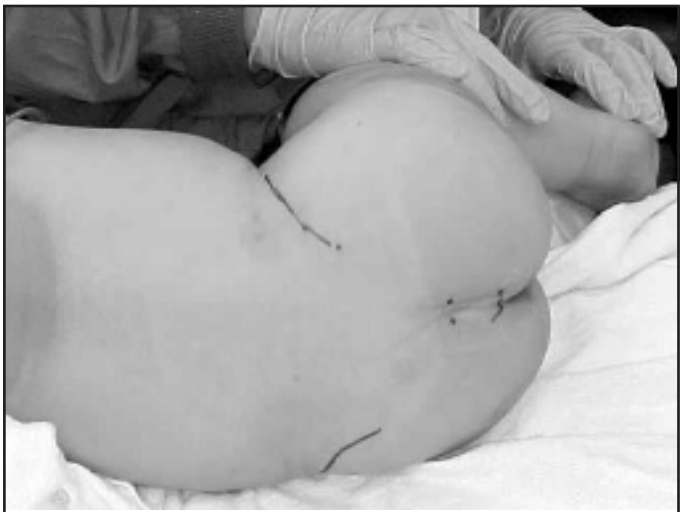

Figure 1: Positioning and Anatomy of Sacral Hiatus

Advancement of the cannula rather than the needle may reduce the incidence of inadvertent dural or vascular puncture and easy progression of the cannula is a good prognostic sign of success. Test aspiration should be gentle as vessel walls can easily collapse producing a false negative. If no blood or CSF is aspirated then the appropriate amount of local anesthetic is injected in small amounts, with repeated aspirations throughout the injection. An epinephrine containing test dose can be used to exclude intravascular injection. The most important test for correct placement (not including intravascular placement) is ease of injection. If the local anesthetic solution can be injected with little resistance, it is mostly likely in the correct space. If there is initial resistance or resistance develops over the course of the injection, the injection should be stopped and the needle location reassessed. There will be some increase in resistance as the potential space of the caudal epidural space is expanded, but this should be minimal.

If the hands are positioned as seen in figure 4, subcutaneous bulging, indicating subcutaneous injection will be detected by the thumb. Injection of air to confirm identification of the caudal space should be avoided because of the risk of air embolus. If the angle of insertion is too shallow, the needle may go subcutaneously. This produces an incomplete block and can cause pressure necrosis if large volumes of solution, especially epinephrine-containing solutions, are injected subcutaneously. If the angle of insertion is too steep, the needle may actually penetrate the vertebral bodies resulting in intraosseous injection and possible osteomyelitis.

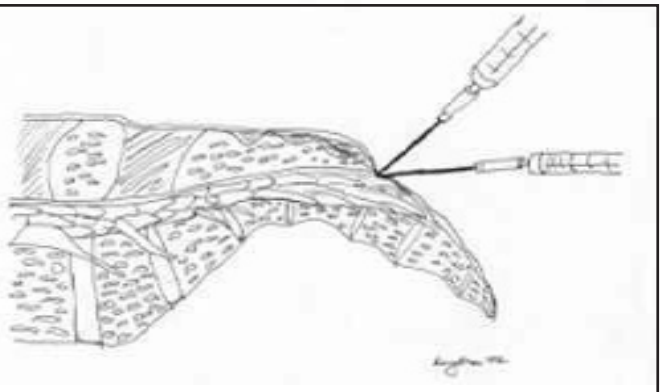

Figure 2: Anatomic Representation of Caudal Epidural Space

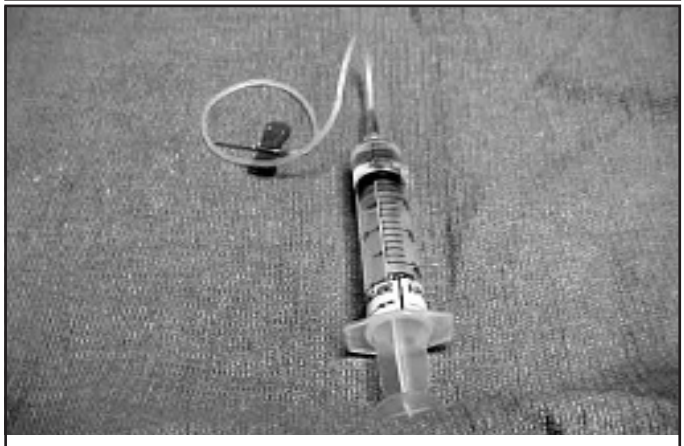

Figure.3: Syringe and Needle attachment for Caudal Epidural

'Single shot' technique: Caudal epidural anesthesia can be used as a "single shot" technique providing anesthesia limited by the duration of the local anesthetic that is chosen. This "single shot " may be repeated at the end of the surgery to prolong the analgesic effect into the postoperative period. Single shot caudal epidural anesthesia has a reported high success rate, frequently over 90%.

'Continuous / catheter' technique: an indwelling catheter can be placed to provide anesthesia of longer duration than single dose of local anesthesia would allow. Another advantage of an indwelling caudal epidural catheter is the ability to thread the catheter to a higher location in the epidural space and therefore achieve a higher, more localized block with less local anesthesia dose. Because of the close proximity of the perineum and likelihood of infection, a caudal catheter should not be left in situ ideally for longer than 36 - 48hrs.

Monitoring

Monitoring for caudal epidural anesthesia must include monitoring of ventilation, oxygenation, and circulation at least every 3 minutes. These can be accomplished with automated equipment such as automated blood pressure monitor, ECG, pulse oximeter, and capnograph. If automated monitoring equipment is not available, vital signs can be just as well be monitored with a sphygmomanometer, pericardial stethoscope and a finger on the temporal pulse. A means of temperature monitoring, such as an axillary thermometer is also needed if the anesthetist expects changes in body temperate due to loss of heat from surgery or cold operating theaters.

Local anaesthetic drugs and additives

Local anesthetics can be divided into two classes of compounds, Amides and Esters. The amides undergo metabolism by the liver, and the esters are hydrolyzed primarily in the plasma by cholinesterase. These different routes of metabolism are important in pediatric patients who may have immature liver function, especially neonates. Neonates have lower levels of alpha1 acid glycoprotein and albumin, 60% and 30% respectively compared to adults. This causes a reduction in the binding of protein bound drugs, such as amide local anesthetics, increasing the free (unbound fraction) thus increasing the possibility of toxic effects (max dose bupivacaine in neonate 1.5mg/kg). The volume of distribution of local anesthetics is larger in children than adults, which results in lower peak plasma levels, but this is counteracted by the reduction in the rate of elimination of local anesthetics in children.

Table 3. Armitage (1989) 0.25% Bupivacaine - Bupivacaine 0.19% for volume in excess of 20mls (one part 0.9% sodium chloride + three parts 0.25% Bupivacaine)

Segmental level of operation	Dose ml/kg
Lumbo-sacral	0.5
Thoraco-lumbar	1.0
Mid-Thoracic	1.25

Figure 4: Initial Insertion

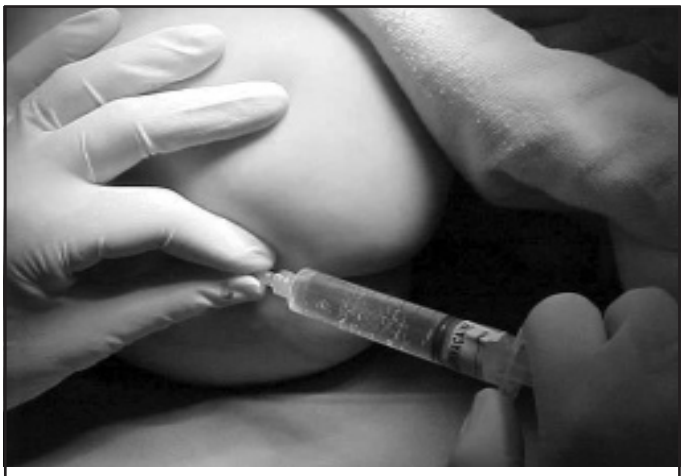

Figure 5 Repositioning and Completion of Epidural Injection

The maximum recommended doses of local anesthetics in children older than 4 weeks (doses should be reduced in neonates), are lidocaine 3mg/kg, (6mg/kg with adrenaline), bupivacaine 2- 2.5mg/kg (addition of adrenaline will delay peak plasma level but will not extend duration). ***Note: malnutrition may also decrease albumin concentration causing reduced protein binding and increased free (unbound fraction) drug - increasing toxic effects.***

The spread of local anesthetic injected into the caudal epidural space in children less than 7yrs of age is predictable and correlates well with age and weight encouraging the use of formulae or normograms.

- **Bupivacaine**: provides reliable, long-lasting anesthesia and postoperative analgesia. An easy rule is 1ml/kg of Bupivacaine 0.25% with epinephrine 1:200,000 provides 3-6 hours of anesthesia for all procedures below the umbilicus. In Infants, less than 2.5 kg a more dilute solution is used (0.125% / 0.19 %) and the volume can be increased to remain below the toxic dose range. See table 1 - 3.

- **Adrenaline (epinephrine) 1:200,000**: combined with the local anesthetic solution can be used as a test dose. If the injection mistakenly occurs into a blood vessel, either vein or artery, the heart rate should increase more than 10 beats in 10 seconds after injection when epinephrine is added. However, this test dose is not 100% conclusive of intravenous injection.

- **Opioids** prolong analgesia in infants and children. Epidural opioids should be reserved for surgery in which catheterization is required and all children should be admitted to an area of the hospital where close monitoring and observation will take place. A dose of 50mcg/kg of preservative free morphine or diamorphine 30mcg/kg can be added to the local anesthetic solution. This will provide 12 to 24 hours of analgesia but can produce urinary retention, nausea, and itching and respiratory depression. However, a dose of 33microgramg/kg of preservative free morphine in the caudal epidural solution can provide prolonged analgesia, with less risk of delayed respiratory depression.

- **Clonidine**: (α2-adrenergic agonist, with spinal analgesic action). A dose of 0.5-1.0 microgram/kg improves the quality and duration of analgesia with bupivacaine without causing significant bradycardia or respiratory depression, lasting for up to 12 hours. Doses greater than 1 microgram/kg are often associated with increased sedation.

- **Ketamine**: an NMDA antagonist. In doses of 0.25 - 1.0 mg/kg, causes significant prolongation of postoperative analgesia, when compared to 0.25 % bupivacaine alone . There is no increase in adverse effects including delayed motor strength, time to micturation, postoperative sedation or postoperative nausea and vomiting. Though in doses higher than 0.5 mg/kg, the neuroleptic effects of ketamine appear to be more of a problem. Preservative free ketamine should be used at all times if possible, although animal studies have been performed using ketamine with benzothonium chloride demonstrating no histologic or pathologic changes in the spinal cord or roots but these have not been confirmed in human subjects.

Complications

The complications for caudal epidural anesthesia can be classified as:

- **Failed or incomplete block**. Between 5- 25 % of caudal epidural blocks can be considered "failed or incomplete", this includes a number of different problems.

The anesthetist may not be able to identify the anatomic landmarks and are therefore unable to insert the caudal needle into the epidural space. This occurs frequently in small children with anomalies of those structures originating from the urogential ridge such as hypospadias, imperforate anus or chloacal atresia. In some of these children, it is impossible to palpate the sacral hiatus.

Also as the child advances in age the sacral plate tends to flatten out, making the insertion of the needle through the sacrococcygeal ligament more difficult. By far the easiest insertion is in the child below the age of 7 years. Though caudal anesthesia can and is accomplished in the older patient, it is technically more difficult.

- **Unilateral block**: less common than with lumbar epidural because the sacral/ caudal epidural space is bigger and requires more volume to fill. Patchy and one-sided blocks are rare with caudal epidural anesthesia but can result from too rapid injection

of local anesthesia dose. Local anesthetics should be injected slowly over 2 minutes after test dose. It is not infrequent though to have too low a block. This is a result of insufficient local anesthetic volume. Remember that the volume of the dose is often limited by total mg/kg dose of the local anesthetic that is chosen and must remain less than the toxic dose for that drug. (See table 2.) One solution to this problem is to give a more dilute solution. Decreasing the concentration allows the anesthetists to give a larger volume of local anesthetic, though it may decrease the intensity and duration of the block.

In my practice, I limit caudal epidural anesthesia to children who are still small enough for their mothers to carry. In this way, if the child is released from the hospital and still has some motor weakness of the lower extremities, the parent can carry the child and I am less fearful that the child will fall and injure himself.

- **Local anesthetic toxicity**

Intravascular injection: Even though most local anesthetics have close to 100% bio-availability from the epidural space, they are absorbed over time. Intravascular injection allows immediate bioavailability of the total dose of the local anesthetic with consequent systemic toxicity if the peak plasma concentrations are with the toxic range. Peak concentration is lower if drugs are injected slowly. As the extradural veins have no valves, local anesthetic can enter the cerebral circulation by retrograde flow, producing convulsion at doses lower than recommended maximum safe doses. If large volumes of local anesthetic are given (>10mls) the anesthetist should aspirate again in the middle of the injection as the expansion of the potential epidural space can displace the tip of the needle. The anesthetist should be aware of potential intravascular injection throughout the injection.

Absorption / overdose: If either incorrect dosing or volume is injected then absorption of the local anesthetic will result in a rise in plasma level over time into the toxic range (not immediately as with intravascular injection). It is important to strictly follow the guidelines of local anesthetic dose given in table 2.

- **Dural puncture (intrathecal injection)**. The spinal cord typically ends at the first lumbar vertebra in the adult but can be as low as the third or fourth lumbar vertebra in the neonate and premature infant, with the corresponding dural sac extending 1-2 vertebral segments below this. There is considerable variation in the level of termination of the spinal cord. If unintentional dural puncture is performed, a large dose of local anesthetic is injected intrathecally. This will produce a 'total spinal block', characterized by sudden apnea, unconsciousness and dilated pupils. There is usually little in the way of haemodynamic disturbance in young children and babies.

- **Intraosseous injection**. An intraosseous injection is equivalent to an intravenous injection.

- **Penetration of the sacrum**. In infants and young babies, the vertebral bodies can be soft due to incomplete calcification and the anesthetist can pass the needle into the body of the sacrum and through the vertebral body into the pelvis damaging either pelvic viscera or aorta.

- **Bleeding and infection**: haematoma and abscess formation are very uncommon after caudal epidural anesthesia but can result in serious and permanent neurologic damage involving the spinal cord or cauda equina.

Conclusions

Caudal epidural anesthesia is a safe and effective method of anesthesia in pediatric patients. It can be used as the sole anesthetic agent or combined with general anesthesia to reduce both intraoperative anesthetic requirement and postoperative need for additional analgesia. The addition of opioids, clonidine or ketamine can significantly enhance and prolong the anesthetic effects, even when used in minimal amounts and can reduce the need for postoperative narcotics in some of the sickest and smallest of children. However, as with all regional anesthetic techniques, extreme diligence should be taken to insure sterility and avoid intravascular injection or toxicity due to overdose of local anesthetic solutions.

Further Reading

1. Update in Anaesthesia 1998 No. 8