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Guidelines for Pediatric Regional Anesthesia

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Introduction

This syllabus will discuss the salient differences between children and adults as far as the performance of regional anesthesia is concerned. The majority of discussion will be reserved for examination of the controversies surrounding the performance of regional anesthesia in anesthetized subjects who are unable to report the existence of paresthesias, whether this might increase the risk of regional anesthesia, and an overall assessment of the risk of regional anesthesia in children.

The last section of this syllabus is a brief "how to" for various common peripheral and central blocks in children, but this material will *not* be reviewed in the spoken lecture. It is placed here in this syllabus for your further reading and use.

Assuring Success - What Are the Requirements for Regional Anesthesia in Children?

Anticipation of the problems that commonly arise in performing regional anesthesia for children and formulating a plan for dealing with these problems will assure the success of the anesthesiologist in incorporating this important technique into his or her practice. These problems may be generic to any technique (patient selection, equipment issues, pharmacokinetic differences between children and adults, and problems unique to performing blocks on sedated or anesthetized subjects), or they may be specific to certain techniques (for example anatomical considerations, side effect management related to epidural opiate administration, etc.). The successful application of regional anesthesia techniques for children should be easily attainable in any hospital or outpatient surgery center setting with the following features in mind.

SKILL PERFORMING REGIONAL ANESTHETIC BLOCKS ON ADULTS. The child is not the appropriate subject for mastering regional block skills.

SUPPORTIVE SURGICAL COLLEAGUES. Without the support of your surgeons, who must tolerate somewhat longer induction times, and who will support your efforts when discussing the anticipated procedure with parents, regional anesthesia becomes a contentious issue.

ASSISTANCE IN THE OPERATING ROOM. Depending upon your patient's airway, your degree of skill and comfort with the pediatric airway, and the nature of the background general anesthetic, you may need skilled assistance administering and monitoring your patient's general anesthetic while you perform the regional block. This is easily accomplished in the teaching hospital setting, or in practices in which CRNA's and anesthesiologists start cases as a team, but is less easily accomplished (but not impossible!) in settings in which anesthesiologists practice alone.

PROPER EQUIPMENT. Most adult block kits and needles are not appropriate for children. Several manufacturers are now marketing regional block kits and needles specifically designed for the pediatric patient. The most important feature is to have needles that are short; the gauge of the needle need not be reduced for pediatric applications.

NURSING POLICIES AND PROCEDURES. Many PACU's still require the return of motor function before discharge, and/or require PACU stays of a certain minimum duration. Among the advantages of regional anesthesia in children is the ability to discharge from a Phase I PACU within 15-30 minutes, and to discharge home within one hour. We routinely move children out of the Phase I environment when awake regardless of the duration of time that has elapsed since administration of an anesthetic; indeed, with regional blocks in combination with propofol administration it is often feasible to bypass the Phase I PACU altogether! There need not be any requirement for voiding prior to discharge home. (Coad and Hain 1989; Fisher Q A. et al. 1993; Shyr M H. et al. 1990) We also routinely discharge children with residual motor and sensory blockade home (Burns et al. 1990; Coad and Hain 1989) in the care of parents or guardians provided that certain requirements have been met: (1) a qualitative judgment has been made about the capability of the parents to understand and follow instructions, (2) the acceptance of the parents of the additional responsibility associated with early discharge, and (3) discharge teaching regarding protection of weak and numb body parts.

Successful application of epidural analgesia in children requires the organization of a pain management service, appropriate nursing protocols and procedures, and the hospital support to provide electronic monitoring of children (e.g. pulse oximetry and perhaps ECG) at other than an ICU setting.

Assuring Success - What are the Differences between Children and Adults?

Recognition and recall of these 4 differences will assure successful regional blocks:

ANATOMY. Target nerves are smaller, closer to other (vascular) anatomic structures, and are closer to the skin. The ability to predict the depth at which the needle will encounter the epidural space, subarachnoid space, nerve sheath, etc., will greatly enhance one's success rate. This is discussed in more detail below. The caudal extent of the spinal cord and dural sac extends approximately two interspaces lower in the newborn and infant than in the older child and adult. Finally, the contents of the epidural space in the child are more gelatinous and less fibrous than in the adult, which both favors the spread of local anesthetics and allows the passage of epidural catheters to a greater distance in the space.

PHYSIOLOGY. Clinically significant changes in blood pressure related to neuraxial sympathectomy are quite unusual in children less than 8 years of age. This obviates the need for volume loading prior to performing subarachnoid or epidural blocks in young children. The reason for this blood pressure stability has not been defined, but may be related to the reduced resting sympathetic tone in children compared to adults, or a greater ability to compensate for a fall in SVR.

PHARMACOLOGY. Both pharmacokinetic changes (e.g. peak plasma levels of local anesthetics and metabolism of local anesthetics) and pharmacodynamic changes (e.g. dose-response relationship and toxicity) exist for children and adults and determine the safe maximum doses that may be administered.

Generally, the volume of distribution of local anesthetics is greater in children than adults, resulting in lower peak plasma levels. (Murat et al. 1988) This means that on a mg/kg basis, larger doses are tolerated in children and are associated with peak plasma levels well below the toxic threshold. Doses of bupivacaine of up to 3mg/kg, and lidocaine up to 10mg/kg are associated with peak plasma levels of less than 2μg/kg, which is well below the toxic plasma level. (Bruguerolle B. et al. 1990; Mobley K A. et al. 1991; Stow P J. et al. 1988)

However in newborn infants less than 6 months of age, serum protein binding of local anesthetics is approximately half of that of older children and adults, and hepatic metabolism is similarly depressed. (Stow P J. et al. 1988) This will result in both higher peak plasma levels and a greater free (unbound) fraction of local anesthetic in the blood, allowing toxicity to occur at lower blood levels than normal. The maximum dose of amide local anesthetics should therefore be reduced by 50% in this age group.

Table 1. Recommended Local Anesthetic Doses

Block	*Lidocaine 2%+ Tetracaine 0.1%*	*Bupivacaine 0.25%* *Levo-Bupivacaine, 0.25%* *Ropivacaine 0.2%*
Brachial Plexus	0.25 - 0.5 cc/kg	0.25 - 0.5 cc/kg
Femoral	0.25 - 0.5 cc/kg	0.25 - 0.5 cc/kg
Sciatic	0.25 - 0.5 cc/kg	0.25 - 0.5 cc/kg
Lumbar Epid		0.5 cc/kg
Caudal (to T10 level)		0.5 cc/kg
Caudal (to T6 level)		1.0 cc/kg
Penile Block		2cc
Ilio-inguinal		5cc

PSYCHOLOGY. As the reader begins to read this section, the thought probably running through the mind is that this is the most obvious and the least important section of this syllabus. "Of course children behave differently than adults." However, the truth is that it is the difference in behavior that give rise to the greatest controversies in pediatric regional anesthesia.

Because, as is self evident, rarely children will allow the performance of a regional block without deep sedation or general anesthesia, two problems are created: (1) the inability to recognize paresthesias, and (2) the effect of general anesthetic agents on the ability of a test dose to identify accidental intravascular injection of local anesthetic.

Several blocks do not require a paresthesia to identify location of the nerve (axillary block, femoral block, ilio-inguinal block, penile block, popliteal nerve block). Interscalene and sciatic nerve block do, however, (Dalens B. et al. 1990) and therefore require the use of a nerve stimulator. In the ambulatory surgery setting I therefore would not choose to use these blocks unless specifically indicated for the type of surgery performed (e.g. shoulder surgery).

An area of considerable controversy is the performance of blocks under general anesthesia, during which a paresthesia indicates something may have gone awry, but cannot be reported. Some experts in this field believe that the inability to recognize a paresthesia will increase a patient's risk of experiencing a nerve injury because the anesthesiologist will persist in the performance of the block absent a report of paresthesia. However, while conventional wisdom and experience suggest that nerve injury may be prevented by discontinuing a block in the presence of a paresthesia, it is far from certain that this is indeed the case. In fact, it might be cogently argued that the safety of regional techniques may in some ways be enhanced by general anesthesia, by virtue of providing a still subject who may be optimally positioned by assistants. Let us examine the evidence that the inability to elicit a paresthesia will increase the risk of regional anesthesia:

Paresthesias are an early warning before permanent neurologic injury occurs. Spinal nerve roots both within the epidural space and within the subarachnoid space are mobile (in the absence of scarring), and move away from an advancing needle. This probably accounts for the rarity of permanent neurologic disability in spite of the relatively common occurrence of paresthesia during the performance of epidural or subarachnoid anesthesia. However if it were not the case that nerves were mobile, contusion or laceration of a spinal nerve by an epidural needle would frequently result, producing both severe pain as well as permanent injury. Yet, neurologic injury is less common after regional anesthesia than after general anesthesia (Kroll et al. 1990).

Paresthesia or pain will alert the anesthesiologist that the subarachnoid space has been entered, and that the needle is encountering the spinal cord. The dura mater is usually punctured without producing sensation, as anesthesiologists frequently observe. The presence of CSF is generally the sign that alerts the anesthesiologist that the subarachnoid space has been entered, not sensation or paresthesia on the part of the patient. As is the case in the epidural space, subarachnoid spinal nerve roots would be expected to move away from an advancing needle unless tethered by scar formation, arachnoiditis, etc. Furthermore, the spinal cord is enveloped in the pia mater, which does not contain sensory nerve endings, nor are there sensory neurons within the spinal cord itself that would warn the anesthesiologist that intramedullary needle placement had occurred before the injection of air or local anesthetic was attempted. Evidence for this comes from neurosurgeons inducing spinal cord lesions or tractotomies for management of chronic pain, who report that no pain is induced in the awake patient when the advancing needle is inserted into the spinal cord, and that pain does not occur until a lesion is created by radiofrequency energy or freezing (Coffey 1992).

According to some, the standard of care dictates that all epidurals above the termination of the spinal cord are to be placed in awake patients. The standard of care in medicine is ultimately determined by the common practice of physicians, and safe, common sense. The readers of this should know that it has been an accepted practice and therefore the standard of care for many years amongst pediatric anesthesiologists to place caudal, lumbar and thoracic epidural catheters in anesthetized children, and this standard of care and the collective published and unpublished experience of our subspecialty withstands the rare singular report of a complication in an adult. While this controversy will continue to be debated by proponents of pediatric regional anesthesia and those who believe that regional nerve blocks must be performed on awake subjects, the considerable experience in pediatric anesthesia is that this practice is safe and beneficial to the patient (Krane et al. 1998).

The effect of halogenated inhalation agents on the development of tachycardia following intravascular injection of an epinephrine containing test dose is also controversial. Desparmet et al. (Desparmet et al. 1990) found that many false negative test doses occurred with children breathing 1 MAC halothane, while pretreatment with atropine improved the accuracy of the test dose but did not eliminate false negatives. Recently the effect on the accuracy of test dosing with epinephrine of inhalation of sevoflurane was studied. Tanaka, et al. (Tanaka and Nishikawa 1998) found that 1.0 MAC of sevoflurane in 60% N_2O did not reduce the ability to recognize an intravenous injection of lidocaine with epinephrine; the sensitivity of a threshold of 20 bpm increase in heart rate was 100%. The effects of isoflurane and desflurane are similar, (Tanaka et al. 1995; Tanaka et al. 1995) but the effects of intravenous anesthetics are untested. It seems prudent based upon Desparmet's and Tanaka's work to administer 10µg/kg of atropine prior to the test dose if children are anesthetized with halothane, and also to fractionate the total local anesthetic dose and to administer it over 2-3 minutes for all children administered local anesthetics while anesthetized with general anesthetics. Atropine may not be necessary during sevoflurane inhalation, but will improve the sensitivity of detecting an intravascular injection. The use of other markers of an intravascular injection, such as isoporoterenol, has been tested, but probably holds no value over epinephrine. (Desparmet et al. 1991; Tanaka 1996; Tanaka 1997; Tanaka and Nishikawa 1998)

Unlike some other experts in this field, I do not advocate abandoning the test dose because the majority of times it will indeed detect inadvertent intravascular injection even in the anesthetized child.

General Principles

Any and all blocks may be performed in children with the appropriate indication. The following describes the salient differences in performing blocks between children and adults–

- The targets are smaller and closer to other neurovascular structures. The caudal extent of the spinal cord and dural sac extend 2–3 interspaces lower in the infant than child/adult. The iliac crests are at the level of L4 spinous process.
- Neuraxial blocks rarely produce hypotension children <10 yrs, therefore crystalloid volume loading should not be performed.
- Peripheral nerve blocks provide longer lasting analgesia than central nerve blocks, and are associated with a lower rate of complications
- The maximum dose of amide local anesthetics is somewhat higher, but the block duration is somewhat shorter than in adults.
- However in infants <2 mo, the maximum amide l.a. dose should be reduced by 50% to compensate for decreased serum protein binding by plasma alpha-1-glycoprotein.
- Test doses are as important in children as adults, but the presence of general anesthesia decreases their sensitivity. For example, during halothane administration IV epinephrine may increase blood pressure and reduce heart rate, rather than produce a tachycardia during a test dose. Prior administration of atropine 0.01 mg/kg *increases the reliability* of test doses during halothane anesthesia. During inhalation of sevoflurane, however, the sensitivity of test dosing with 0.01 mg/kg of epinephrine is 100% using a 10 beat per minute increase in heart rate as the definition of a positive test dose. Atropine is not needed to achieve this sensitivity. There are no data regarding test dosing during enflurane, or desflurane inhalation.
- The total dose should be administered in fractions over a few minutes in case a false negative test dose has occurred.
- Blocks usually require a GA or deep sedation.
- Extremity blocks require up to 30 minutes to become established; perform the block ASAP after induction to allow time for the block to set up.
- Peripheral nerve blocks are amenable to catheter techniques to assure long lasting postoperative analgesia. An infusion of 0.25% bupivacaine or levo-bupivacaine, or 0.2% ropivacaine, at 0.1 ml/kg/hr is an appropriate rate.

Using a Nerve Stimulator:

- Not all nerve stimulator are appropriate for needle use. The drug company give-aways are USUALLY NOT. Only nerve stimulators with digital amperage readout capable of delivering 0.2–2mA of current are safe to use.
- It is not necessary to use insulated needles, but it is better to use them if they are available.
- The negative (anode) terminal from the stimulator is attached to the needle (remember: "N to N").
- The positive terminal is attached to an ECG patch near the block site.
- The needle is positioned near the nerve while an assistant observes for muscle contractions in the distal extremity. You are close enough to the nerve when:
- Contractions are recognized with <0.7mA current, or when injection of 1cc of local anesthetic ablates the contraction.

Table 2. Common Surgical Procedures and Appropriate Regional Nerve Blocks

Procedure	Appropriate Block	Comment
ORIF elbow	Brachial plexus	Provides needed vasodilatation when there is vascular compromise from the fracture. Makes postoperative evaluation of neurological function and integrity of ulnar/median nerves impossible.
Syndactyly repair	Brachial plexus	Axillary approach provides more successful distal block
Pectus repair; Anterior Spine Fusion	Thoracic epidural	The thoracic epidural space may be cannulated directly or by threading a caudal catheter proximally.
Thoracotomy; Correction of coarctation or PDA	Thoracic epidural Paravertebral block	See above
Abdominal surgery	Lumbar epidural	The lumbar epidural space may be cannulated directly or by threading a caudal catheter proximally.
Gastrostomy	Rectus sheath block Paravertebral block	
Appendectomy	Rectus sheath block Paravertebral block	
Herniorrhaphy, hydrocelectomy, orchiopexy	Caudal block Paravertebral block Ilioinguinal block Rectus sheath block	Shortest duration postoperative analgesia after caudal block; Ilioinguinal block may distort surgical tissues in infants and smaller children
Hip arthroplasty/osteotomy	Lumbar epidural	
Femoral osteotomy; femoral fracture repair	Lumbar epidural Paravertebral block Femoral nerve block Fascia iliaca block	
Arthroscopic knee surgery	Fascia iliaca block	
Tibial osteotomy	Lumbar epidural Caudal block Sciatic+femoral block Popliteal+saphenous block	Compartment syndrome is a significant risk after tibial fractures or surgery; complete anesthesia of the foreleg will obscure pain as a symptom of a compartment syndrome, and necessitates frequent and excellent nursing observation to assure circulation to the foot distal to the cast.
Ankle arthroplasty Club foot repair	Caudal block Sciatic+femoral block Popliteal+saphenous block	

COMMON BLOCKS PERFORMED IN CHILDREN

NEURAXIAL BLOCKS

Caudal Block:

A. Indications: Surgery below diaphragms
B. Contraindications:
   1. Sacral deformities
   2. Perianal surgery
   3. Same day surgery in patients >6 years, 30kg, etc.
   4. Bacteremia
C. Equipment:
   1. Single shot: Appropriate needle
      a. 23G butterfly (orange)
      b. 20-22G angiocath
   2. Catheter:
      a. 20G epidural catheter
      b. 18G angiocath
      c. Sterile towels
D. Technique: With patient in decubitus or semi prone position with knees drawn toward chest, palpate the posterior superior iliac spines, and visualize an equilateral triangle with the posterior superior iliac spines as the upper two corners.

Figure 1. *Surface landmarks for the caudal block.*

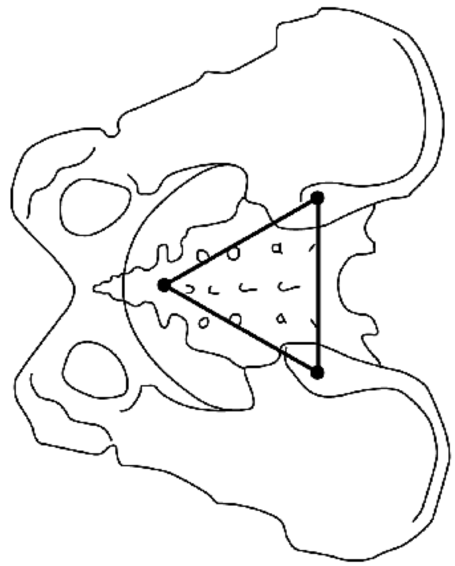

Figure 2. *The boney structures underlying the surface landmarks of the caudal block.*

The lower apex of the triangle identifies the sacral ligament between the sacral cornua. The most common mistake is to insert the needle too caudad, in the region of the coccyx; the space is usually more cephalalad than you think. *Note at the right how the correct entry point is well above the intergluteal folds.* Insert the needle at 45° to the skin in the midline. A distance "give" or "pop" will be felt as the needle passes the sacral ligament into the caudal space.

Figure 3. *Threading a caudal catheter.*

Advance only 1–2mm further and then either pass the catheter or inject the drug after an appropriate test dose. A catheter may be passed into the thoracic epidural space in small children, if the catheter meets no resistance whatsoever during insertion. The following is a video of this technique

E. Drug Selection/Dose:
  1. T10 level: Bupivacaine 0.25%, ± epinephrine, 0.25 cc/kg
     L-bupivacaine 0.25%, ± epinephrine, 0.25 cc/kg
     Ropicacaine 0.2%, 0.25 cc/kg
     Lidocaine, 0.25cc/kg
  2. T6 level: as above, 1–1.2 cc/kg
  3. Maximum dose: Bupivacaine 3 mg/kg, Lidocaine 10 mg/kg
  4. Analgesics: See Epidural (Lumbar and Thoracic) below.

Epidural (Lumbar and Thoracic)

A. Indications: Surgery below clavicles.
B. Contraindications: Spine deformity, bacteremia; inexperience of the anesthesiologist
C. Equipment: Pediatric epidural tray–
  1. 18G 5cm Tuohy needle.
  2. 20G epidural catheter
D. Technique:

Position patient in lateral decubitus position with knees to chest. Sterile prep and drape. Tuohy needle with glass syringe containing 3cc N.S. is inserted in interspace.

The lumbar space is usually encountered at 2.2–2.5 cm, accurately predicted by the formula:

$$EpiduralSpaceDepth(mm) \approx 18 + 1.5 \times age(yrs)$$

The depth of the thoracic space cannot be easily predicted because it depends upon the approach (paramedian vs. midline) and the needle's angle of entry. Generally in the midline with an entry angle of about 45 degrees, it will be 0.5-1 cm shallower than the equation above predicts for the lumbar space.

Be aware the softer more elastic tissues of the back may give you a false LOR before the ligamentum flavum is pierced, and the more saline you inject into the soft tissues of the back the harder it is to do the block. After the space is identified the catheter is passed an appropriate length.

E. Drug Selection/Dose:
  1. Lumbar: Bupivacaine 0.25%, ± epinephrine, 0.5 cc/kg
     L-bupivacaine 0.25%, ± epinephrine, 0.5 cc/kg
     Ropicacaine 0.2%, 0.25 cc/kg1.5%
     Lidocaine, 0.5cc/kg
  2. Thoracic: same solutions, 0.3 cc/kg
  3. Maximum dose: Bupivacaine 3 mg/kg, Lidocaine 10 mg/kg
  4. Analgesics:
     a. Preservative free morphine: 30-50 µg/kg
     b. Hydromorphone 5-10 µg/kg
     c. Fentanyl 0.25-0.5 µg/kg
     d. Clonidine 0.5-1 µg/kg
     e. Ketamine 0.3 mg/kg

Paravertebral Block:

A. Indications: To provide unilateral local anesthesia following trauma or surgery of the chest, flank, or abdomen, between the C6 and L1 dermatomes..

B. Contraindications: Spine deformity(relative contraindication), bacteremia (for placement of a catheter), etc.

C. Equipment: 2.5 - 5.0 cm block or Tuohy needle. Epidural catheter if desired.

D. Technique: With the patient in the lateral decubitus position, with the block side uppermost, the spinous processes of the desired dermatomal levels are marked with a skin marker. Needle insertion is performed 1.5cm (for infants) - 2.5cm (for adolescents) lateral to the midline of the spinous process, level with the superior aspect of the spinous process. The needle is advanced until the transverse process is encountered, then it is withdrawn to the skin. It is then reinserted in a cephalad direction so that it walks off the transverse process superiorly. As the paravertebral space is entered, there is usually a loss of resistance to needle advancement, and at that point saline or local anesthetic may be injected without resistence. If resistence to injection is encountered, the needle tip lies within a ligament and must be advanced another 2-3mm.

   Local anesthetic, 2-4ml, is injected at each spinal level. If a continuous catheter technique is employed, the same technique above is used, inserting the Tuohy needle at the center of the dermatomes that should be anesthetized, and injecting a total of 0.25-0.5ml/kg at one site. A continuous infusion of 0.1ml/kg/hr may then be delivered through the catheter.

E. Drug Selection:
   Rapid onset + long duration: Mixture of 2% lidocaine + 0.5 % bupivacaine/levobupivacaine
   Continuous infusion: 1% lidocaine or 0.25% bupivacaine/levobupivacaine

F. Complications:
   Pneumothorax (excessive needle advancement)
   Epidural anesthesia
   Subarachnoid block

Subarachnoid (spinal) Block:

A. Indications: Generally only performed in ex-preemies undergoing herniorrhaphy, circumcision, etc., in whom general anesthesia and/or sedatives are to be avoided, and yet muscle relaxation is needed.

B. Contraindications: Spine deformity, bacteremia, etc.

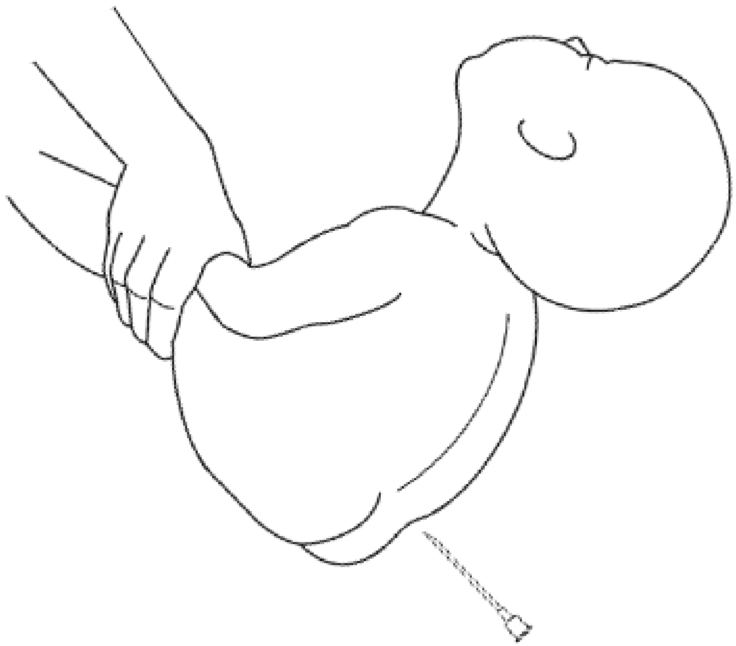

Figure 4. *With the patient held in the lateral decubitus position, or sitting bent over, the appropriate interspace is selected (L4/5 or L3/4). Note at right how the neck is not held in flexion so that airway occlusion does not occur.*

C. Equipment: Pedi spinal tray with 3cm 26G needle.

D. Technique: A local skin wheal with bicarbonated lidocaine is injected. After the infant settles down, the spinal needle is slowly advanced in the interspace until CSF returns freely.

While one might not expect CSF to flow freely from a 25G needle, the

Figure 5. *25G spinal needle showing free flow of CSF.*

the short length of the needle allows this to happen (Figure 5).

The desired dose is quickly injected and the needle is withdrawn. Do not allow the scrub nurse to elevate the feet to place the grounding pad on the back. After performing the block, place an IV in the foot, measure blood pressures in the leg.

Restrain the limbs with soft restraints. Give the infant a pacifier dipped in sugar water from the coffee lounge.

E. Drug Selection/Dose: Tetracaine with epi, 0.5–1 mg/kg.
Mix crystalline tetracaine with sterile water to a concentration of 1%, then dilute with an equal volume of D10W to a concentration of 0.5% (5mg/cc). The dose to be administered will need to be drawn up in a TB syringe. When injecting, administer an extra 0.1–0.2cc to compensate for needle dead space.

UPPER EXTREMITY BLOCKS

Brachial Plexus Blocks:

We see many patients having hand surgery for repair of congenital deformities, finger reimplantation, burn treatment, etc. Blocks of the upper extremity provide excellent postoperative analgesia, protect delicate repairs from patient movement, and in the case of vascular repairs, reduce arterial spasm.

Axillary Approach (At level of trunks; blocks C5–T1)

A. Indications: Surgery on the hand and arm.
B. Contraindications: Generally, injuries or surgery that carry a significant risk of neurovascular injury and neuropraxia should not be managed with nerve blocks in order to facilitate a complete peripheral nerve examination by the surgeon following surgery. In that way, a discovered nerve injury may be returned to the operating room for early repair. Typical examples of this in pediatrics are supracondylar and condylar fractures of the elbow, which are often associated with ulnar nerve injuries.

Figure 6. *Surface anatomy of the axilla of a child, with the brachial plexus indicated. Note the nerve sheath does not run through the midline of the diamond described by the triceps/biceps/and pectoralis muscles, but rather runs anterior to that plane.*

C. Equipment: A nerve stimulator capable of delivering currents <1 mA may be used. Butterfly needles (23G-orange and 25G-red) are suitable block needles, or a 1.5" 25G spinal needle or (insulated) beaded block needle with a T-piece attached. 20cc syringe. Sterile towels.

D. Technique: There are two techniques that work best in my experience. Without a nerve stimulator: Pin the axillary artery against the humerus with your nondominant hand; the needle is inserted through a skin wheal over the axillary artery, directing the needle tip just inferiorly to the axillary pulse (inferior trunk® ulnar nerve). When the sheath is entered (slight "give" on the needle) half of the dose is injected. The needle is then withdrawn to just under the skin and is redirected just superior to the pulse, and the remainder of the dose is injected (superior trunk® median/musculocutaneous nerves). In the second technique, the nerve bundles are identified by nerve stimultor, and 1/2 of the dose is injected at each nerve. When the output of the stimulator is ~0.5–0.7mA the needle tip is near enough to reliably anesthetize the target. If in either technique the artery is accidentally punctured, continue to advance the needle through the artery while continuously aspirating. When blood can no longer be withdrawn, inject half the dose. Then withdraw the needle while aspirating, and again when aspiration is negative above the artery, inject the remaining dose. Maintain pressure on the artery for 2 minutes to prevent hematoma formation.

To ablate all tourniquet pain you must also anesthetize the intercostobrachial nerve which runs subcutaneouly in the axilla. Reserve 3-5cc of l.a. solution used for your block, and inject it subcut. 2-5cm caudally from your previous needle entry site over the axillary pulse.

E. Drug Selection/Dose:

For long duration:
Bupivacaine 0.25%, ± epinephrine, 0.25 - 0.5cc/kg
L-bupivacaine 0.25%, ± epinephrine, 0.25 - 0.5cc/kg
Ropicacaine 0.2%

For fast onset and medium duration:
Lidocaine 2% + crystalline tetracaine 5mg/10cc lidocaine ± epinephrine, 0.25 - 0.5cc/kg.

Interscalene Approach (At level of roots; blocks C4–T1, especially C4–C7)

A. Indications: Surgery on the shoulderand upper extremity.
B. Contraindications: See axillary approach.
C. Equipment: See axillary approach. A nerve stimulator must be used.
D. Technique: Turn head slightly to the opposite side, with the neck in slight extension. Identify landmarks: cricoid cartilage, lateral border of SCM muscle, groove between scalene muscles just posterior to the SCM border.
E. Insert needle over interscalene groove at level of cricoid (C6), keeping needle perpendicular to skin at all planes. If bone is encountered redirect laterally. When hand contraction is seen with 0.5–0.6mA of stimulating current, confirm negative aspiration and inject a test dose, then the remainder of the dose. Injection at too shallow a depth will produce a Horner's syndrome and phrenic nerve anesthesia. Needle entry too cephalad in direction can enter intervertebral foramen and produce spinal block, hypotension, etc.
F. Phrenic nerve block, recurrent laryngeal nerve block, and/or Horner's syndrome are common.
G. Drug Selection/Dose: See axillary approach.

Dalens Method (At level of roots; blocks C4–T1, especially C4–C7)

A. Indications: Surgery on the shoulder and upper extremity.
B. Contraindications: See axillary approach.
C. Equipment: See axillary approach. A nerve stimulator must be used.
D. Technique: Turn head *slightly* to the opposite side, with a rolled towel under the shoulders. Identify landmarks: cricoid cartilage, lateral border of SCM muscle, Chassagnac's tubercle (at level of cricoid at lateral border of SCM).
E. Draw line from midclavicle to Chassagnac's tubercle. Trisect the line.
F. Insert needle at junction of lower and middle third of line, with needle perpindicular to the bed directed due posteriorly, using a nerve stiumulator to identify the roots of the brachial plexus.
G. Phrenic nerve block, recurrent laryngeal nerve block, and/or Horner's syndrome are common.
H. Drug Selection/Dose: See axillary approach.

Supraclavicular Approach:

Usually not used in children because of the higher rise of the cupola of the lung and the greater subsequent risk of pneumothorax.

LOWER EXTREMITY BLOCKS:

The major advantages of selective lower extremity blocks over lumbar or caudal epidural blocks are their increased duration of effect (10–12hr vs. 2-4hr), and the fact that patients will still be able to weight bear on at least one leg after the block, which facilitates their transfer in and out of bed, in and out of the family car, etc. Therefore, these blocks may be safely performed on outpatients, while neuraxial blocks should probably not be performed on outpatients who are not babes in arms, and whom the parents cannot easily carry in and out of the car, home, etc. Furthermore, many children over 5 or 6 years of age are distressed by the numbness and paralysis following neuraxial blocks in spite of best efforts to prepare them for this sensation preoperatively.

Femoral Nerve Block (L2–L4):

A. Indications: Anterior branch: surgery of anterior-lateral thigh, femur fractures, quadriceps muscle biopsy, etc; posterior branch gives rise to saphenous nerve: surgery on the medial part of lower leg, and medial aspect of ankle. Note the medial knee is innervated by the obturator nerve.

B. Contraindications: Local adenopathy or skin sepsis.

C. Equipment: A nerve stimulator capable of delivering currents <1 mA may be used. Butterfly needles (23G-orange and 25G-red) are suitable block needles, or a 2.5" 25G spinal needle or (insulated) beaded block needle with a T-piece attached. 20cc syringe. Sterile towels.

D. Technique: The femoral arterial pulse is identified below the inguinal ligament, and the needle is inserted just lateral to the pulse. If a nerve stimulator is used, the needle is positioned to obtain quadriceps contractures at ~0.5–0.6mA. If not, the needle should be close enough to the artery to pulsate when disconnected from a syringe. 75% of the dose is injected at the approximate depth of the arterial pulse and while moving the needle from that point to the subcutaneous tissues. One-fourth of the dose is reserved for a subcutaneous fan injection from a point 1cm medial and inferior from the anterior superior iliac spine in order to anesthetize the lateral femoral cutaneous nerve.

E. Drug Selection/Dose:
   1. For long duration:
      Bupivacaine 0.25%, ± epinephrine, 0.5cc/kg
      L-bupivacaine 0.25%, ± epinephrine, 0.5cc/kg
      Ropicacaine 0.2%
   2. For fast onset and medium duration:
      Lidocaine 2% + crystalline tetracaine 5mg/10cc lidocaine ± epinephrine, 0.5cc/kg.

Fascia Iliaca Block (An alternative to a femoral nerve block; L2–L4):

A. Indications: See femoral nerve block. This block anesthetizes the obturator nerve, lateral femoral cutaneous nerve, and femoral nerve with one single injection (see Anesth Analg 1989;69:705-13 for original description of this block).

B. Contraindications: Local adenopathy or skin sepsis.

C. Equipment: 2.5" 25G spinal needle or block needle with a T-piece attached. 20cc syringe. Sterile towels.

D. Technique: The inguinal ligament is mentally trisected in its length from the pubis to the anterior superior iliac spine, and the needle is inserted

0.5–1cm below the juncture of the middle and lateral thirds of the ligament, directing the needle 90° to the skin. A fascial plane will be punctured and a loss of resistance to injection will occur as the needle crosses the fascia latta, then the needle is further advanced until a second LOR occurs as the fascia iliaca is pierced; then, while exerting pressure just caudal to the needle site, the dose is injected. The needle is withdrawn, and the groin "massaged" to encourage further proximal spread of l.a

Figure 7. *Surface anatomy of the groin of a child, with the landmarks for the fascia iliaca block illustrated.*

E. Drug Selection/Dose:
  1. For long duration:
     Bupivacaine 0.25%, ± epinephrine, 0.5cc/kg
     L-bupivacaine 0.25%, ± epinephrine, 0.5cc/kg
     Ropicacaine 0.2%
  2. For fast onset and medium duration:
     Lidocaine 2% + crystalline tetracaine 5mg/10cc + epinephrine, 0.7cc/kg
  3. 1:1 mixture of 0.5% bupivacaine+1% lidocaine, 0.7 cc/kg
  4. If combined with a sciatic block, keep total bupivacaine dose to <3.2mg/kg by using 1/4–3/8% bupivacaine for each block

Sciatic Nerve Block (L4–S3):

A. Indications: Surgery of lateral side of lower leg, tibia/fibula, lateral aspect of ankle, and entire foot. In addition to the territory covered by the popliteal fossa block, a conventional sciatic nerve block anesthetizes the posterior aspect of the thigh.
B. Contraindications: Local skin sepsis.
C. Equipment: A nerve stimulator capable of delivering currents <1 mA should be used. 3.5" 25G spinal needle or insulated block needle with a T-piece attached. 20cc syringe. Sterile towels.
D. Technique: The patient is placed in the lateral decubitus position with the operative extremity on top, leg slightly flexed at hip and knee. A line is drawn from the posterior superior iliac spine (PSIS) to the greater

$$Depth(mm) \approx Weight(kg) + 5/Age(yr)$$

trochanter of the femur; flex the hip so the axis of the femur lines up with this line. From the midpoint of this line draw a second perpendicular line caudally 3 cm in length. Insert the block needle at the end of the second line perpendicular to the skin until it contacts bone (ischial spine), then walk the needle off the bone toward the PSIS. Position the needle tip to achieve maximum contraction of a muscle while stimulating with 0.5–0.6mA. The anticipated depth of the sciatic nerve may be predicted from the following formula in children of average weight (compensate for the overweight or slight child appropriately):

E. Drug Selection/Dose:

a. For long duration:
   Bupivacaine 0.25%, ± epinephrine, 0.5cc/kg
   L-bupivacaine 0.25%, ± epinephrine, 0.5cc/kg
   Ropicacaine 0.2%

b. For fast onset and medium duration:
   Lidocaine 2% + crystalline tetracaine 5mg/10cc lidocaine ± epinephrine, 0.5cc/kg.

c. If combined with a femoral block/fascia iliaca block, keep total bupivacaine dose to <3.2mg/kg by using 3/8% bupivacaine for each block.

Popliteal Nerve Block (Sciatic Nerve behind the knee, L4–S3):

A. Indications: Surgery of lateral side of lower leg, tibia/fibula, lateral aspect of ankle, and entire foot.

B. Contraindications: Local skin sepsis.

C. Equipment: A nerve stimulator capable of delivering currents <1 mA may be used. 2.5" 25G spinal needle or (insulated) beaded block needle with a T-piece attached. 20cc syringe. Sterile towels.

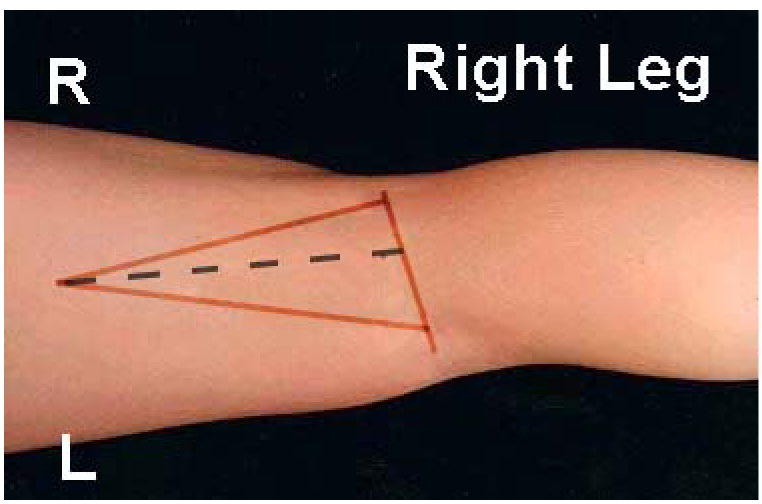

Figure 8. *The popliteal fossa block anatomy. The popliteal nerve runs slightly lateral to the middle of the triangle defined by the popliteal crease and the two edges of the biceps femoris muscles (hamstrings).*

D. Technique: With the patient in the decubitus or prone position, and the knee straight, the bifurcation of the biceps femoris muscle, the "hamstrings" is identified. This forms the apex of the popliteal fossa. The arterial pulse is identified, if possible, in the fossa. The popliteal nerve lies in a fat filled space lateral to the arterial pulsation. The local anesthetic may be blindly injected lateral to the pulse, or a nerve stimulator may be used to identify the nerve more accurately. Either way the block will be effective, because there are no septations or sheaths in the space.

E. Drug Selection/Dose:
   1. For long duration:
      Bupivacaine 0.25%, ± epinephrine, 0.5cc/kg
      L-bupivacaine 0.25%, ± epinephrine, 0.5cc/kg
      Ropicacaine 0.2%
   2. For fast onset and medium duration:
      Lidocaine 2% + crystalline tetracaine 5mg/10cc lidocaine ± epinephrine, 0.5cc/kg.
   3. If combined with a sciatic block, keep total bupivacaine dose to <3.2mg/kg by using 3/8% bupivacaine for each block.

Saphenous Nerve Block:

A. Indications: Surgery of the medial calf or medial ankle.

B. Contraindications: local skin sepsis.

C. Equipment: syringe and needle.

D. The saphenous nerve is a branch of the femoral nerve, and is a pure sensory nerve, therefore a nerve stimulator is not used. It ennervates the medial calf and medial ankle.

E. The saphenous nerve lies under the sartorius muscle, which runs from the anterior superior crest of the ilium to the medial condyle of the femur.

F. It may be blocked in 3 ways:
   1. At the level of the medial condyle, enter the sartorius muscle using a local anesthetic filled syringe and a 23 gauge needle, pushing gently on the plunger of the syringe. After the needle exits the muscle, there will be a subtle loss of resistance to injection. The anesthetic is then deposited in this space after negative aspiration.
   2. Draw a line from the tibial tubercle to medially to the medial calf. Inject a band of subcutaneous local anesthetic underneath this line.
   3. At the medial border of the sartorius muscle, half-way along its length, a nerve stimulator needle is introduced in a posterior direction. Here the nerve runs with the vastus medialus nerve that ennervates the quadriceps muscle. When muscle twitches are seen with a stimulating current of <0.5 mA, inject the local anesthetic.
   4. Technique #1 has the greatest success rate.

G. Drug Selection/Dose:
   1. For long duration:
      Bupivacaine 0.25%, ± epinephrine, 0.25cc/kg
      L-bupivacaine 0.25%, ± epinephrine, 0.25cc/kg
      Ropicacaine 0.2%, 0.25cc/kg
   2. For fast onset and medium duration:
      Lidocaine 2% + crystalline tetracaine 5mg/10cc lidocaine ± epinephrine, 0.25cc/kg.

3. If combined with a sciatic block, keep total bupivacaine dose to <3.2mg/kg by using 3/8% bupivacaine for each block.

PERIPHERAL NERVE BLOCKS OF THE TRUNK:

Ilio-Inguinal/Ilio-Hypogastric Nerve Block:

A. Indications: Inguinal herniorrhaphy, hyrdrocelectomy, orchidopexy. They do not provide anesthesia of the peritoneum, therefore a deep anesthetic plane is required until peritoneal manipulation by the surgeon is complete and wound closure has begun.

B. Contraindications:
   1. Local skin sepsis
   2. Should not be used preoperatively in small infants (e.g. <6 months) preoperatively because of distortion of nearby surgical tissues.

C. Equipment:
   1. Single shot: Appropriate needle
      a. 25G butterfly (red)
      b. 25-27G needle

D. Technique:
   1. Identify the anterior superior iliac prominence
   2. Insert a 23 - 27G needle 1cm medial to the prominence, aiming toward the wing of the ilium at a 45º angle.
   3. 2 very subtle "pops" will be felt as the aponeuroses of the external and internal oblique muscles is punctured. Inject after the second pop.
   4. If these are not appreciated, contact the ilium with the needle, withdraw 2mm, and inject.
   5. Remove the needle, and reinsert in the same site, injecting a "fan" subcutaneously in a 45º arc directed toward the inguinal ligamen

E. Drug Selection/Dose:
   1. Bupivacaine 0.25%, ± epinephrine, 2-5 cc
   2. L-bupivacaine 0.25%, ± epinephrine
   3. Ropicacaine 0.2%

Rectus Sheath Nerve Block

A. Indications: Inguinal herniorrhaphy, hyrdrocelectomy, orchidopexy. Bilateral for ventral herniorrhaphy and umbilical herniorrhaphy. This does not provide anesthesia of the peritoneum, therefore a deep anesthetic plane is required until peritoneal manipulation by the surgeon is complete and wound closure has begun.

B. Contraindications: Local skin sepsis

C. Equipment:
   1. Single shot: Appropriate needle
      a. 25G butterfly (red)
      b. 25-27G needle

D. Technique:
   1. Identify the lateral margin of the rectus sheath.
   2. Insert a 23 - 27G needle 1cm at the level of the umbilicus at a 45º angle toward the midline, using loss of resistance technique to identify when the needle has penetrated the rectus sheath.

   3. A very subtle "pop" will be felt. Inject the local anesthetic after negative aspiration.

E. Drug Selection/Dose:

   1. Bupivacaine 0.25%, 2-5 cc
   2. L-bupivacaine 0.25%,
   3. Ropicacaine 0.2%

References

1. Bazin, J. E., B. Dalens, et al.: [Continuous epidural anesthesia in children under 1 year of age]. Agressologie 31: 37-8, 1990
2. Benlabed M, Ecoffey C, Levron JC, Flaisler B, Gross JB: Analgesia and ventilatory response to CO2 following epidural sufentanil in children. Anesthesiology 67:948-951, 1987
3. Berde C: Epidural analgesia in children [editorial; comment]. Can J Anaesth 41:555-560, 1994
4. Bhatt Mehta V, Rosen DA: Management of acute pain in children. Clin Pharm 10:667-685, 1991
5. Bloch EC: Update on anesthesia management for infants and children. Surg Clin North Am 72:1207-1221, 1992
6. Bolte RG, Stevens PM, Scott SM, Schunk JE: Mini-dose Bier block intravenous regional anesthesia in the emergency department treatment of pediatric upper-extremity injuries. J Pediatr Orthop 14:534-537, 1994
7. Bosenberg AT: Caudal epidural morphine in children--a need for caution! [letter]. S Afr Med J 83:367,1993
8. Bouaziz: Saphenous nerve block. Reg Anesth 21:490- , 1996
9. Broennle AM, Cohen DE: Pediatric anesthesia and sedation. Curr Opin Pediatr 5:310-314, 1993
10. Burns AM, Shelly MP, Dewar AK: Caudal analgesia for pediatric day case surgery: assessment of motor function prior to discharge. J Clin Anesth 2:27-30, 1990
11. Campbell FA, Yentis SM, Fear DW, Bissonnette B: Analgesic efficacy and safety of a caudal bupivacaine-fentanyl mixture in children [published erratum appears in Can J Anaesth 1993 Mar;40(3):288]. Can J Anaesth 39:661-664, 1992
12. Chauvet P, Lefeuvre M, Chemla C, Guyot E, Guillet H, Rendoing J: [Caudal block in the surgical repair of vesico-renal reflux] Interet de l'anesthesie caudale dans la cure chirurgicale du reflux vesico-renal. Agressologie 31:32-33, 1990
13. Colizza WA, Said E: Intravenous regional anesthesia in the treatment of forearm and wrist fractures and dislocations in children. Can J Surg 36:225-228, 1993
14. Courreges. Rectus sheath block. Paediatr Anaesth 7: 211-214, 1997.
15. Dalens BJ, Khandwala RS, Tanguy A: Staged segmental scoliosis surgery during regional anesthesia in high risk patients: a report of six cases. Anesth Analg 76:434-439, 1993
16. Dalens, B.: Regional anesthesia in children. Anesth Analg 68: 654-72, 1989
17. Dalens, B.: [The value of peripheral blocks in pediatric anesthesia]. Cah Anesthesiol 38: 547-59, 1990
18. Dalens, B.: [Acute pain in children and its treatment]. Ann Fr Anesth Reanim 10: 38-61, 1991
19. Dalens, B.: [Lower limb blocks in children]. Cah Anesthesiol 41: 635-41, 1993
20. Dalens, B.: [Diprivan and locoregional anesthesia in children over 3 years of age]. Ann Fr Anesth Reanim 13: 625-9, 1994
21. Dalens, B.: [Peripheral nerve block of the limbs in children]. Cah Anesthesiol 43: 291-7, 1995
22. Dalens, B., J. E. Bazin, et al.: Epidural bubbles as a cause of incomplete analgesia during epidural anesthesia. Anesth Analg 66: 679-83, 1987

23. Dalens, B. and J. P. Haberer: Epidural anesthesia in children [letter]. Anesthesiology 66: 714-6, 1987

24. Dalens, B. and A. Hasnaoui: Caudal anesthesia in pediatric surgery: success rate and adverse effects in 750 consecutive patients. Anesth Analg 68: 83-9, 1989

25. Dalens, B. and O. Mansoor: [Practical methods of using propofol as a complement to loco-regional anesthesia in children]. Cah Anesthesiol 41: 245-9, 1993

26. Dalens, B. and A. Tanguy: Intrathecal morphine for spinal fusion in children. Spine 13: 494-8, 1988

27. Dalens, B., A. Tanguy, et al.: Lumbar epidural anesthesia for operative and postoperative pain relief in infants and young children. Anesth Analg 65: 1069-73, 1986

28. Dalens, B., A. Tanguy, et al.: Lumbar plexus block in children: a comparison of two procedures in 50 patients. Anesth Analg 67: 750-8, 1988

29. Dalens, B., A. Tanguy, et al.: Lumbar plexus blocks and lumbar plexus nerve blocks [letter; comment]. Anesth Analg 69: 852-4, 1989

30. Dalens, B., A. Tanguy, et al.: Sciatic nerve blocks in children: comparison of the posterior, anterior, and lateral approaches in 180 pediatric patients. Anesth Analg 70: 131-7, 1990

31. Dalens, B., G. Vanneuville, et al.: Penile block via the subpubic space in 100 children. Anesth Analg 69: 41-5, 1989

32. Dalens, B., G. Vanneuville, et al.: A new parascalene approach to the brachial plexus in children: comparison with the supraclavicular approach. Anesth Analg 66: 1264-71, 1987

33. Dalens, B., G. Vanneuville, et al.: Comparison of the fascia iliaca compartment block with the 3-in-1 block in children [published erratum appears in Anesth Analg 1990 Apr;70(4):474] [see comments]. Anesth Analg 69: 705-13, 1989

34. Dalens, B. J., R. S. Khandwala, et al.: Staged segmental scoliosis surgery during regional anesthesia in high risk patients: a report of six cases. Anesth.Analg. 76: 434-439, 1993

35. Davis PJ, Cook DR: Clinical pharmacokinetics of the newer intravenous anaesthetic agents. Clin Pharmacokinet 11:18-35, 1986

36. Davis PJ, Stiller RL, Cook DR, Brandom BW, Davin Robinson KA: Pharmacokinetics of sufentanil in adolescent patients with chronic renal failure. Anesth Analg 67:268-271, 1988

37. Ecoffey C. Cah Anesthesiol 40:533-536, 1992

38. Ferguson, Rectus sheath block. Paediatr Anaesth 6:463-466, 1996.

39. Gaignon I, Veyckemans F, Gribomont BF: Latex allergy in a child: report of a case. Acta Anaesthesiol Belg 42:219-223, 1991

40. Gamble JG: Intravenous regional anesthesia: a safe and cost-effective outpatient anesthetic for upper extremity fracture treatment in children [letter; comment]. J Pediatr Orthop 12:675-676, 1992

41. Garc'ia Pedrajas F., Monedero P: Rev Esp Anestesiol Reanim 40:217-229, 1993

42. Giaufre E, Bruguerolle B, Morrison-Lacombe G, Rousset-Rouviere B: The influence of midazolam on the plasma concentrations of bupivacaine and lidocaine after caudal injection of a mixture of the local anesthetics in children. Acta Anaesthesiol Scand 34:44-46, 1990

43. Glenski JA, Friesen RH, Lane GA, Young S, Glascock J: Low-dose sufentanil as a supplement to halothane/N2O anaesthesia in infants and children. Can J Anaesth 35:379-384, 1988

44. Greeley WJ, de Bruijn NP, Davis DP: Sufentanil pharmacokinetics in pediatric cardiovascular patients. Anesth Analg 66:1067-1072, 1987

45. Guay J, Gaudreault P, Tang A, Goulet B, Varin F: Pharmacokinetics of sufentanil in normal children. Can J Anaesth 39:14-20, 1992

46. Guinard JP, Borboen M: Probable venous air embolism during caudal anesthesia in a child [see comments]. Anesth Analg 76:1134-1135, 1993

47. Gunter J B., Forestner JE, Manley CB: Caudal epidural anesthesia reduces blood loss during hypospadias repair. J Urol 144:517-9; discussion 530, 1990

48. Gunter JB, Dunn CM, Bennie JB, Pentecost DL, Bower RJ, Ternberg JL: Optimum concentration of bupivacaine for combined caudal--general anesthesia in children. Anesthesiology 75:57-61, 1991

49. Gunter JB, Eng C: Thoracic epidural anesthesia via the caudal approach in children. Anesthesiology 76:935-938, 1992

50. Gwinnutt C: Day surgery. Practitioner 235:738, 740, 7421991

51. Haberkern C M., Tyler DC, Krane EJ: Postoperative pain management in children. Mt Sinai J Med 58:247-256, 1991

52. Haberkern CM, Tyler DC, Krane EJ: Postoperative pain management in children. Mt Sinai J Med 58:247-256, 1991

53. Haung L H., Hseu SS, Liu K, Tsai SK, Tseng KF, Huang GM, Lee TY: Sacroepidural analgesia for post-operative pain relief in children. Ma Tsui Hsueh Tsa Chi 28:157-162, 1990

54. Henneberg S W., Hole P, Madsen de Haas I, Jensen PJ: Epidural morphine for postoperative pain relief in children. Acta Anaesthesiol Scand 37:664-667, 1993

55. Holland R, Anderson B, Watson T, McCall E: Introduction of continuous regional techniques for postoperative paediatrics patients: one years' experience from two hospitals. N Z Med J 107:80-82, 1994

56. Jamali S, Monin S, Begon C, Dubousset AM, Ecoffey C: Clonidine in pediatric caudal anesthesia. Anesth Analg 78:663-666, 1994

57. Jean G, Cortambert F, Roy P, Foussat C, Moussa M, Dodat H, Bertrix L, Giaufre E, Rastello C: [Gastroesophageal reflux with combined caudal and halothane anesthesia in children] Reflux gastrooesophagien sous anesthesie caudale et halothane au masque chez l'enfant [Ten years' locoregional anesthesia in children in a private hospital] Dix ans d'anesthesie loco-regionale chez l'enfant dans un hopital prive. Cah Anesthesiol 40:177-181, 1992

58. Jones RD, Gunawardene WM, Yeung CK: A comparison of lignocaine 2% with adrenaline 1:200,000 and lignocaine 2% with adrenaline 1:200,000 plus fentanyl as agents for caudal anaesthesia in children undergoing circumcision. Anaesth Intensive Care 18:194-199, 1990

59. Juliano PJ, Mazur JM, Cummings RJ, McCluskey WP: Low-dose lidocaine intravenous regional anesthesia for forearm fractures in children. J Pediatr Orthop 12:633-635, 1992

60. Krane E J. Delayed respiratory depression in a child after caudal epidural morphine. Anesth Analg 67:79-82, 1988

61. Krane E J., Tyler DC, Jacobson LE: The dose response of caudal morphine in children. Anesthesiology 71:48-52, 1989

62. Krane EJ: Delayed respiratory depression in a child after caudal epidural morphine. Anesth Analg 67:79-82, 1988

63. Krane, E.J., Dalens, B.J., Murat, I. and Murrell, D., The safety of epidurals placed during general anesthesia, Reg Anesth Pain Med, 23 (1998) 433-438.

64. Kumar T P., Jacob R: A comparison of caudal epidural bupivacaine with adrenaline and bupivacaine with adrenaline and pethidine for operative and postoperative analgesia in infants and children. Anaesth Intensive Care 21:424-428, 1993

65. Lafferty PM, Gordon NH, Winning TJ: A comparison of postoperative pain relief techniques in orchidopexy. Ann R Coll Surg Engl 72:7-8, 1990

66. Londergan TA, Hochman HI, Goldberger N: Postoperative pain following outpatient pediatric urologic surgery: a comparison of anesthetic techniques. Urology 44:572-576, 1994

67. Lonnqvist PA: Continuous paravertebral block in children. Initial experience [see comments]. Anaesthesia 47:607-609, 1992

68. Mazoit J X., Denson DD, Samii K: Pharmacokinetics of bupivacaine following caudal anesthesia in infants. Anesthesiology 68:387-391, 1988

69. McCloskey J J., Haun SE, Deshpande JK: Bupivacaine toxicity secondary to continuous caudal epidural infusion in children. Anesth Analg 75:287-290, 1992

70. McCloskey JJ, Haun SE, Deshpande JK: Bupivacaine toxicity secondary to continuous caudal epidural infusion in children [see comments]. Anesth Analg 75:287-290, 1992

71. Meignier M, Ganansia MF, Lejus C, Testa S: [Intrathecal morphine therapy in children with cancer]. Cah Anesthesiol 40:487-490, 1992

72. Meistelman C, Benhamou D, Barre J, Levron JC, Mahe V, Mazoit X, Ecoffey C: Effects of age on plasma protein binding of sufentanil. Anesthesiology 72:470-473, 1990

73. Mevorach D L., Perkins FM, Isaacson SA: Bupivacaine toxicity secondary to continuous caudal epidural infusion in children. Anesth Analg 77:1305-1306, 1993

74. Moine P, Ecoffey C: [Caudal block in children: analgesia and respiratory effect of the combination bupivacaine-fentanyl] Bloc caudal chez l'enfant: analgesie et effets respiratoires de l'association bupivacaine-fentanyl. Ann Fr Anesth Reanim 11:141-144, 1992

75. Murat I., Montay G, Delleur MM, Esteve C, Saint Maurice C: Bupivacaine pharmacokinetics during epidural anaesthesia in children. Eur J Anaesthesiol 5:113-120, 1988

76. Murat I., Walker J, Esteve C, Nahoul K, Saint Maurice C: Effect of lumbar epidural anaesthesia on plasma cortisol levels in children. Can J Anaesth 35:20-24, 1988

77. Nicholson C, Ridolfo E: Avoiding the pitfalls of epidural anesthesia in obstetrics. AANA J 57:220-230, 1989

78. Payne KA, Hendrix MR, Wade WJ: Caudal bupivacaine for postoperative analgesia in pediatric lower limb surgery. J Pediatr Surg 28:155-157, 1993

79. Pietropaoli J A Jr., Keller MS, Smail DF, Abajian JC, Kreutz JM, Vane DW: Regional anesthesia in pediatric surgery: complications and postoperative comfort level in 174 children. J Pediatr Surg 28:560-564, 1993

80. Pullerits J, Holzman RS: Pediatric neuraxial blockade [published erratum appears in J Clin Anesth 1993 Nov-Dec;5(6):529]. J Clin Anesth 5:342-354, 1993

81. Pullerits J, Holzman RS: Pediatric neuraxial blockade. J Clin Anesth 5:342-354, 1993

82. Ready L B., Loper KA, Nessly M, Wild L: Postoperative epidural morphine is safe on surgical wards. Anesthesiology 75:452-456, 1991

83. Rice LJ, Pudimat MA, Hannallah RS: Timing of caudal block placement in relation to surgery does not affect duration of postoperative analgesia in paediatric ambulatory patients. Can J Anaesth 37:429-431, 1990

84. Rosen KR, Rosen DA: Caudal epidural morphine for control of pain following open heart surgery in children. Anesthesiology 70:418-421, 1989

85. Schryer NM: Epidural catheters: pain management in the child. Dimens Crit Care Nurs 8:347-355, 1989

86. Schulte-Steinberg O: [The use of regional blocks in children] Uber den Einsatz von Leitungsblockaden bei Kindern. Anaesthesiol Reanim 15:43-54, 1990

87. Schumann EH, Hoffmann R: [Plexus anesthesia done by the surgeon] Die Plexusanaesthesie in der Hand des Chirurgen. Chirurg 63:131-133, 1992

88. Serlin S: Single-dose caudal epidural morphine in children: safe, effective, and easy. J Clin Anesth 3:386-390, 1991

89. Sethna NF, Berde CB: Pediatric regional anesthesia equipment. Int Anesthesiol Clin 30:163-176, 1992

90. Sparkes ML, Klein AS, Duhaime AC, Mickle JP: Use of epidural morphine for control of postoperative pain in selective dorsal rhizotomy for spasticity. Pediatr Neurosci 15:229-232, 1989

91. Stow P J., Scott A, Phillips A, White JB: Plasma bupivacaine concentrations during caudal analgesia and ilioinguinal-iliohypogastric nerve block in children. Anaesthesia 43:650-653, 1988

92. Tanaka M, Suto K, Nishimoto C, Nishikawa T. Simulation of an epidural test dose with intravenous epinephrine in sevoflurane-anesthetized children, submitted for publication and personal communication from Dr. Tanaka.

93. Tanaka, M. and Nishikawa, T., Simulation of an epidural test dose with intravenous epinephrine in sevoflurane-anesthetized children, Anesthesia and Analgesia, 86 (1998) 952-7.

94. Tanaka, M. and Nishikawa, T., The combination of epinephrine and isoproterenol as a simulated epidural test dose in isoflurane-anesthetized adults, Anesthesia and Analgesia, 86 (1998) 1312-7.

95. Tanaka, M., Epidural test dose: isoproterenol is a reliable marker for intravascular injection in anesthetized adults, Anesthesia and Analgesia, 82 (1996) 1056-9.

96. Tanaka, M., Simulation of an epidural test dose with intravenous isoproterenol in isoflurane-anesthetized adults, Anesthesia and Analgesia, 85 (1997) 639-43.

97. Tanaka, M., Takahashi, S., Kondo, T. and Matsumiya, N., Efficacy of simulated epidural test doses in adult patients anesthetized with isoflurane: a dose-response study [see comments], Anesthesia and Analgesia, 81 (1995) 987-92..

98. Tobias J D., Deshpande JK, Wetzel RC, Facker J, Maxwell LG, Solca M: Postoperative analgesia. Use of intrathecal morphine in children. Clin Pediatr Phila 29:44-48, 1990

99. Tobias J D., Lowe S, O'Dell N, Holcomb GW, III: Thoracic epidural anaesthesia in infants and children. Can J Anaesth 40:879-882, 1993

100. Tobias J D., Oakes L, Austin BA: Pediatric analgesia with epidural fentanyl citrate administered by nursing staff. South Med J 85:384-387, 1992

101. Tobias J D., Oakes L, Rao B: Continuous epidural anesthesia for postoperative analgesia in the pediatric oncology patient. Am J Pediatr Hematol Oncol 14:216-221, 1992

102. Tobias JD, Rasmussen GE: Pain management and sedation in the pediatric intensive care unit. Pediatr Clin North Am 41:1269-1292, 1994

103. Tyler D C., Krane EJ: Epidural opioids in children. J Pediatr Surg 24:469-473, 1989

104. Wolf AR, Hughes D, Wade A, Mather SJ, Prys-Roberts C: Postoperative analgesia after paediatric orchidopexy: evaluation of a bupivacaine-morphine mixture. Br J Anaesth 64:430-435, 1990