Pediatric Epidural and Caudal Analgesia and Anesthesia in Children

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Epidural Blockade for pediatric surgery (General Aspects)

Introduction

Epidural analgesia has many beneficial effects in the pediatric patient population. In clinical practice, it is commonly used to augment general anesthesia and to manage postoperative pain. Effective postoperative pain relief from epidural analgesia has numerous benefits including earlier ambulation, rapid weaning from ventilators, reduced time spent in a catabolic state and lowered circulating stress hormone levels.1 Precise placement of epidural needles and catheters for single-shot and continuous epidural anesthesia ensures the dermatomes involved in the surgical procedure are selectively blocked, allowing for lower doses of local anesthetics and sparing of unnecessary blockade in the regions where blockade is not desired. 2-4.

Anatomical Considerations

Significant anatomic differences in comparison with adults, should be considered while utilizing regional anesthesia in children. For instance, in neonates and infants, the conus medullaris is located lower in the spinal column (at approximately the L3 vertebra) compared to adults where it is situated at approximately the L1 vertebra. This dissimilarity is a result of different rates of growth between the spinal cord and the bony vertebral
column in infants. However, at approximately 1 year of age the conus medullaris reaches similar L1 level as in an adult. The sacrum of children is also more narrow and flat compared to the adult population. At birth, the sacral plate, which is formed by five sacral vertebrae, is not completely ossified and continues to fuse until approximately 8 years of age. The incomplete fusion of the sacral vertebral arch forms the sacral hiatus. The caudal epidural space can be accessed easily in infants and children through the sacral hiatus. Due to the continuous development of the sacral canal roof, there is considerable variation in the sacral hiatus. In children, the sacral hiatus is located more cephalad compared to adults. Therefore, caution is warranted when placing caudal blocks in infants as the dura may end more caudad thereby increasing the risk of accidental dural puncture. It has also been suggested that the epidural fat is less densely packed in children than in adults.5 This loosely packed epidural fat may facilitate not only the spread of local anesthetic, but it may also allow the unimpeded advancement of epidural catheters from the caudal epidural space to the lumbar and thoracic level.

Clinical Pearls

- In the neonate the intercristal line bisects L5 (cf L4 or L3/4 interspace in the adult) and the spinal cord ends at L3 in first year of life (cf L1 in the adult).
- As a general rule the epidural space will be found at 1 mm/kg of body weight, however, there is considerable individual variation.

Considerations for Choosing Local Anesthetic Solution for Epidural and Caudal Anesthesia and Analgesia

Newer local anesthetics with favorable potencies, durations of effect and decreased toxicity profiles have been introduced in the past decade. Local anesthetic concentration and volume are important factors in determining the density and level of blockade. Since most pediatric patients receive epidural analgesia in conjunction with a general anesthetic, the main purpose of the epidural catheter is to deliver sufficient local anesthetic solution for effective intraoperative and postoperative analgesia. Knowledge of total drug dose is important to avoid local anesthetic toxicity, particularly in pediatric patients.

Clinical Pearls
High concentrations of local anesthetics such as 0.5% bupivacaine or 0.5% ropivacaine are rarely used in pediatric population.

Instead, larger volumes of more dilute local anesthetic are more commonly used to cover multiple dermatomes.

A more detailed description of local anesthetics solutions, their characteristics and toxic potential has been described elsewhere in this text. As a general rule, however, high concentrations of local anesthetics such as 0.5% bupivacaine or 0.5% ropivacaine are seldom used in pediatric population particularly in the epidural space. Instead, larger volumes of more dilute local anesthetic are more commonly used to cover multiple dermatomes. Opioids prolong the duration of analgesia of local anesthetic, but have also been associated with unacceptable side effects, particularly in pediatric outpatients. Various non-opioid adjuncts like clonidine and alpha-2 agonist offer more favorable side effect profiles; however relatively little information is available regarding their use pediatric patients.

**Selection of epidural local anesthetic solutions**

**Clinical Pearls**

- In pediatric population, body weight is a better correlate than patient age in predicting spread of local anesthetic following a caudal block.
- For caudal use, the optimum concentration of bupivacaine is 0.125-0.175%.
- The maximal safe dose of bupivacaine is 2.5 mg/kg. to 4 mg/kg
- For continuous epidural infusion, bupivacaine 0.2 mg/kg/h for neonates and 0.4 mg/kg/h for older children is often used.
- For a single-shot caudal block, a bolus of 1 ml/kg of 0.2% ropivacaine is recommended.
- A continuous infusion of 0.2 mg/kg/hr of 0.1% ropivacaine in infants and 0.4 mg/kg per hour in older children for 48 hrs, has been shown to be effective and safe regimen.

Bupivacaine and ropivacaine are the two most commonly used local anesthetics for neuraxial anesthesia in children. Lidocaine is not often used.
because of its short duration of action and excessive motor block. Body weight is usually a better correlate than patient age in predicting spread of local anesthetic following a caudal block. The maximal safe dose of bupivacaine is 2.5 mg/kg to 4 mg/kg. For caudal use, the optimum concentration of bupivacaine is 0.125-0.175%. Compared with the 0.25% preparation, this concentration provides a similar duration of postoperative analgesia (4 to 8 hours) but with less motor blockade. Some clinicians prefer administering doses on a volume per weight basis. A dose of 1.0 mL/kg of a dilute solution such as 0.125% bupivacaine to a maximum volume of 30 mL can reliably provide T10 sensory block without exceeding maximum levels recommended in the literature. Higher doses such as 1.25 mL/kg, or even 1.5 mL/kg, may be administered to provide a more cephalad block without the risk of local anesthetic toxicity. For continuous epidural infusion, a commonly accepted dosage guideline of bupivacaine is 0.2 mg/kg/h for neonates and 0.4 mg/kg/h for older children. Cumulative toxicity is a concern even at lower rates of local anesthetic solution infusions. The alternate use of 2-chloroprocaine may be well tolerated by neonates.

Newer local anesthetic agents include the levo-entimomers ropivacaine and levobupivacaine. Ropivacaine has a higher therapeutic index than the older local anesthetic bupivacaine. At low concentrations, ropivacaine may produce less motor block and comparable analgesia when compared to bupivacaine with decreased incidence of cardiac and central nervous system toxicity. Due to its possible vasoconstricting properties, ropivacaine may undergo slower systemic absorption than bupivacaine. This may have clinical implications when a prolonged local anesthetic infusion is used in children with impaired hepatic function. For a single-shot caudal block, a bolus of 1 ml/kg of 0.2% ropivacaine is recommended. An infusion of 0.2 mg/kg/hr of 0.1% ropivacaine in infants and 0.4 mg/kg per hour in older children lasting no longer than 48 hrs, has also been shown to be effective and safe.

Levobupivacaine, the S (-)-isomer of bupivacaine, is less likely to cause myocardial depression and fatal arrhythmias and is also less toxic to the central nervous system than racemic bupivacaine. A dose of 0.8 ml/kg of 0.25% levobupivacine injected caudally provides analgesia in children having penile or groin surgery. For continuous epidural infusions, the dose for levobupivacaine is similar to racemic bupivacaine.

**Adjuvants to local anesthetics solutions**
Adjuvants may be used to prolong the duration of blockade, particularly for single-shot caudal epidural blocks. Single-shot caudal block is mainly used for ambulatory surgery. The major problem associated with this technique is the limited duration of analgesia and unwanted motor blockade. Recent research has focused on trying to resolve these problems with the addition of various adjuvants.

(i) Epinephrine: The most commonly used adjuvant for single-shot caudal anesthesia is epinephrine in a concentration of 1:200,000. Epinephrine has the added benefit of serving as a marker for an inadvertent intravascular injection.

(ii) Opioids: Epidural opioids may enhance and prolong analgesia. However, opioid use in an ambulatory setting may not be advisable due to the potential for respiratory depression and other unfavorable side effects (e.g. nausea and vomiting, itching, urinary retention). As a result, the use of caudal epidural opioids in children should be restricted to special clinical situations. Fentanyl has been used with desirable effects for epidural analgesia in adults for a number of years. Whether there is benefit for fentanyl as an additive in children undergoing single-shot caudal blockade is still debated amongst clinicians. One study found an increased incidence of nausea and vomiting when fentanyl was added to the local anesthetic solution for a single-shot caudal block. A dose of 2 µg/kg of fentanyl for single-shot caudal anesthesia along with the standard local anesthetic solution has been recommended for more extensive or painful procedures or in patients who have a urinary catheter in the postoperative period. The addition of 1 µg/mL to 2 µg/mL of fentanyl to 0.1% bupivacaine for continuous epidural infusions has also been used with success in neonates and children in a well monitored inpatient setting.

(iii) Clonidine: Clonidine, an alpha-2 agonist, acts by stimulating descending noradrenergic medullo-spinal pathways which inhibits the release of nociceptive neurotransmitters in the dorsal horn of the spinal cord. The addition of clonidine (1 to 5 µg/kg) can improve the analgesic effect of local anesthetics for single-shot caudal blockade as well as prolong its duration of action without the unwanted side effects of epidural opioids. For continuous epidural infusions clonidine 0.1 µg/kg/h has been used with good effect. It should be cautioned that higher doses have been associated with sedation and hemodynamic instability in the form of hypotension and bradycardia, and doses as low as 2 µg/kg have been associated with postoperative sedation.
blunts the ventilatory response to increasing levels of end-tidal carbon dioxide (PCO2). Although respiratory depression does not appear to be a common problem,81 apnea has been reported in a term neonate who received a caudal block consisting of 1 mL/kg of 0.2% ropivacaine with clonidine 2 µg/kg.82 Caution should be exercised while using clonidine in very young infants due to the sedation and hypotension that may ensue.

(iv) **Ketamine:** The addition of ketamine or S-ketamine to single-shot caudal block prolongs the analgesic effect of local anesthetics. The minimal disadvantage of ketamine are its psychomimetic effects. However, at low doses (0.25-0.5 mg/kg), ketamine is effective without noticeable behavioral side effects.78 Ketamine 1 mg/kg can also be used as an effective caudal analgesic solely without the addition of local anesthetic solution.83,84 The combination of S(+)-ketamine (0.5-1 mg/kg) and clonidine (1 or 2 µg/kg) has shown to provide effective analgesia after inguinal herniotomy in children with prolonged duration of effect (>20 hours) without any adverse CNS effects or motor impairment.84,85 However, the safety of ketamine for central neuraxial block has been questioned, particularly with the racemic formulations that contain preservatives. Results from a small clinical trial and case series indicate a single bolus administration of preservative-free S-ketamine appears to be safe and effective.7,59 Regardless, these reports lack statistical power and detailed postoperative evaluations to draw definitive conclusions regarding the safety of ketamine for neuraxial use. An additional concern regarding use of ketamine in neonates relate to a controversial series of animal studies that suggest ketamine can produce apoptotic neurodegeneration in the developing brain.86,87 Other infant animal studies have demonstrated that ketamine may have a neuroprotective effect.88,89 Nevertheless, many anesthesiologists are hesitant to introduce caudal S-ketamine into their routine clinical practice and it is unlikely ketamine will be widely adopted in countries where preservative-free formulas are not available.

(v) **Midazolam:** Epidural midazolam (50 µg/kg), when used alone, produces postoperative analgesia without motor weakness or behavioral changes.78 This is due to its ability to inhibit GABA receptors in the spinal cord. When added to local anesthetic solutions, midazolam can prolong the duration of analgesia but this effect has not been consistently demonstrated.90 Similar to ketamine, the safety of midazolam for neuraxial use has not been established and a preservative-free formulation is not universally available.59

(vi) **Neostigmine:** Neostigmine (2 µg/kg) alone produces postoperative
analgesia by inhibiting the breakdown of acetylcholine at muscarinic receptors in the dorsal horn.1 When combined with bupivacaine, a significant synergistic effect is observed. The addition of neostigmine (2 µg/kg) to 0.25% bupivacaine prolongs the duration of analgesia from 5 to 20 hours after hypospadias repair.1,91 However, it is associated with an unacceptably high incidence of vomiting (20-30%).91 This will likely preclude its use particularly in an ambulatory setting. Preservative–free neostigmine has not been widely available and has limited applications in pediatric regional anesthesia.

Complications Associated with Epidural and Caudal Analgesia

Neurologic injury

Major complications from either single-shot or continuous epidural blocks are rare if proper technique is employed.33,34 A large prospective study, which summarized data from over 15,000 central blocks in children, reported no incidence of permanent neurologic injuries and concluded that the incidence of complications is rare.92 However, three infant deaths and two other incidences of paraplegia and quadriplegia were reported in another large retrospective report published in 1995 with over 24,000 epidural blocks in children.93 This study also reported two cases of transient paraesthesia.93 Although the overall risk seems very low, devastating complications from direct damage to the spinal cord can occur during direct thoracic and high lumbar epidural needle placement. Since the placement of epidural needles/catheters are usually performed under sedation or general anesthesia, the fact that unconscious patients are unable to report pain or paresthesias (the currently accepted warning sign of needle encroachment on the spinal cord) raises concern.43,48-50 Recently, a case report described a spinal cord injury after placing single shot thoracic epidural under general anesthesia for appendectomy.52 This case report highlights the need for clinicians to routinely assess risk/benefit ratio of placing direct thoracic epidurals for less extensive surgery. Thoracic and high lumbar epidural catheter placement in particular should be limited to extensive thoracic and abdominal procedures and should be performed by anesthesiologists with experience in thoracic epidural placement. Before using a direct thoracic
approach in patients less than 2 years old, some prefer to make an attempt in threading the epidural catheter from the lumbar or caudal space with a proper epidural confirmation technique.

**Epidural hematoma**

Epidural hematoma associated with epidural analgesia is extremely rare. This may be because anticoagulation protocols are rarely indicated during the perioperative period in pediatric patients. Nonetheless, epidural analgesia should be avoided in patients with clinically significant coagulopathy or thrombocytopenia. The guidelines for use of epidural anesthesia in anticoagulated adult patients should probably also be applied in pediatric patients.

**Infection**

Compared to lumbar epidural catheters, there is some concern regarding catheter infection with the prolonged use of caudally placed catheters due to the proximity of the sacral hiatus to the rectum. Although studies have not found clinical evidence of higher infection rates with the caudal approach, bacterial colonization has been reported as higher. Staphylococcus epidermidis is the predominant microorganism colonized on the skin and catheters of lumbar and caudal epidurals.94 Gram-negative bacteria has also been demonstrated on the tips of the caudal catheter. 94 While the overall infection rate associated with caudal epidural catheters appears to be quite low, there have been isolated case reports of infection related to epidural catheters in children. Even with widely used single-shot caudal blocks, infection such as sacral osteomyelitis can still occur.95 Perforation of the rectum may occur if the caudal needle is angled too steeply.96 To reduce the risk of contamination by stool and urine techniques such as catheter tunneling or fixing the catheter with occlusive dressing in a cephalad direction can be used.15,97 A strict aseptic technique including the use of a sterile closed infusion system should also be employed and care should be taken to avoid local tissue trauma. Daily inspection of the dressing and entry site are also important.
Dural puncture and post-dural headache

Dural puncture during caudal epidural analgesia is uncommon if caution is taken to avoid advancing the needle too far into the sacral canal. Treatment for post-dural puncture headache (PDPH) include bed rest, oral or intravenous hydration, simple analgesia such as regular acetaminophen, non-steroidal anti-inflammatory agents, and anti-emetics. Bed rest, although relieving the severity of the headache, has no effect on the incidence or duration of PDPH. Hydration should be maintained in order to continue CSF production and to avoid dehydration which may alleviate symptoms. Simple analgesics can be all that is required until there is spontaneous resolution of symptoms. In adults, caffeine has been used for both prophylaxis and treatment for PDPH. Caffeine causes cerebral vasoconstriction by blocking adenosine receptors, which dilate vessels when activated. Reducing cerebral blood flow decreases the amount of blood in the brain and may lessen the traction on pain sensitive intracranial structures, relieving PDPH. Caffeine is not frequently used in children for relief of PDPH and an optimal dose is not known. Side effects are usually mild and may include nausea, insomnia, restlessness and lightheadedness.

The use of epidural blood patch (EPB) to treat PDPH has been used with success in adults since 1960. There are now many reports of its successful use in children as well. EPB is thought to be effective through the formation of a gelatinous cover over the dural hole by the injected blood. In the short term, EPB seals the hole and relieves CSF hypotension both by mass effect from CSF cranial displacement and by increasing the intracranial volume and pressure. Actual healing takes place over the longer term. In children it is recommended that approximately 0.3 mL/kg is injected, in the awake or mildly sedated patient if possible, in order to detect the appearance of radicular symptoms.

Hemodynamic effects and total spinal anesthesia

Significant changes in blood pressure are uncommon in pediatric patients after the proper administration epidural
analgesia. A high sympathetic single-shot caudal block to T6 had no significant changes in heart rate, cardiac index and blood pressure in children. Even when thoracic epidural block is combined with general anesthesia, cardiovascular stability is usually maintained in otherwise healthy pediatric patients. Hypotension should prompt anesthesiologists to immediately rule out a total spinal and/or intravascular injection leading to local anesthetic toxicity. Once these complications are ruled out, other causes such as hydration status, intravascular filling pressure, inotropic state, and the depth of anesthesia should be assessed. If a total spinal occurs, supportive measures have to provided until the effect of the block have dissipated. However, in the event of life-threatening extensions of total spinal and if attempted supportive measures are neither effective nor an option, cerebrospinal lavage can be considered as a last maneuver. A recent case report, suggested that 20 mL to 30 mL of CSF can be withdrawn and replaced with 30 to 40 ml of preservative-free normal saline, Ringer’s lactate or Plasma-lyte via the epidural catheter. It is believed this intervention may possibly shorten the recovery times, minimize potential neurotoxic insult and reduce the incidence of postdural puncture. In light of the limited experiences and information on cerebrospinal lavage, the potential risks and benefits should be evaluated on a case-by-case basis before using this technique.

**Local anesthetic toxicity**

Local anesthetic toxicity often stems from accidental intravascular injection into epidural blood vessels. This complication can often be avoided by using careful aspiration and test dosing, Table 1.

**Table 1: Test-Dosing for Epidural Blockade**

**Recommendations**

1. Use test dosing routinely, even while recognizing that test dosing with all available agents is not 100% sensitive. In addition, because the true incidence of intravascular placement is relatively low, most of the positive tests (heart
rate increases) will be false positives. When there is a borderline response, repeating the test dose may increase the specificity and sensitivity.

2. Continuously monitor the ECG and cycle the blood pressure cuff repeatedly. With epinephrine-containing solutions, if the heart rate does not increase, an increase in blood pressure should also raise suspicion of intravascular placement.

3. Avoid performing test dosing when the child is in a very light plane of anesthesia or when there is stimulation (e.g. repositioning the patient on the operating table, instrumentation of the airway, incision, etc.). Performing the test dose under these conditions increases the likelihood of false-positive, stimulation-induced increases in heart rate or blood pressure.

4. Following the test dose, the remainder of the full dose should be administered incrementally. Incremental dosing and continuous monitoring helps increase the odds that intravascular placement will be detected and further injection will be halted before full cardio-depressant doses are administered.

For single shot caudal, this is more likely to occur when needles are advanced too far into the caudal canal or when sharp-tipped needles are used.104 For continuous epidural infusion, neonates and very young infants are at greater risk for local anesthetic toxicity.3 Seizures have been reported in children receiving continuous infusions of local anesthetics.2,105 This can be avoided by using dilute solutions of local anesthetics (≤ 0.125% bupivacaine) and by following current dosing recommendations (see local anesthetic section).106 More importantly, vigilant monitoring during the administration of epidural analgesia should be priority.

Other adverse effects

In a retrospective review based on a prospective collected data from 286 pediatric patients; pruritus (26.1%), nausea and vomiting (16.9%), and urinary retention (20.8%) were the most common side effects encountered during epidural anesthesia
using an infusion of bupivacaine and fentanyl infusion. Sedation and excessive block each occurred in less than 2% of patients. The incidence of respiratory depression was 4.2%, but the administration of naloxone, for severe respiratory depression, was never necessary. Table 2 summarizes the recommended treatment for the common adverse effects.

**Table 2: Side-effects of epidural analgesia and suggested treatment**

**A. Itching**

1. Exclude and/or fix other remediable causes
2. Low-dose naloxone infusions or partial agonist-antagonists (nalbuphine) are both more effective and less sedating than antihistamines
3. If itching persists despite naloxone or nalbuphine, consider substituting clonidine for opioid in the epidural infusion.

**B. Nausea**

1. Exclude and/or fix other remediable causes
2. 5-HT antagonists, e.g. ondansetron, dolasetron
3. Low-dose naloxone infusions or nalbuphine
4. Substitute clonidine for opioids in epidural infusion

**C. Ileus and bowel dysfunction**

1. Exclude and/or fix other remediable causes
2. Laxatives, if not otherwise contraindicated
3. Substitute clonidine for opioids in epidural infusion
4. Low-dose naloxone infusions or nalbuphine
5. Peripherally or enterally-constrained opioid antagonists, including methylnaltrexone or alvimopan (investigational)

**D. Sedation or hypoventilation**

Exclude and/or fix other remediable causes

1. Depending on severity, reduce or hold dosing of opioids or clonidine
2. Awaken, stimulate, encourage deep breathing
3. If severe, consider naloxone or assisted ventilation as needed
E. Urinary retention

1. Exclude and/or fix other remediable causes
2. Avoid use of anticholinergics or antihistaminics if alternatives are available
3. Low-dose naloxone infusions or nalbuphine
4. Bladder catheterization
5. Selective alpha-1a antagonists such as Flomax
6. Substitute clonidine for opioids in the epidural infusion

Epidural Block Technique

Introduction

Epidural analgesia can be delivered via a single-shot or a continuous infusion technique. These needles and catheter can be inserted at the caudal, lumbar or thoracic level. Aspiration tests and test doses indicate possible inadvertent intravascular or intrathecal needle/catheter placement. Other new advances in the field of epidural analgesia have focused on accurately positioning continuous epidural catheters. Epidural stimulation, epidural ECG and ultrasound techniques have been developed in addition to conventional x-ray imaging to assist with accurate epidural needle/catheter placement.

Confirmation of Proper Epidural Needle/Catheter Placement

Aspiration/test dose

An aspiration test performed prior to local anesthetic injection is used to avoid a total spinal and intravascular injection. However, a negative aspiration of blood or cerebrospinal fluid (CSF) should not be considered as an absolute indicator of proper needle and catheter placement. The specificity of ECG changes, (i.e. >25% increase in T wave) following the injection of an epinephrine test dose (0.5 µg/kg), on the other hand, can help predict intravascular injection. When used, the ECG should be continuously monitored while injecting local anesthetic via the caudal space, Table 3.
Table 3: Electrical stimulation test

<table>
<thead>
<tr>
<th>Catheter Location</th>
<th>Motor Response</th>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subcutaneous</td>
<td>None</td>
<td>&gt;10 mA</td>
</tr>
<tr>
<td>Subdural</td>
<td>Bilateral (many segments)</td>
<td>&lt; 1 mA</td>
</tr>
<tr>
<td>Subarachnoid</td>
<td>Unilateral or Bilateral</td>
<td>&lt; 1 mA</td>
</tr>
<tr>
<td>Epidural space</td>
<td>Unilateral</td>
<td>&lt; 1 mA</td>
</tr>
<tr>
<td>Against Nerve Root</td>
<td>Unilateral</td>
<td>&lt; 1 mA</td>
</tr>
<tr>
<td>Nonintravascular</td>
<td>Unilateral or Bilateral</td>
<td>1-10 mA (threshold current increase after local anesthetic injected)</td>
</tr>
<tr>
<td>Intravascular</td>
<td>Unilateral or Bilateral</td>
<td>1-10 mA (no change in threshold current after local anesthetic injected)</td>
</tr>
</tbody>
</table>

Radiographic methods

X-ray imaging in conjunction with a contrasting agent precisely identifies the tip of the catheter at a specific spinal level.9 However, without contrast, a radiograph will not be able to distinguish inadvertent intrathecal or subdural catheter placement from proper epidural placement. In addition, standard x-ray does not allow the anesthesiologist to adjust the position of the catheter during insertion unless fluoroscopy is utilized. While fluoroscopy permits the real-time monitoring and adjustment of advancing catheters, it requires additional set-up, incurs increased expense, and increases a patient’s exposure to ionizing radiation. As a result, fluoroscopy is not routinely used and is usually limited to difficult and/or special circumstances such as long-term epidural catheter placement.
for cancer pain.

**Ultrasound-guided techniques**

Ultrasound allows the real-time visualization of anatomical structures and offers the potential to guide epidural needle and catheter placement. Ultrasound can be beneficial for guiding peripheral nerve block placement in both in adult patients,10,11 and in children. Although the images produced by ultrasound can be used to guide caudal needle placement, they may be of limited value in older children.12,13 Calcification of the posterior vertebral bodies in children greater than 6 months prevents reliable imaging of the spinal cord.13 At the present time, ultrasound guidance can be helpful for caudal and epidural blocks only in infants and small children, as the sacrum and vertebrae are not fully ossified.

**Epidural stimulation test**

Recently, the use of low current electrical stimulation has been suggested to monitor and guide the position of the epidural catheter during insertion.14,15 The epidural stimulation test (Table 3) can be used confirms epidural catheter placement through stimulation of the spinal nerve roots (not the spinal cord) with low electrical current conducted through normal saline in the epidural space via an electrically conducting catheter.14

**Table 3: Confirmation of the Epidural Catheter Position**

**Intraoperatively (while the patient is under general anesthesia)**

1. Radiography with contrast
2. Electrical stimulation
3. ECG
4. Ultrasonography (infant)

**Postoperatively (while the patient is awake, whether or not they can give verbal responses)**

1. Electrical stimulation
2. Radiography with contrast
3. Chloroprocaine test: Incremental dosing of chloroprocaine 3% solution to demonstrate analgesia (by self-report or behavioral measures as appropriate) and signs of segmental effect
   1. lumbar catheter tip:
      at least partial sensory and motor blockade in both legs
      warming of the volar surface of the toes
   2. lower thoracic catheter tip:
      reduced strength in hip flexion
      reduced abdominal skin reflexes
      some reduction in heart rate and blood pressure
   3. upper thoracic catheter tip:
      some reduction in heart rate and blood pressure
      warming of the volar surface of the hands
      unilateral or bilateral Horner’s syndrome

4. Dosing is given in 4 increments at 60 second intervals according to body weight:
   0-10 kg - 0.2 ml/kg increments (0.8 ml/kg total)
   10-25 kg - 0.15 ml/kg increments (0.6 ml/kg total)
   25-40 kg - 0.1 ml/kg increments (0.4 ml/kg total)
   > 40 kg - 0.075 ml/kg increments (0.3 ml/kg total, to a maximum of 20 mls)

The stimulating catheter set-up requires the cathode lead (black for block) of the nerve stimulator to be connected to the epidural catheter via an electrode adapter while the anode lead is connected to an electrode on the patient’s skin as the grounding site, **Figure 1**. To avoid misinterpretation of the stimulation

**Figure 1. Epidural stimulation test:**
**Equipment.** The stimulating catheter set-up requires the cathode lead (black for block) of the nerve stimulator to be connected to the epidural catheter via an electrode adapter while the anode
response (e.g. local muscle contraction may be confused with epidural stimulation), the ground electrode is placed on the lower extremity for thoracic epidurals and on the upper extremity for lumbar epidurals. Correct placement of the epidural catheter tip (1-2 cm from the nerve roots) is indicated by a motor response elicited with a current between 1-10 mA.14,16,17 A motor response observed with a significantly lower threshold current (<1 mA) suggests that the catheter is in the subarachnoid or subdural space, or is in close proximity to a nerve root.18,19 In these (rare) cases, a motor response is elicited with a significantly lower threshold current because the stimulating catheter may be very close (<1 cm) to the nerve roots or because it may be in direct contact with highly conductive CSF.

While chronic spinal cord stimulation is a safe and effective means of pain management,20-23 the safety of this epidural stimulation test is not completely known. However, it is anticipated that the risk of a brief intermittent electrical stimulation used in this test would be even lower than the risk of chronic epidural stimulation used in long-term pain management. In addition, epidural stimulation uses milliamperges (mA) within the range used for patients with chronic pain disorders (4 to 30 mA)24 and for intraoperative monitoring during spinal surgery (2 to 40 mA).25-27 Although no known complications or patient discomfort have resulted from the epidural stimulation test, it has been recommended to keep the current below 15 mA and the stimulation time as brief as possible.14,15,17,28 In particular, the current output must be carefully increased from zero and stopped once motor activity is visible to ensure that all motor responses, even those elicited with low current (<1 mA), are detected. The nerve stimulator must be sensitive enough to allow a gradual increase in current output to at least 10 mA. It should be noted that most nerve stimulators currently manufactured for electro-location of peripheral nerves do not deliver currents greater than 5 mA and therefore are not ideally suited for epidural stimulation.

Pediatric epidural stimulation catheter: A thin metal stylet is
essential for effective threading of the epidural catheter from a lower spinal level to the target upper spinal level. A styletted catheter has a soft and flexible tip and is made from a soft polyurethane polymer. The stylet of the epidural catheter ends 10 mm proximal to the tip which allows the tip of the catheter to fold back on itself in a “J” configuration during insertion (Arrow International™). This feature allows retention of the soft and blunted tip of the catheter while the stylet wire provides stiffness for ease of advancement within the epidural space. For monitoring advancement, elicited muscle twitches are observed from the lower limbs to the intercostal muscles as the catheter is advanced cranially. This minimizes the concerns of the catheter coiling or kinking by immediately identifying these events at the time of insertion, allowing for any necessary adjustments. The absence of muscle twitches or resistance to the advancing epidural catheter may be indicative of a curled or kinked catheter. Epidural stimulation test relies on a small electrical current being transmitted through a conducting fluid injected into the epidural space. An ionic solution such as normal saline is used as the priming solution for the catheter. Normal saline dissociates into ions that are sufficient for effective electrical conduction over a short distance. The long length of the epidural catheter or any air lock within its lumen increases the resistance to current flow. Consequently, the lumen of the catheter must contain a metal element to reduce the impedance of the conducting solutions and to ensure proper conduction of electricity through the entire length of the catheter. Many commercial epidural catheters with metal elements are now available through a number of major manufacturers and can be used for the purpose of epidural stimulation test.

**Epidural ECG technique**

One disadvantage of the epidural stimulation technique is that it cannot be performed reliably if any significant clinical neuromuscular blockade is present or local anesthetics have been administered in the epidural space. To overcome this limitation, an alternative monitoring technique using electrocardiograph (ECG) monitoring has been suggested. Using epidural ECG monitoring lead, the anatomical position of the epidural catheter is determined by comparing the ECG signal from the tip of the catheter to the torso or proximal lead.
catheter to a signal from a surface electrode positioned at the ‘target’ segmental level. A standard reference ECG (lead II) is recorded by connecting the right-arm electrode (white) to a skin electrode on the patient’s back at the target spinal level, while the left-arm electrode (black) and left-leg electrode (red) are placed at their standard position, **Figure 2**. Next, the right-arm electrode is connected to the metal hub of the electrode adapter (Johans ECG Adapter, Arrow International, Inc., Reading, USA) to record a tracing from the epidural catheter. When the epidural catheter tip is positioned in the lumbar and sacral regions, the amplitude of the QRS complex is relatively small, because the recording electrode (epidural tip) is far away from the heart and the vector of the cardiac electrical impulse is at approximately a 90° angle. As the epidural tip advances toward the thoracic region, the amplitude of the QRS complex increases as the recording electrode comes closer to the heart and the ECG recording becomes more parallel to the cardiac electrical impulse. The amplitude should match the reference surface electrode amplitude as it passes the target level. Based on these observations, the advancement of an epidural catheter from the lumbar or sacral region into the thoracic region can easily be monitored and placed within two vertebral spaces of the targeted level under ECG guidance. However, unlike the epidural stimulation test, the ECG technique cannot warn of a catheter placed in the subarachnoid or intravascular space. In addition, this technique may not be suitable when threading catheters a short distance because the reference ECG and epidural ECG may be too similar to compare.

**Figure 2. Epidural ECG technique.** Using epidural ECG monitoring lead, the anatomical position of the epidural catheter is determined by comparing the ECG signal from the tip of the catheter to a signal from a surface electrode positioned at the ‘target’ segmental level. When the epidural catheter tip is positioned in the lumbar and
sacral regions, the amplitude of the QRS complex is relatively small, because the recording electrode (epidural tip) is far away from the heart and the vector of the cardiac electrical impulse is at approximately a 90° angle. As the epidural tip advances toward the thoracic region, the amplitude of the QRS complex increases as the recording electrode comes closer to the heart and the ECG recording becomes more parallel to the cardiac electrical impulse. The amplitude should match the reference surface electrode amplitude as it passes the target level.

Technique

Several epidural techniques currently used in children will be described in this chapter. The most common types of epidural analgesia are (A) caudal analgesia which constitutes the most commonly used regional technique in children; (B) lumbar epidural analgesia and (C) thoracic epidural analgesia

Single-shot caudal technique

Single shot caudal epidural blockade ('kiddy caudals') is widely used to provide perioperative analgesia in pediatric practice. As a single injection, it offers a reliable and effective block for patients undergoing urological, general and orthopedic surgery involving the lower abdomen and lower limbs. A single-shot caudal epidural may not be suitable for every case as it has a limited dermatomal distribution and a short duration of action. New local anesthetics and adjuvants, as well as continuous catheter approaches may overcome these limitations.

Choice of needle for caudal analgesia
A variety of needles are available for single-shot caudal blockade. The size or type of needle does not appear to affect the rate of success or the incidence of complications of caudal blockade. Short-bevel 22 gauge needles (< 4 cm in length) with stylets are believed to offer a better tactile sensation when the sacrococcygeal ligament is punctured.33 Theoretically, the use of a styletted needle may reduce the risk of introducing a dermal plug into the caudal space, although an epidermal cell graft tumor in the epidural space has yet to be reported. The use of 22-gauge Angiocath® is also advocated because with the advancement of these catheters into the caudal space may indicate proper positioning.34 There is also indications that it is easier to detect intravascular placement and interosseous placement with angiocatheters.6 To avoid tissue coring with these angiocatheters, the needle must be removed before any injection is made.35

**Technique for performing caudal epidural block**

Patients are placed either in a lateral decubitus position with the knees drawn up to the chest or in a prone position with a roll under the hips for caudal epidural block placement, **Figure 3.** Following proper positioning, the landmarks for caudal epidural block are easily identified in children. After initially identifying the coccyx and continuing to palpate in the midline in a cephalad fashion, the sacral cornua can be felt on either side of the midline approximately one centimeter apart, **Figure 4.** The sacral hiatus is felt as a depression between two bony prominences of the sacral cornua. Under sterile conditions, the needle is inserted and advanced into the sacral hiatus at approximately a 70-degree angle to the skin until a distinctive “pop” is felt as the sacrococcygeal ligament is punctured, **Figure 5.** Following this puncture, the angle of the needle should be reduced to approximately 20 to 30 degrees while the needle is advanced 2 to 4 mm into the caudal canal. If using an angiocatheter (**Figure 6**), the plastic catheter of the needle should easily advance into the caudal epidural space. Any advancement past this point is not recommended as the risk of an inadvertent dural puncture increases significantly.
**Figure 3.** Patient Positioning. Shown is left lateral position with hips maximally flexed.

**Figure 4.** Landmarks for caudal anesthesia. Shown are posterior superior iliac spines (two fingers) which form equalateral triangle with sacral cornua (single finger).

**Figure 5.** Needle advancement in caudal block. Cannula is advanced in a cephalad direction. Occasionally, a pop is felt as the sacrococcygeal ligament is penetrated. At this point the cannula is advanced a few cm off the needle.

**Figure 6.** Cannula placement. Easy passage of the cannula confirms correct placement.
Clinical Pearls

- Posterior superior iliac spines and sacral hiatus form equalateral triangle
- Sacral Cornua either side of hiatus (0.5-1.0 cm apart)
- Dural sac extends to S4 in the infant less than 1 year (S2 in the adult)

Confirmation of needle placement

The classic “pop”, felt as sacrococygeal membrane is pierced is usually sought for proper caudal needle placement. The absence of subcutaneous bulging and the lack of resistance upon injection of local anesthetic are additional signs of proper needle placement, Figure 7. Aspiration of the needle should be clear of blood and CSF and a negative response to a test dose of epinephrine should be also used to rule out intrathecal and intravascular placement, Figure 8. Other tests to confirm proper needle placement include the “whoosh” test, the “swoosh” test, and the use of nerve stimulation.36,37 The “whoosh” test requires the injection of 2.5 ml of air through the caudal needle, with a “whoosh” being heard with a stethoscope placed over the thoracolumbar spine. However, this can lead to a patchy block. More importantly, it can cause a venous air embolism if the needle is inserted into an epidural vessel especially in small infants. The “swoosh” technique avoids these problems by injecting local anesthetic or saline in place of air but the benefit of confirming needle placement prior to local anesthetic injection is lost. Excessive saline injection may dilute subsequent local anesthetic injections and lead to an inadequate block. When using nerve stimulation, proper needle placement is confirmed by motor activity in the anal sphincter with 1-10 mA of current through an insulated needle.37 The sensitivity and specificity of predicting proper needle placement approaches 100% with this approach, although the requirement for an insulated sheathed needle limits its use.37 Furthermore, most insulated needles lack a stylet and may be more expensive than standard non-insulated needles. Ultrasound has been used to provide real-time images to guide needles into the caudal space.12 Other predictors of accurate
block placement following the injection of local anesthetic have been attempted. Relaxation of the anal sphincter predicts successful caudal blockade, but pupillary reflex dilation and skin temperature changes are not clinically useful.

Figure 7. The cannula is stabilized. Figure 8. Bloody tap. In the infant with the left hand while the local anesthetic syringe is connected and inadvertently cannulated as evidenced by the free flow of venous blood. The EKG is monitored during injection. Cannula is consequently removed and for an increase in heart rate of 10; the process repeated. beats/min or a 20% change in T wave amplitude. The reliability of these signs without EKG strip monitoring remains untested. The area of skin immediately over the sacrum should be visible to observe for inadvertent subcutaneous injection.

Clinical Pearls

- Formulae exist for the volume of local anaesthetic required to achieve a given dermatomal spread. In practice, a dose of 1ml/kg of 0.25% bupivacaine with epinephrine will give four hours of postoperative analgesia with a low incidence of motor block.
- The only additives that have been shown to prolong analgesia without increasing side effects are:
  - Clonidine 1-2 mcg/kg (approximately 8 hours postoperative analgesia)
  - Ketamine (preservative free) 0.5 mg/kg (up to 12 hours)
hours postoperative analgesia)

- These agents have been shown to prolong the time to first analgesic following minor surgery. In our experience, after the local anaesthetic block has worn off, these agents provide only mild analgesia.

**Continuous caudal epidural to lumbar or thoracic space**

Continuous caudal epidural analgesia overcomes the limited duration and segmental effect of a single-shot technique. Caudal catheters advanced to a lumbar or thoracic level can be used for surgery involving dermatomes above T10. This technique may carry a smaller risk of dural puncture or spinal cord trauma than a direct thoracic epidural approach.

**Technique**

The technique for needle insertion for continuous caudal analgesia is very similar to the single-shot caudal approach. An intravenous catheter (an 18-gauge angiocatheter for a 20-gauge epidural catheter or a 16-gauge angiocatheter for a 19-gauge epidural catheter) or an 18-gauge Crawford needle is inserted through the sacrococcygeal ligament as described for the single-shot technique. The complete angiocatheter with the needle set should then be advanced no more than 1 cm into the sacral canal. After withdrawing the metal needle, the plastic sheath is gently advanced completely into the caudal space. This allows the epidural catheter to easily pass through the plastic sheath. The appropriate length of epidural catheter is measured against the back of the child from sacral to the target spinal level or approximate dermatomal coverage required for the surgical procedure. The epidural catheter is then advanced carefully from the caudal space to the target level. Minor resistance to the passage of the catheter can usually be overcome by simple flexion or extension of the patient’s vertebral column and/or by simultaneously injecting normal saline through the advancing specialized stimulation epidural catheter (Epidural Positioning System using Tsui test, Arrow International Inc., USA™). The location of the catheter tip should be verified using an objective test described as in the previous section (radiography, nerve stimulation, internal monitoring, etc.).
electrocardiography,31,32 or ultrasound12). While some may criticise these techniques as cumbersome or redundant, these tests are valuable teaching aids and may avoid extensive follow-up on patients with inadequate analgesia as a result of poorly situated catheters. Studies have suggested that caudal catheter placement should be limited to patients under 1 year of age due to the development of a lumbar curve during infancy preventing easy cephalad advancement of the catheter.9 However, recent reports have demonstrated that cephalad advancement is possible in older children using epidural stimulation.15,41,42 The improved success rate in older children has been attributed to the use of a styletted catheter which allows the simultaneous injecting of saline during advancement, and, more importantly, to the stimulation test which monitors the advancement of the catheter tip.15

Clinical Pearls

- Advantages of a cannula over a needle are;
  - Confidence of placement if the cannula slides off the needle easily
  - Possibly reduced intraosseous injection risk
  - Possibly reduced intravascular injection risk
  - Possibly reduced dural puncture risk

Lumbar epidural anesthesia

Lumbar epidural analgesia is commonly used for continuous infusions and is rarely employed as a single-shot technique. A direct lumbar approach is primarily indicated for providing pain control during and following lower extremity surgery. Lumbar epidural placement, particularly in young children, is performed after the induction of general anesthesia. However, this approach may also be performed awake in a select group of cooperative children and adolescents. The risk/benefit ratio of inserting thoracic epidural catheters in children under general anesthesia is controversial.41,43 Although this issue is not as controversial for lumbar epidural analgesia as thoracic epidural analgesia,43 caution should be exercised whenever performing lumbar epidural analgesia above the level of spinal cord to avoid direct needle trauma.

Technique for placement of lumbar epidural analgesia
A midline approach to lumbar epidural needle placement is preferred. Identification of the epidural space is commonly achieved by loss of resistance (LOR) to saline. LOR to air should be avoided due to the risk of introducing a venous air embolism particularly in neonates and infants. Children should be positioned in the lateral decubitus position for direct lumbar epidural placement, **Figure 9**. An 18-gauge Tuohy needles with a 20-gauge epidural catheter is often used in children, **Figure 10, Figure 11**. Although identification of the intervertebral space and ligamentum flavum in most pediatric patients is easy, the ligamentum flavum can be less tensile in children and hence a distinctive “pop” may not be easily felt when penetrating this layer. In addition, the distance from the skin to the epidural space can be shallow. Formulas for estimating the distance from skin to epidural space distance have been proposed.44-46 (Table:4) Formulae are only a guidelines and will change depending on the angle of placement of the epidural needle.

**Figure 9.** Landmarks for epidural anesthesia in small children

The landmarks are similar in adult population except that the intercristal line bisects L5. In this child the L1 spinous process is marked with an arrow.

**Figure 10.** Epidural
Figure 10. Epidural anesthesia in children: Hand position

Patient in the left lateral position. Left hand index and middle finger either side of chosen interspace. Right hand holds needle hub.

Figure 11. Epidural anesthesia in children: Needle Advancement

Needle is advanced with stylet in place until interspinous ligament is reached. Stylet is removed and saline filled loss of resistance syringe connected to needle. Both plunger and needle continuously advanced. Initially an increase in resistance is felt as the ligamentum flavum is entered before a loss of resistance. These sensations are very subtle in the small infant.

Table 4: Formula for depth of epidural space from skin

1. Rough estimate 1 mm/kg body weight
2. Depth(cm) = 1 + 0.15 X age (years)
3. Depth (cm) = 0.8 + 0.05 X weight (kg)
4. Mean depth in neonates= 1 cm

Lumbar to thoracic approach

Catheters placed via the lumbar route may be advanced cephalad to thoracic
vertebral levels, **Figure 12-16.** Similar to the problems encountered when advancing catheters in the caudal space in older children, significant resistance also prevents the easy advancement of lumbar epidural catheters to the thoracic levels. Despite favorable results using stimulation via a caudal approach, there has been only one recent case report demonstrating the successful placement of a thoracic epidural catheter via the lumbar route with epidural stimulation guidance.47 Further research and study is warranted for using the stimulating technique for this approach.

**Figure 12.** Epidural anesthesia in children: Catheter insertion

Catheter advancement is associated with greater resistance than in the adult. The catheter stabilizing attachment may help (not used here).

**Figure 13.** Epidural anesthesia in children: Preventing the leakage

Preventing the leakage of local anesthetic in pediatric patients is important because this can comprise a significant percentage of the total drug delivered. The puncture site can be sealed using several methods, one of which is with ‘Liquid Bandage’ (Johnson and Johnson) using the supplied product applicator.
**Figure 14.** Epidural anesthesia in children: Securing the catheter

Tincture of benzoin is applied to improve adhesion of the fixation device.

**Figure 15.** Epidural anesthesia in children: Securing the catheter

Epidural catheters that are not secured well in small children dislodge very easily. The device used here is the Simms Portex ‘lockit’ device. In the small child/infant allowance should be made for the relatively small distance between adjacent vertebrae. Leaving 3 cm of catheter in the epidural space means the tip of the catheter may be three segments higher (or lower) than the needle insertion point. In this child the epidural space was located 2 cm deep to the skin. Leaving the catheter at 5 cm (3cm in space) will result in the catheter being situated at approximately T10 (three segments above T12/L1 interspace).
Clinical Pearls

- Various formulae exist for calculating the volume of local anesthetic required to block a given number of segments. Because sympathetic blockade is well tolerated in children with very little change in both heart rate and blood pressure, in practice, (following an appropriate test dose) a bolus of 0.5-1.0 ml/kg of 0.25% bupivacaine is administered to establish the block.

- For postoperative analgesia, the most common agent used is a combination of bupivacaine 0.125% with fentanyl 2 mcg/ml at the following rates.
  - Age > 3 months 0.20-0.35 ml/kg/hr (<0.4mg/kg/hr bupivacaine)
  - Age < 3 months 0.1-0.15 ml/kg/hr (<0.2 mg/kg/hr bupivacaine)

- In preschool age children and especially infants, irritability/agitation may occur despite an apparently well functioning epidural. This is most likely the result of the IV line, nasogastric tube, urinary catheter or even the hospital environment. Satisfactory sedation can be achieved with either,
  - IV boluses of morphine 25 mcg/kg as required or
  - Adding clonidine 0.5 mcg/ml to the epidural mixture

- PCEA (Age > 7) may provide less motor block than an infusion only prescription without compromising analgesia.
  - Infusion 0.15 ml/kg/hr
  - Bolus 0.07 ml/kg lockout 20 minutes

Thoracic epidural analgesia
Controversy exists concerning the safety of placing thoracic epidurals under heavy sedation or general anesthesia, as unconscious patients are unable to report symptoms that may warn the anesthesiologist of potential neurological complications.43,48-50 Direct needle trauma to the spinal cord during epidural insertion is rare but can cause devastating complications. Recent reports have detailed cases of direct needle trauma to the spinal cord during epidural placement in both awake and anesthetized patients.51-53 The advancement of catheters from the lumbar and caudal epidural spaces to the thoracic level can be alternative approach. However, for reasons poorly understood, the advancement of catheters in the epidural space becomes increasingly difficult with advancing age. The reason for this is poorly understood but it has been suggested that the increase in resistance to catheter advancement parallels the development of the lumbar curvature.9 Direct placement of thoracic epidural catheters are still used but more commonly at tertiary care centers limited for extensive procedures involving thoracic and abdominal surgery with well trained personnel. A recent study in pediatric patients suggested that electrical stimulation applied to an advancing epidural needle may be used as an additional safety measure to warn of needle proximity to the intrathecal space, spinal cord or nerve root.54 This study demonstrated that the mean current necessary to elicit a motor response with insulated needles in the epidural space is much higher than that in the intrathecal space (5.2 2.4 mA versus 0.6 0.3 mA, respectively).54 Individually, electrical stimulation and LOR have their limitations, but together, both these techniques may compensate for each other’s weaknesses to facilitate optimal needle placement. A similar concept using electrophysiological monitoring is common practice in spinal surgery, but currently there is no clear evidence that electrical stimulation would directly benefit thoracic epidural placement.55 This concept is still in its infancy and further research is warranted.

Clinical Pearls

- Because children require a significantly higher volume/dose of local anesthetic compared to adults to achieve the same dermatome spread, it is important to have the tip of the catheter at the intended surgical site.
- Intended high thoracic catheter advancement from a lumbar insertion site is rarely successful.
- Thoracic epidural insertion should only be performed by practitioners experienced with pediatric lumbar epidural
Technique

Epidural needle insertion in pediatric patients can be performed at any thoracic interspace using either a midline or paramedian approach. The paramedian approach is preferred in adults while a midline approach is often used in children.

**Midline approach**

Using midline approach, insertion of the needle is easier at the lower thoracic level (T10 to T12) than at the mid-thoracic (T4 to T7) level. The lower border of the shoulder blade, which is level with 7th thoracic vertebra, is commonly used as an anatomical landmark. After the patient is placed in the lateral decubitus position, the spinuous process of the targeted vertebral level is identified. A 20-gauge Tuohy epidural needle is then inserted at the interspace at a cephalad angle of approximately 70 degree to the longitudinal axis of the spine (Figure 4). Continuous resistance should be felt as the needle is inserted through the supraspinous and interspinous ligaments. In pediatric patients, the resistance met at the ligamentum flavum may not be noticeably different from the other ligaments. The thoracic epidural space is identified with loss of resistance to saline. The advantage of the midline approach is that its technique is very similar to lumbar epidural insertion with the needle angulated only in one plane.

**Paramedian approach**

The paramedian approach permits entry to the epidural space at any spinal level. This approach is usually performed with patients in the lateral decubitus position. Right-handed clinicians may prefer to use a right paramedian approach because
it increases the working space and it may facilitate needle placement with the patient on the same side as the needle. The needle is initially inserted next to the spinal process and slowly advanced in a direction perpendicular to the skin until lamina is contacted. It is important to take note of lamina depth as it provides an estimated depth of the epidural space from the skin.56,57 (Figure 5) The needle is redirected medial before being inclined cephalad toward the interspace. Again, LOR to saline will identify the epidural space. Many believe that this approach requires more skill and experience as the needle must be angled in 2 planes (i.e. medially and cephalad). Thus, anesthesiologists with extensive experience and confidence in epidural analgesia should perform this technique.

Managing Epidural Infusions Postoperatively

In order for epidural analgesia to be effective and safe systematic and regulated approaches to patient care must be practiced. A dedicated pediatric acute pain team, consisting of anesthesiologists and nurses, is vital to ensure standardized assessments of pain, vigilant patient monitoring and the proper treatment of any adverse effects. Recommendations for epidural troubleshooting and managing inadequate analgesia are summarized in Table 5. Precise placement of epidural needles and catheters is the key to successful epidural analgesia. This requires employing the use of a reliable method to confirm the location of the catheter tip (e.g. x-ray, epidural stimulation). The use of opioids or alpha-2 agonists in the epidural space may lead to better analgesia. An average length of epidural infusion is about 72 hours although it may be necessary to continue the infusion for longer periods especially in children with complicated medical histories and prolonged need for analgesia. A team of dedicated personnel with a focus on pain management should care for these children. When plans to discontinue the epidural infusion are in place, an oral opioid should always be administered to enable the patient to continue to have excellent analgesia. Finally the success of the process is based on properly written orders which are a crucial part of executing adequate analgesia. A sample of an order sheet for managing epidural analgesia is attached, Table 6.

Table 5: Tips for improving epidural analgesia
Inadequate Analgesia

- If there is any doubt about the adequacy of analgesia or the position of the catheter, prove the catheter’s position using one of the approaches outlined in Table 4. The use of chloroprocaine can provide catheter tip position and rapidly providing analgesia in most cases.
- If the epidural infusion does not already include either an opioid or clonidine or S(+) ketamine along with the local anesthetic, consider inclusion of one of these additives, unless there are specific contraindications or unmanageable side-effects.
- Use bolus dosing to produce analgesia relatively promptly (while staying within maximum allowable local anesthetic dosing parameters). Simply increasing an infusion rate by 10 or 20% will require hours to reach a steady state, and will subject the patient to prolonged pain.
- Titrate the local anesthetic upwards into the acceptable range, if this has not been done already, unless specifically contraindicated or unless limited by motor or autonomic blockade.
- For adolescents and young adults with thoracic catheter tips for upper abdominal or thoracic surgery, if there is inadequate analgesia when the local anesthetic infusion is titrated upwards to more than 12 ml/hour, consider next increasing the local anesthetic concentration, e.g. increasing bupivacaine to 0.15%, while maintaining a maximum hourly dosing within the 0.4 mg/kg/hr limit.
- If the catheter tip is in lumbar dermatomes and the surgery is thoracic or upper abdominal, add a hydrophilic opioid, such as hydromorphone or morphine, unless there are specific contraindications.
- If the catheter is in the epidural space, but the block is preferentially one-sided to the wrong side, consider addition of a hydrophilic opioid, either hydromorphone or morphine, unless there are specific contraindications.

References


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