Pediatric Pain Management

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- Ultrasound and pediatric

Regional anesthesia has become an integral part of adult anesthesia. Although regional anesthesia is not routinely used in children because of the need for general anesthesia that is necessary to keep the patients from moving and cooperating with the operator, it has been gaining immense popularity in the last decade. Adjuvant pain medications, including opioids and nonsteroidal analgesics, have been used for managing pain postoperatively. In addition, there is always the fear of damaging nerves when regional anesthesia is performed in a child who is asleep and not able to physically respond to the needle placed intraneurally. Although there is not much objective evidence, both large prospective databases and expert opinion have demonstrated the ability to continue to perform regional anesthesia in the asleep child safely because major neural damage has not been reported in children.[1,2] A large database is currently maintained in North America (Pediatric Regional Anesthesia Network) that may shed light into the benefits, adverse effects, and feasibility of regional anesthesia in children (Santhanam Suresh, MD, personal communication, 2011). The use of ultrasonography and its introduction to the practice of regional anesthesia in children has markedly improved the application of regional anesthesia to routine pediatric anesthesia care. Methodical detailed systematic reviews of ultrasound-guided regional techniques are available for practitioners to apply to their routine practice.[3,4] The use of regional anesthesia and its application to every day practice has spawned because of data available to demonstrate decreased morbidity in children and better outcomes.[5] Teaching and providing hands-on dedicated pediatric regional anesthesia workshops at national meetings, including the American Society of Anesthesiology, the American Society for Regional Anesthesia and Pain

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Medicine (ASRA), and the Society for Pediatric Anesthesia (SPA), and the International Anesthesia Research Society (IARS) have provided platforms for gaining knowledge and dialogue amongst practitioners to increase their application of regional anesthesia in neonates, infants, children, and adolescents. This review discusses a comprehensive approach to acute pain management in infants, children, and adolescents.

ASSESSMENT OF PAIN

Infants, toddlers, and younger children are unable or unwilling to verbalize or quantify pain like adults. Because of these cognitive or maturational differences, several developmentally appropriate pain assessment scales have been designed for use in either infants or children. These scales can be subdivided into validated self-report, behavioral, and/or physiologic measures. Children at approximately 8 to 10 years of age may be able to use the standard adult numeric rating or visual analog scale to self-report their pain. Specialized self-reporting scales such as the Bieri FACES scale[6] are available for children and can be used in patients as young as 3 to 4 years. Behavioral or physiologic measures are available for younger ages and for developmentally disabled children (**Table 1**). The FLACC (Face, Legs, Activity, Cry, Consolability) scale is one such behavioral scale that is widely used, easy to use, and validated.[7] The scale has also subsequently been revised (FLACC-R) for use in children with cognitive impairment.[8]

THE ACUTE PAIN SERVICE

Hospital-based acute pain services have been established to coordinate and provide pain management in children and have become increasingly common over the past 2 decades. Although the structure of such services varies, in the United States these are largely organized and run by anesthesiology departments, often staffed by pediatric anesthesiologists, anesthesia fellows and residents, and/or pain nurse practitioners. With the success and proliferation of such services, they have expanded to cover painful nonsurgical conditions such as sickle cell disease and pediatric malignancies.

Table 1
FLACC behavioral pain scale

Categories	Scoring 0	Scoring 1	Scoring 2
Face	No expression or smile	Occasional grimace or frown, withdrawn and disinterested	Frequent constant frown, clenched jaw, quivering chin
Legs	Normal position or relaxed	Uneasy, restless, and tense	Kicking or legs drawn up
Activity	Lying quietly, normal position, moves easily	Squirming, shifting back and forth, tense	Arched, rigid, or jerking
Cry	No cry (awake or asleep)	Moans or whimpers, occasional complaint	Crying steadily, screams or sobs, frequent complaints
Consolability	Content, relaxed	Reassured by occasional touching, hugging, being talked to, distractible	Difficult to console or comfort

Data from Merkel S, Voepel-Lewis T, Malviya S. Pain assessment in infants and young children: the FLACC scale. Am J Nurs 2002;102(10):55–8.

Most recently, there has been a focus on ensuring the continuity of pain management outside the hospital for the increasing number of children undergoing outpatient surgery.

PATIENT-CONTROLLED ANALGESIA

Intravenous patient-controlled analgesia (PCA) is commonly and effectively used in children,[9] with more than 2 decades of accumulated published experience, research, and clinical studies to guide therapy. Alternative pro re nata (p.r.n.) or as-needed dosing potentially leads to cycles of pain interspersed with excessive sedation or other opioid-related side effects from the pro re nata rescue dosing. Indeed, PCA has been safely and effectively used in children as young as 5 to 6 years, with reports of "medically sophisticated" children as young as 2 years successfully using PCA. Compared with pro re nata intramuscular opioids, PCA has been shown to be safe in children and to provide more effective analgesia with greater patient satisfaction.[10] Morphine is the more frequently used and studied PCA opioid of choice. Hydromorphone and fentanyl are commonly used alternatives (**Table 2**). A continuous (aka background or basal) infusion is sometimes added for patients after major surgery to optimize analgesia. Opioid-related side effects are minimized with the use of lower-dose (eg, 0.01–0.02 mg/kg/h morphine) continuous infusions and are routinely used at our institution.[11]

The concept of PCA has been expanded to allow parent- or nurse-assisted analgesia in select cases in which the patient is unwilling or unable, because of age, developmental delay, or physical disability, to activate the PCA button. Although more commonly used in infants and children with cancer treatment–related pain, such as oral mucositis with bone marrow transplantation, it has been safely used for postoperative analgesia as well. Parent- or nurse-assisted initiation of PCA boluses has been safely used in patients younger than 1 year, with opioid-related side effects similar to those observed in older patients.[12] Respiratory depression occurred rarely but emphasizes the need for close monitoring and rescue protocols.

EPIDURAL ANALGESIA

There are several differences in the performance of epidural analgesia in children versus adults. Often overlooked but deserving of brief mention is the issue of patient assent.[13] Assent is defined as a "child's affirmative agreement (preference) to participate" (National Committee for Protection of Human Subjects, 1977). Although there is no specific age mandate or cutoff at which a child's assent must be obtained, 10 to 12

Table 2 PCA parameters[a]			
Choice of Opioid	**Morphine**	**Hydromorphone**	**Fentanyl**
Loading Dose (Over 1–5 min)	0.05–0.20 mg/kg	1–4 μg/kg	0.5–2.0 μg/kg
Demand Dose	0.01–0.02 mg/kg	2–3 μg/kg	0.2–0.4 μg/kg
Lockout Time (min)	5–15	5–15	5–15
1-h Limit (Optional)	0.10–0.20 mg/kg	30–40 μg/kg	3–4 μg/kg
Continuous Infusion (Optional)	0.01–0.02 mg/kg/h	2–3 μg/kg/h	0.2–0.4 μg/kg/h

[a] Dose ranges are approximate; selection of opioid and actual parameters depend on assessment of individual patient.

Data from Birmingham PK. Recent advances in acute pain management. Curr Probl Pediatr 1995;25:99–112.

years of age is used in most research protocols,[14] and the same practice can be applied toward the child undergoing epidural needle and/or catheter placement. In obtaining parental consent or patient assent, physician surveys indicate a tendency to routinely discuss common minor risks and rarely discuss severe major risks,[15] yet parent surveys indicate that 74% to 87% of parents want to know all the risks for their child, including the risk of death.[16] A recent prospective national pediatric epidural audit of more than 10,000 epidurals revealed an incidence of 1:2000 for serious complications, with an incidence of 1:10,000 for persisting sequelae at 12 months. No deaths or cardiac arrests were reported. More recently, a similar risk level was reported with opioids via PCA, nurse-controlled analgesia, and continuous opioid infusions.[17]

Another issue is whether an epidural is better administered in the awake versus anesthetized child. The practice of inserting epidural catheters in the awake adult patient is often not applicable to children, in whom sedation or general anesthesia is necessary to allow safe performance of regional anesthesia. It is accepted practice and has been the standard of care for many years to place epidurals in anesthetized children.[18] Recent practice advisory guidelines by the ASRA state, "The benefit of ensuring a cooperative and immobile infant or child may outweigh the risk of performing neuraxial regional anesthesia in pediatric patients undergoing general anesthesia or heavy sedation."[2]

Although chlorhexidine has been shown in children to reduce epidural catheter and insertion site colonization rates in comparison with povidone iodine, it is not approved for use in infants younger than 2 months because of concerns about skin irritation and/or absorption.[19]

In addition to differences in the termination of the spinal cord and dura mater in infants versus adults, the intercristal line surface landmark, connecting the posterior superior iliac spines, crosses the lumbar spine lower in infants, at the L5-S1 level versus the L3-L4 interspace in adults. Also, the depth of the epidural space from the lumbar skin varies more in children than in adults. Different formulas have been developed using body weight to calculate the distance (D) from the skin to the lumbar epidural space:

$$D \text{ (mm)} = (\text{weight in kg} + 10)\, 0.8$$

For example, in a 20-kg child the D would be calculated as follows: $(20 + 10)\, 0.8 = (30)\, 0.8 = 24$ mm $= 2.4$ cm distance to the epidural space. An alternative simpler approximation is D (mm) = 1 mm/kg body weight. So in the 20-kg child D would be 20 mm or 2 cm.[20] Because of the shorter distance relative to adults, a shorter epidural needle length is desirable and commercially available for use in children.

In infants and children up to approximately 5 years of age, it is possible to make use of the excellent caudal landmarks that are below the level of spinal cord termination to successfully thread catheters from the caudal epidural space to lumbar and lower thoracic levels[21,22] with the goal of placing the catheter tip close to the dermatomes desired for blockade. Catheter tip location can be verified by fluoroscopy with use of contrast media, electromyography, electrocardiography, or more recently ultrasonography.[23,24]

Before injection of a local anesthetic solution, the needle or catheter is inspected for passive blood or cerebrospinal fluid (CSF) return and then aspirated for blood or CSF. Because a negative aspirate may not guarantee correct needle or catheter position, an epidural test dose is given using local anesthetic and an intravascular marker such as epinephrine in a concentration of 1:200,000 (5 μg/mL) (**Box 1**).[25]

Box 1
Epidural test dosing

- Local anesthetic, 0.1 mL/kg (maximum of 3 mL), with 1:200,000 epinephrine
- Observation period of 60 seconds for any of the following 3 markers
  - Heart rate increased by 10 beats per minute or more
  - Systolic blood pressure increased by 10% or more
  - T wave amplitude increased by 25% or more
- Repeat procedure if equivocal

CAUDAL BLOCKS

Caudal block is the most widely used pediatric regional technique for postoperative analgesia as a single-injection technique. Its popularity stems in part from the readily palpable landmarks and relative ease of caudal block insertion in infants and children compared with adults. Dosing formulae have been developed using age, weight, and number of spinal segments to be blocked. Weight is a better correlate in predicting spread and is more commonly used. Volumes of 0.5 to 1.0 mL/kg achieve blockade from L1 to T6 dermatomes, respectively.[26] Bupivacaine is the most commonly used local anesthetic, usually in a concentration of 0.125%. Duration of analgesia with bupivacaine, ropivacaine, and levobupivacaine is on average 4 to 6 hours. Clonidine is the most commonly used additive[27]; doses of 1 to 2 μg/kg of clonidine may enhance analgesia by 2 to 3 hours. Maximum initial dosing and approximate durations for commonly used local anesthetics is listed in **Table 3**.

ADVERSE EFFECTS

Neurotoxicity such as seizures from a local anesthetic bolus or subsequent infusion can be treated with barbiturates, benzodiazepines, or propofol, although seizure activity can be masked under general anesthesia. Recent evidence indicates that the most successful treatment of local anesthetic cardiotoxicity is the use of lipid emulsion, which is now considered the first-line therapy.[28] Epinephrine in doses exceeding 10 μg/kg may actually impair lipid resuscitation (**Box 2**). A recent pediatric case report described successful resuscitation from ropivacaine/lidocaine-induced ventricular arrhythmias after posterior lumbar plexus block in a child.[29] There is a growing consensus that lipid emulsion be immediately available in cases in which regional anesthesia is administered.

Table 3
Local anesthetic solution: suggested maximum initial dosing

Local Anesthetic Solution	Maximum Dose (mg/kg)	Duration of Action (h)
Bupivacaine	2.5	3–6
Ropivacaine	3	2–4
Levobupivacaine	3	2–4
Lidocaine	7	1.5–2.5
Chloroprocaine	20	1.0–1.5

> **Box 2**
> **Treatment of local anesthetic toxicity**
>
> - Administer 1 mL/kg of 20% lipid emulsion over 1 minute
> - Repeat dose every 3 to 5 minutes to a maximum of 3 mL/kg
> - Maintenance infusion of 0.25 mL/kg/min under circulation restored
> - Propofol (10% lipid) is not a substitute

Epidural Analgesia

Continuous epidural infusions via an indwelling catheter are used for extensive lower extremity orthopedic surgery, major abdominal procedures, and chest wall surgeries including thoracotomies.

Local anesthetic and additive solutions similar to those in adults are used in infants and children (**Table 4**). Lower infusion rates are generally recommended in neonates and infants younger than 3 to 6 months because of decreased plasma protein binding and consequently higher free (unbound) fractions of drug and pharmacokinetic differences, potentially resulting in higher plasma levels and prolonged drug half-life. Additives such as clonidine[30] may have a wider index of safety than previously thought. Three patients aged 14 months to 5 years received 100 times the intended dose of clonidine in single-dose caudal blocks. Although somnolence was reported, no respiratory depression, desaturation, or hemodynamic instability resulted.[31]

Patient-Controlled Epidural Analgesia

The concept of PCA, well established with intravenous opioids, has been extended to epidural analgesia in children as well. Using parameters outlined in **Box 3**, patient-controlled epidural analgesia was used in 128 patients (132 procedures) as young as 5 years. Ninety percent of patients achieved satisfactory analgesia, with no patients requiring treatment of sedation or respiratory depression. More recently, the concept of parent/nurse-assisted epidural analgesia has been introduced to optimize dosing flexibility and pain relief given via the epidural route in patients unable to self-activate the demand dose button.[32] Results similar to the patient-controlled epidural

> **Table 4**
> **Suggested pediatric epidural dosing guidelines**
>
> | Drug | Infusion Solution | Infusion Limits |
> | --- | --- | --- |
> | Bupivacaine | 0.0625%–0.1% | ≤0.4–0.5 mg/kg/h |
> | Ropivacaine | 0.1%–0.2% | ≤0.4–0.5 mg/kg/h |
> | Fentanyl | 1–5 µg/mL | 0.5–2.0 µg/kg/h |
> | Morphine | 5–10 µg/mL | 1–5 µg/kg/h |
> | Hydromorphone | 2–5 µg/mL | 1.0–2.5 µg/kg/h |
> | Clonidine | 0.5–1.0 µg/mL | 0.1–0.5 µg/kg/h |
>
> These are approximate dose ranges. Actual dose selected depends on individual patient assessment. Infants younger than 3 to 6 months of age generally receive a 30% to 50% reduction in initial dosing and hourly infusion rates of local anesthetic or opioid.
> *Data from* Malviya S, Polaner DM, Berde C. Acute pain. Chapter 44. In: Cote CJ, Lerman J, Todres ID, editors. A practice of anesthesia for infants and children. 4th edition. Philadelphia: Saunders Elsevier; 2009.

Box 3
Patient-controlled epidural analgesia parameters

- Administering 0.1% bupivacaine with 2 to 5 μg/mL fentanyl

- Starting infusion rate of 0.1 to 0.2 m/kg/h (thoracic catheter maximum, 8–10 mL/h) (lumbar catheter maximum, 12–15 mL/h)

- Demand dose of 0.5 to 2.0 mL

- A lockout of 15 to 30 minutes

- Hourly maximum (continuous + demand) of 0.4 mg/kg/h or less

- For example: in a 20-kg patient: 4 mL/h + 1 mL every 30 minutes = 6 mL/h (8 mL/h maximum allowed)

Data from Birmingham PK, Wheeler M, Suresh S, et al. Patient-controlled epidural analgesia in children: can they do it? Anesth Analg 2003;96(3):686–91.

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analgesia group were obtained, with effective analgesia in 86% of patients and no patient requiring treatment of sedation or respiratory depression. The technique was used in patients as young as 5 months.

PERIPHERAL NERVE BLOCKS

Peripheral nerve blockade has been growing in use as a means of providing regional anesthesia in the pediatric population. These nerve blocks are able to provide both intraoperative and postoperative analgesia and have also been shown to reduce postoperative nausea and vomiting in children.[1] The use of traditional regional anesthesia techniques has been challenging in infants and children because of the need to target neural structures that run very close to vessels and other critical structures,[3] but the addition of nerve stimulators and ultrasound guidance to the anesthesiologist's toolkit has expanded the potential for safe and effective use of peripheral nerve blockade in pediatric pain management. The indications for several commonly performed peripheral nerve blocks as well as a summary of the associated anatomy and techniques used for successful blockade are discussed (**Table 5**).

Table 5
Peripheral nerve block: indications and dosing of bupivacaine 0.25%

Block	Indication	Dosing	Adverse Side Effects
Supraorbital	Craniotomy	1–2 mL	Rare
Infraorbital	Cleft lips	0.5–1 mL	Upper lip numbness, hematoma
Occipital	Craniotomy	1–2 mL	Rare
Superficial cervical plexus	Mastoid surgery	1–2 mL	Intravascular injection, hematoma
Brachial plexus	Upper extremity surgery	0.3 mL/kg	Intravascular injection
Femoral nerve block	Femoral fractures	0.3 mL/kg	Intravascular injection
Sciatic nerve	Foot surgery	0.3 mL/kg	Intravascular injection
Transversus abdominis plane block	Abdominal surgery	0.3 mL/kg per side	Rare
Ilioinguinal nerve	Hernia surgery	0.1 mL/kg	Rare
Rectus sheath	Umbilical hernia	0.1 mL/kg	Rare, hematoma

HEAD AND NECK NERVE BLOCKS

Head and neck nerve blocks are particularly useful for postoperative pain control in pediatric patients. Often, these blocks can be successfully completed using the landmark techniques outlined later.

Supraorbital Nerve

The supraorbital nerve is the first division of the trigeminal nerve as it exits the supraorbital foramen and supplies the forehead and the area anterior to the coronal suture. This block is indicated for surgery on the forehead, including craniotomy. We have used this block successfully for infants undergoing Ommaya placement without the use of general anesthesia.[33]

Technique
After sterile preparation, a 30-gauge needle is inserted at the level of the supraorbital foramen, which is usually located in the midpupillary line in the eyebrow. The local anesthetic solution is injected subcutaneously to provide analgesia for the forehead (**Fig. 1**).

Infraorbital Nerve

The second division of the trigeminal nerve exits the infraorbital foramen and supplies the maxillary area. This nerve is usually blocked to provide analgesia for sinus surgery[34] and cleft lip repairs.[35]

Technique
An intraoral approach to the infraorbital nerve is preferred in our institution. After eversion of the lip, a 27-gauge needle is inserted with the needle trajectory toward the infraorbital foramen; after aspiration, 0.5 mL to 2.0 mL is injected to provide analgesia for the upper lip and the maxilla (**Fig. 2**).

Occipital Nerve

The greater occipital nerve is derived off the C2 nerve root to supply the occipital portion of the scalp. This supply is used for managing patients with occipital neuralgia as well as in patients with transformed migraines.[36] This can also be used in patients with postoperative pain after posterior fossa craniotomies. The occipital nerve can be

Fig. 1. Supraorbital nerve block.

Fig. 2. Infraorbital nerve block.

identified in the posterior fossa below the nuchal line situated near the occipital artery. More recent findings for occipital nerve blocks with the use of ultrasonography can facilitate accurate placement of these blocks.[37]

Technique

After palpation of the occipital protuberance, the finger is slid down and the occipital artery palpated; the nerve is located medial to the artery caudad of the superior nuchal line and lateral to the artery superiorly. Alternatively, using ultrasound guidance, the C2 transverse process is located. The probe is then tilted cephalad and the obliquus capitis muscle identified. The greater occipital nerve is noted to be on top of the obliquus capitis muscle in this position. Local anesthetic is injected into the area of the nerve (**Fig. 3**).

Superficial Cervical Plexus

The superficial cervical plexus is derived off the cervical roots C3 and C4. The superficial cervical plexus wraps around the belly of the sternocleidomastoid and sends out 3 branches: the lesser occipital nerve, the great auricular nerve, and the transverse cervical and supraclavicular nerve. A blockade of the great auricular nerve can provide

Fig. 3. Occipital nerve block.

analgesia for the postauricular area and can facilitate postoperative pain control in children undergoing tympanomastoid surgery.[5]

Technique

After sterile preparation, the lateral border of the sternocleidomastoid is identified at the level of the cricoid cartilage (C6). A needle is placed, with the injection administered subcutaneously; injecting 2 mL of the local anesthetic solution can provide adequate analgesia for postoperative pain control (**Fig. 4**).

UPPER EXTREMITY BLOCKS

Peripheral nerve blockade can be useful in providing analgesia for both open and closed surgical procedures of the upper extremity in the pediatric population. Upper extremity blocks can be accomplished with a variety of approaches, including axillary, interscalene, supraclavicular, and infraclavicular. These blocks may be safer and more effective when using ultrasonography to visualize the pertinent anatomy during administration of the nerve block.[3]

Axillary Approach

The axillary approach is the most commonly performed brachial plexus block in children.[38] This technique is indicated for surgical procedures on the elbow, forearm, or hand because the axillary approach blocks the radial, median, and ulnar nerves. With the arm abducted and externally rotated, the probe is placed perpendicular to the axillary fold, and the branches of the brachial plexus can be seen surrounding the axillary artery, superficially between the biceps muscle and humerus. The musculocutaneous nerve can exit the axillary sheath proximal to the placement of this block; so if the biceps or forearm is involved in the surgical procedure, blocking the musculocutaneous nerve within the belly of the coracobrachialis is recommended in addition to blocking the axillary brachial plexus.[3]

Technique

The arm is abducted, a linear ultrasound probe is placed in the axilla, the nerves surrounding the axillary artery are identified, and the local anesthetic solution is injected to block each one of the individual branches, including the median, radial,

Fig. 4. Superficial cervical plexus.

ulnar, and musculocutaneous nerves. Care has to be taken to ensure that the needle is not placed in the artery.

Interscalene Approach

The interscalene approach is indicated for surgical procedures on the shoulder, upper arm, and elbow because the interscalene approach blocks the C5, C6, and C7 nerve roots between the anterior and middle scalene muscles.

Technique

A small footprint, high-frequency probe is placed at the posterolateral aspect of the sternocleidomastoid muscle in a transverse oblique plane at the level of the cricoid cartilage. The brachial plexus can be visualized as a hyperechoic structure in the interscalene groove posterior to the sternocleidomastoid muscle, and a needle can be advanced and local anesthetic delivered into the space surrounding the plexus for blockade.

Supraclavicular Approach

The supraclavicular approach is indicated for most surgical procedures of the upper extremity, including procedures of the upper arm and elbow, because this approach blocks the trunks and divisions of the brachial plexus as it courses just anterior and lateral to the first rib.

Technique

The probe is placed lateral and superior to the clavicle, in a coronal oblique plane, and the brachial plexus is visualized superior and lateral to the subclavian artery.[39] A needle is inserted lateral to the probe, advanced in plane, and directed medially to deliver local anesthetic. This can be performed using ultrasound guidance for postoperative pain control after checking the integrity of the nerves after upper extremity fracture reductions.[40]

Infraclavicular Approach

The infraclavicular approach is indicated for surgical procedures of the arm, elbow, and forearm because this approach blocks the cords of the brachial plexus as they course lateral, posterior, and medial to the axillary artery.[41]

Technique

A high-frequency probe is placed in a parasagittal plane immediately medial and inferior to the coracoid process, and the brachial plexus is seen as 3 cords surrounding the axillary artery. A needle is inserted inferomedially to the coracoid process with an in-plane approach, advanced through pectoralis major and minor, and aimed at the hyperechoic posterior cord of the brachial plexus.[39] After aspiration, the local anesthetic solution is injected and the spread of the local anesthetic is visualized. This block may be performed without the aid of neurostimulation in patients with fractures.

LOWER EXTREMITY BLOCKS

Regional anesthesia of the lower extremity can be achieved by peripheral nerve blockade of the lumbar plexus, femoral, or sciatic nerves. The lumbar plexus consists of lumbar nerves L1 through L4 and gives rise to the femoral nerve, the lateral femoral cutaneous nerve, and the obturator nerve, whereas the sciatic nerve is derived from the sacral plexus, which consists of the anterior rami of L4 through S3.

Lumbar Plexus

Blockade of the lumbar plexus is indicated for surgical procedures of the hip, pelvis, leg, or foot because this approach blocks the femoral, genitofemoral, lateral femoral cutaneous, and obturator nerves. A low-frequency probe is used to visualize the lumbar plexus because of its depth. The probe is placed on a longitudinal axis lateral to the spinous processes to visualize the transverse processes of L4 or L5. The probe is then rotated to the transverse axis, and the lumbar plexus is visualized within the psoas major muscle below the erector spinae and quadratus lumborum muscles.[42] The needle is advanced in plane, and the injected local anesthetic should be seen spreading within the posterior part of the psoas major.

Femoral Nerve

Femoral nerve blocks are indicated for surgical procedures on the anterior thigh and knee because this approach targets the nerve as it courses lateral to the femoral artery and blocks the areas of the lower extremity supplied by nerve roots L2, L3, and L4.

Technique
The ultrasound probe is placed parallel and inferior to the inguinal ligament, and the nerve is visualized lateral to the femoral artery.[43] The needle can then be advanced in or out of plane, and local anesthetic is injected while adequate spread is visualized.

Sciatic Nerve

The sciatic nerve block is indicated for surgical procedures of the leg, foot, and ankle, and anesthetic can be administered by either a subgluteal approach or a popliteal fossa approach. The subgluteal approach blocks the sciatic nerve proximal to its bifurcation into the common peroneal and tibial nerves.

Technique
A low-frequency curvilinear probe is used to ensure visualization at the depth of the sciatic nerve between the ischial tuberosity and the greater trochanter. A probe is placed transversely below the gluteal fold, and the sciatic nerve can be visualized in cross section deep to the gluteus maximus muscle.[43] The needle is inserted in plane, and the spread of local anesthetic solution is visualized.

The popliteal fossa approach blocks the sciatic nerve as it bifurcates to form the common peroneal and tibial nerves. A probe can be positioned transversely at the popliteal crease, and the anesthesiologist can visualize the common peroneal nerve lateral and the tibial nerve posterior to the popliteal vein and artery. The probe is then moved cephalad to visualize the point of bifurcation, and the sciatic nerve appears as a large round hyperechoic structure proximal to this point. The needle may be placed in or out of plane and local anesthetic injected under ultrasound guidance.

Truncal

Regional anesthestic techniques for peripheral nerve blockade of the anterior trunk are increasingly used to provide anesthesia during surgical procedures of the inguinal, umbilical, and epigastric regions.

Transversus abdominis plane
The transversus abdominis plane block is indicated for surgical procedures on the abdomen because the transversus abdominis plane is a potential space between the internal oblique and transversus abdominis muscle, which contains the thoraco-lumbar nerve roots T8 through L1.

Fig. 5. (*A*, *B*) Transversus abdominis plane (TAP) block. The arrows point out to the nerves.

Technique A high-frequency probe is placed on the abdomen lateral to the umbilicus, and the 3 layers of the abdominal wall are identified. A needle is inserted through the external and internal oblique muscles, into the plane between the internal oblique and transversus abdominis muscle.[44] Local anesthetic injection creates an elliptical opening of the potential space (**Fig. 5**).

Ilioinguinal

The ilioinguinal nerve block is indicated for surgical procedures in the lower abdomen and inguinal region, such as hernia repair and groin surgery, because the ilioinguinal and iliohypogastric nerves are the terminal branches of the L1 nerve root, which run through the transversus abdominis plane and supply the inguinal region.[45]

Technique A high-frequency probe is placed medial to the anterior superior iliac spine with the axis facing the umbilicus. A needle is inserted toward the ilioinguinal nerve as it runs between the transversus abdominis and internal oblique, and the anesthetic solution is injected under visualization (**Fig. 6**). More recently, the use of ilioinguinal nerve block in addition to the use of caudal blocks was examined in children undergoing groin surgery; it was demonstrated to be more useful in children undergoing inguinal hernia surgery than other groin procedures.[46]

Rectus sheath

The rectus sheath block is indicated for surgical procedures of the umbilicus and superficial abdomen because the space between the rectus abdominis muscle and
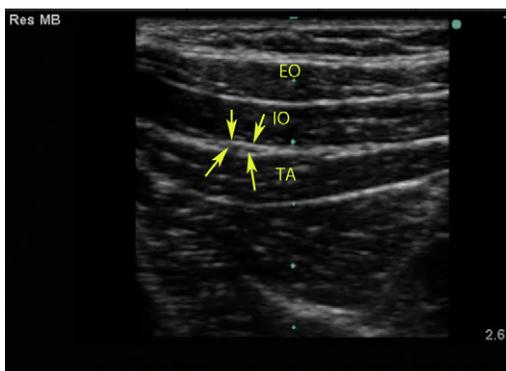

Fig. 6. Ilioinguinal nerve block. The arrows point out to the nerves. EO, external oblique; IO, internal oblique; TA, transversus abdominis.
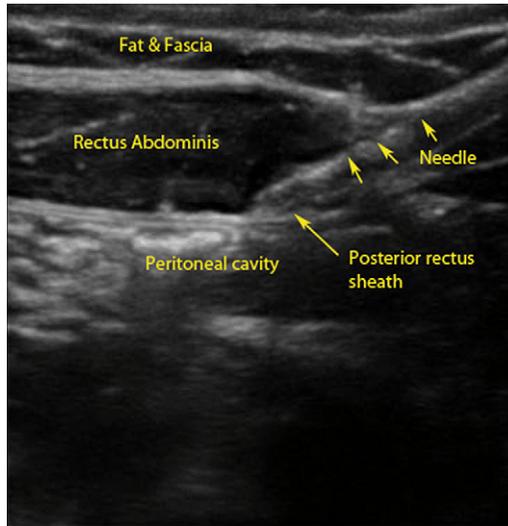
Fig. 7. Rectus sheath block. The arrows point out to the nerves.

the posterior rectus sheath contains the anterior abdominal branches of the intercostals nerves.

Technique A high-frequency probe is placed below the umbilicus and above the arcuate line.[47] The anterior and posterior walls of the rectus sheath are visualized superficial and deep to the rectus abdominis muscle. A needle is inserted through the muscle, and the anesthetic solution is injected into the potential space between the rectus abdominis and the posterior wall of the rectus sheath (**Fig. 7**). This is more useful for children undergoing single-incision laparoscopic procedures or for umbilical hernia repairs.[48]

CONTINUOUS NERVE BLOCK CATHETERS

Continuous nerve block catheters are used in children more frequently than ever before. The use of nerve catheters has decreased the need for hospitalization after major surgery and has decreased the incidence of morbidity, including postoperative nausea and vomiting.[49] Most common catheters used include upper and lower extremity catheters for either the brachial plexus or the femoral and sciatic nerves. Clear instructions should be provided for discharge, including the need for assistance during ambulation if a lower extremity catheter is used. Recently we have started using ilioinguinal nerve catheters for iliac bone grafts[50] as well as transverse abdominis plane block catheters for children who have spinal dysraphism who may not be candidates for epidural or spinal anesthesia.[51]

SUMMARY

Pediatric pain management has undergone some bold changes in the last 2 decades. The introduction of ultrasound guidance has clearly improved the ability to perform common blocks, particularly the use of truncal blocks that could not otherwise be performed in this group of patients without fear of visceral damage. Important work in this

area, including pharmacokinetic work, has to be performed to demonstrate adequate safety of these parameters in infants and children. Introduction of newer drugs, particularly analgesics, has been usually overlooked in children; however, a new Food and Drug Administration mandate allows for the study and use of these drugs that are commonly used in adults to be used in children, allowing the armamentarium to expand rapidly. The old adage that pain in children is a myth is now replaced with the new slogan that pain in children has to be addressed adequately as in the practice in adults. More clinical trials using a variety of algorithms for managing pain in infants and children and adolescents will become available in the next decade.

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