15 Regional Anesthetic Techniques for the Pediatric Patient

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Introduction

Since the original debate in the 1980s regarding the pros and cons of pediatric regional anesthesia [1, 2], safe and effective treatment of acute pain in children remains a high priority as clinical studies have shown pediatric patients experience pain from medical illnesses, during and following therapeutic and diagnostic procedures, and following trauma and surgery [3–11]. Although the safety profile of opiate administration in children has been established [12–17], elimination half-lives in newborns are longer with decreased metabolic clearances when compared to older children and adults [18, 19]. The optimal plasma concentrations for effective opiate analgesia are variable with careful titrations required to obtain effective analgesia while minimizing side effects [19–23].

Regional anesthesia has been shown to be beneficial when compared to general anesthesia. These benefits include reductions in morbidity and mortality [24–35], superior postoperative analgesia [36–43], and cost-effectiveness [39, 44–48]. There have been progressive developments in regional anesthetic techniques for the pediatric patient, since the original publications of the 1950s [49–52], but these techniques are still slow to be implemented due to concerns about neurologic complications, operator inexperience, and availability of proper equipment [53–58]. Many of these concerns were addressed in a sentinel article published in 1996, in a prospective study of greater than 24,000 pediatric blocks, in which 89% were performed under sedation or general anesthesia, with an incidence of 0.9/1000 complications and with no deaths nor long-term sequelae [33]. These findings were confirmed with subsequent studies [34, 35, 43, 59–63]. When properly performed, regional anesthesia is a safe, clinical practice with risk profiles similar to general anesthesia [34, 35, 43, 59–67].

Ultrasonography

All clinical techniques have an incidence of failure. Neurovascular anatomy is variable with subcutaneous electrical current stimulation techniques providing nerve localization with little to no information in proper placement of local anesthetics. Therefore, percutaneous techniques utilizing surface anatomy and projection, even in the best of hands, are fraught with failure [61, 68–70]. With the development of high-resolution portable ultrasound (US) analysis of anatomic

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A. D. Kaye et al. (eds.), *Essentials of Regional Anesthesia*,
https://doi.org/10.1007/978-3-319-74838-2_15

relationships and observed real time spread of administered local anesthetics have made this modality feasible in the conduct of pediatric regional anesthesia [71–75]. To develop skill sets in the use of US for regional anesthesia, one should attend an US-guided regional anesthesia course, begin with simple blocks, then progress to more complicated procedures as experience develops [68, 70, 76–79].

Local Anesthetic Blocks

The technical expertise required in delivering regional anesthesia is tempered with concerns about producing neurologic complications, availability of proper equipment, costs and time limitations as to why regional anesthetic techniques are not utilized in the pediatric population [56–58, 68, 70, 76–80]. In children, most regional techniques require general anesthesia to provide a safe procedural environment [34, 76, 81]. With regard to selection of local anesthetics, the delivery site and the metabolic maturity of the child are also important considerations [82–85]. The introductions of the newer local anesthetics, levobupivacaine and ropivacaine, have similar pharmacokinetic profiles when compared to racemic bupivacaine, and are reported to be less cardiac toxic [84, 86–88], and are shown to be beneficial in children [86, 89–91]. Although local anesthetic toxicity is rare in children, reports of seizures, transient neuropathic symptoms, dysrhythmias, and cardiovascular collapse have been reported [85, 86, 90–93].

Topical Analgesia

As with adults, topical anesthesia is used to anesthetize the skin by local infiltration before intravenous catheter insertion or other minor procedures [94–98]. Likewise, local anesthetic infiltration is also employed to provide postoperative analgesia for incisional pain. Dosing guidelines are comparable to those guidelines for adults [99–102].

Early studies from the 1950s employed mixtures of tetracaine, adrenalin (epinephrine), and cocaine (TAC) in pediatric patients for repair of minor skin lacerations in emergency departments [103–107]. In a large-scale pediatric series, this form of anesthesia resulted in quicker surgical repair times, markedly improved patient acceptance, with wound complication rates not significantly different when compared to lidocaine subcutaneous infiltration. Subsequent studies confirmed these findings [104, 105, 107].

A eutectic mixture of local anesthetics (EMLA) cream was developed in the 1980s that contains 2.5% lidocaine and 2.5% prilocaine [108]. This mixture results in an oil-water emulsification with a total local anesthetic concentration of 5% and has the ability to anesthetize intact skin to a depth of 5 mm [109, 110]. Recommended application is 45 min to 1 h before invasive procedures, with an occlusive dressing applied over the proposed procedural site. Because of EMLA's potential for systemic toxicity, the cream should not be in prolonged contact with mucous membranes or with traumatized skin [111–113]. Common uses include anesthesia for venipuncture, neonatal circumcision, lumbar punctures, vaccinations, biopsies, and laser ablation of port wine stains [85, 114–125].

Another local anesthetic cream with a shorter onset of action (~30 min), ELA-Max is also available and is composed of 4% liposomal lidocaine [126]. One study by Eichenfield and colleagues observed comparable efficacy between ELA-Max at 30 min and EMLA cream applied 60 min before the procedure [127]. ELA-Max may also decrease the incidence of methemoglobinemia as it does not contain prilocaine [85]. ELA-Max has been beneficial for intravenous cannulations and in office meatotomies [127–131].

Applications of local anesthetics to mucous membranes have been reported to decrease discomfort during nasotracheal intubation, nasogastric tube insertions, and bronchoscopy [132–136]. This application may be accomplished by a number of methods including direct spray, nebulization, or ointment or jelly application [137–140].

Regional Anesthetic Blocks

Head and Neck Blocks

Blockade of the great auricular nerve acts as an opioid sparing technique for tympanomastoidectomy and otoplasty, and in the treatments of moyamoya disease and postherpetic neuralgia [141–144]. The nerve arises from the superior cervical plexus (C_2, C_3) and provides sensory innervation to the lateral occipital region and medial auricle. The nerve ascends superficial to the posterior belly of the clavicular head of the sternocleidomastoid muscle (Fig. 15.1). Local anesthetic is injected along this subcutaneous region at the level of the cricoid cartilage. Complications include intravascular injection of the carotid artery or internal jugular vein and phrenic nerve block resulting in Horner's syndrome [54, 145].

Effective pain relief for cleft lip repair as well as for sinus surgery, rhinoplasty, and nasal septal reconstruction can be provided by an infraorbital nerve block [146, 147]. The sensory nerve is derived from the second maxillary division of the trigeminal nerve and exits the skull through the foramen rotundum before passing through the infraorbital foramen. It then divides into four branches—internal and external nasal, superior labial, and inferior palpebral branches. These branches innervate the skin of the upper lip, lower eyelid and cheek and lateral nose. Two field blocks, extraoral and intraoral can block the nerve (Figs. 15.2 and 15.3). The external approach involves locating the infraorbital foramen approximately 0.5 cm inferior to the lower orbital margin. A 27-gauge needle is then inserted until bone is contacted. The needle is then withdrawn slightly and following negative aspiration a small amount of local anesthetic (0.25–0.5 mL) is injected. The intraoral approach starts with the same landmark by palpating the infraorbital foramen with the non-dominant hand to maintain position. The upper lip is then lifted and a 25–27-gauge needle is used to inject 0.5–1.5 mL of local anesthetic following negative aspiration along the inner surface of the lip along the maxillary premolar toward the infraorbital foramen. Other than swelling around the eyelid, which can be reduced by pressure over the injection site for several minutes, complications from this block are rare.

Indications for supraorbital and supratrochlear nerve blocks include procedures on the scalp and forehead such as frontal craniotomies, ventriculoperitoneal shunt revisions, excision of skin lesions,

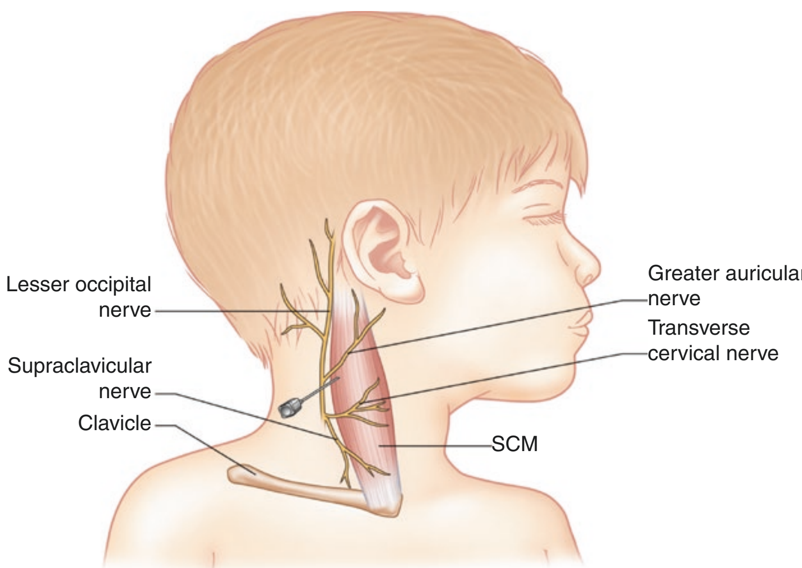

Fig. 15.1 Great auricular nerve block

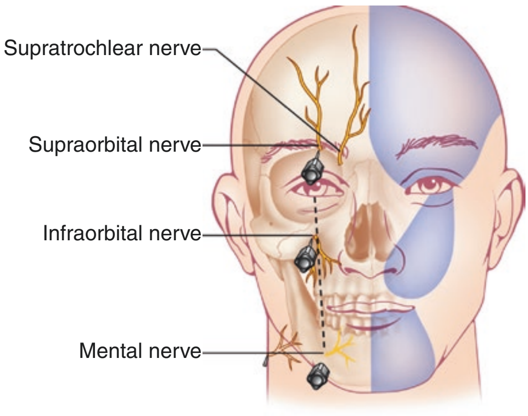

Fig. 15.2 Extraoral nerve block

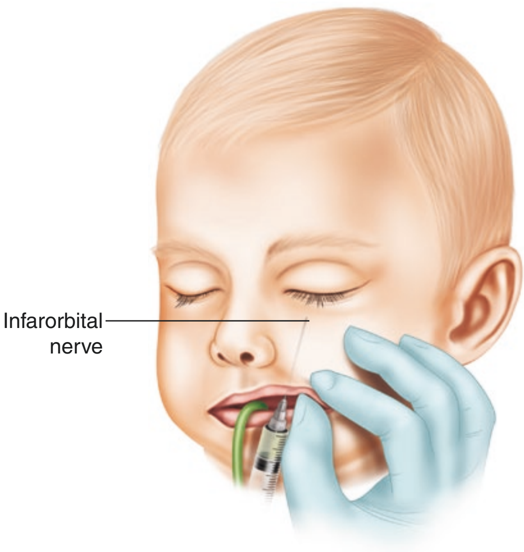

Fig. 15.3 Intraoral nerve block

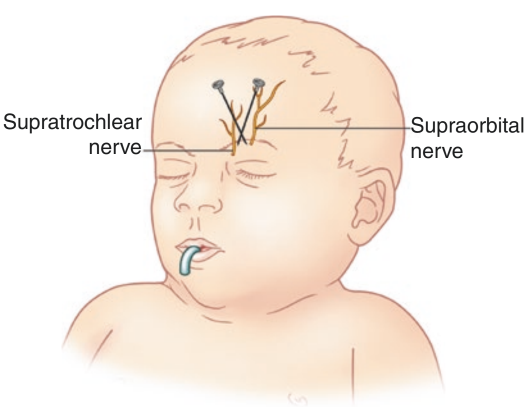

Fig. 15.4 Supraorbital and supratrochlear nerve block

and laser therapy for hemangiomas (Fig. 15.4) [143, 148, 149]. The nerves are branches of the ophthalmic division of the trigeminal nerve and supply the skin of the forehead and conjunctiva of the upper eyelid. The supraorbital nerve is found in the upper margin of the orbit at the supraorbital notch and the supratrochlear nerve is in close proximity and just medially. After palpating the supraorbital notch, a 27-gauge needle is inserted superior to the notch until bone is contacted. Local anesthetic (1 mL) is injected after slight withdrawal and negative aspiration for blood. The needle is withdrawn and directed slightly medially before injecting another 1 mL of local anesthetic following negative aspiration. Hematomas and periorbital edema are common complications [150, 151], but can be minimized by applying pressure for approximately 5 min.

Brachial Plexus Block

Although there are several approaches to the brachial plexus in children, the axillary approach is commonly used for brachial plexus blockade [152, 153]. Recently, the use of US allows infraclavicular and supraclavicular approaches to the brachial plexus [81, 154–157]. The brachial plexus arises from the cervical nerve roots (C_5-T_1). Brachial plexus blocks are easy to perform in children, due to less adipose tissue when compared to adults, and the axillary artery is easier to palpate and isolate [158, 159]. The arm is abducted to a 90° angle in relation to the chest wall. The artery is palpated and fixed in the axilla, and the 22-guage, short-bevel, 2-in. needle allows accurate placement around and when necessary through the axillary artery (Fig. 15.5). With 'through and through' axillary artery puncture technique continuous aspiration is required as the needle is advanced until no blood is aspirated, then one-half of the local anesthetic is injected into the distal portion of the sheath. As the needle is withdrawn, again the needle is continuously aspirated until no blood can be withdrawn, and the remaining half of the local anesthetic can be injected into the proximal portion of the sheath. The recommended dose of local anesthetic is 1 mL/kg of either 0.25% bupivacaine or 0.2%

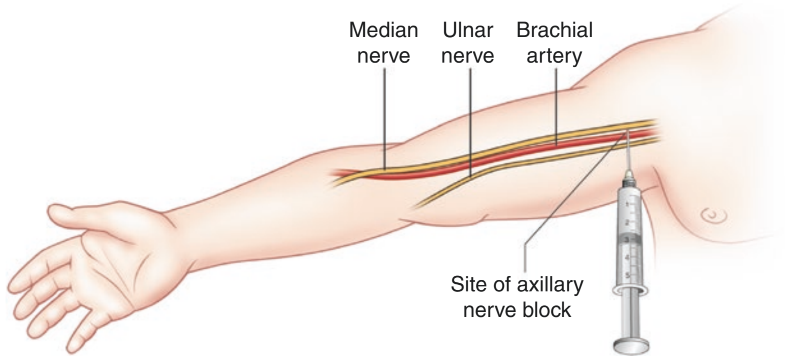

Fig. 15.5 Axillary block

ropivacaine [102]. Vigilant aspiration should be performed to minimize intravascular injection. An additional circumferential subcutaneous cuff block for the intercostobrachial nerve to minimize tourniquet pain is also recommended.

The use of a nerve stimulator can assist the operator in advancing the 22-guage, short-bevel 2-in. needle into the sheath of the brachial plexus superior to the axillary artery. Once a twitch is elicited, local anesthetic solution can be injected into the sheath. Again a ring of local anesthetic can be subcutaneously injected in a ring around the upper arm to block the intercostobrachial nerve to provide tourniquet-related pain relief.

Ultrasound is also effective in visualizing the interscalene approach to the brachial plexus [81, 160–164]. A recent review of the Pediatric Regional Anesthesia Network reported placement of interscalene blocks in children under general anesthesia identified no serious adverse events [81].

Paravertebral Block

With the ability to target specific dermatomes, single-sided paravertebral blockade is indicated for patients undergoing renal surgery, thoracotomy, unilateral abdominal procedures such as cholecystectomy and even inguinal surgery [165, 166]. The bilateral approach expands its use in chronic management of pancreatitis or to procedures that cross or involve the midline, such as Nuss repair of pectus excavatum or following laparoscopic cholecystectomy [167–169]. Lönnqvist and others demonstrated continuous paravertebral blockade to be superior to continuous epidural blockade in reducing morphine requirements in children undergoing renal surgery [165, 166]. Berta and others demonstrated benefits observed in single case reports [167–169] and in patients undergoing major renal surgery [170]. Loftus and colleagues reported beneficial use of paravertebral continuous infusion pain catheters following pectus excavatum repair surgery resulting in shorter hospital length of stays [171].

A wedge-shaped area, the paravertebral space is bound anteriorly by the parietal pleural, posteriorly by the superior costotransverse ligament, laterally by the posterior intercostal membrane, and medially by the vertebra (Fig. 15.6). The space contains spinal roots emerging from the intervertebral foramina from the dorsal and ventral rami and the sympathetic chain. Blockade may involve several dermatomes and can produce sensory, sympathetic, and motor blockade. In the pediatric population, the block is usually performed under general anesthesia with the patient in the lateral position. After establishing the midline, the point of lateral approach is estimated by measuring the distance between spinous processes. The needle is inserted perpendicular to skin until contact with the transverse process. The needle is then slightly retraced and directed caudal to walk off the process. In adults, the needle is then advanced 1 cm deeper than the transverse process, while in children the space is usually more superficial. Further confirmation may be obtained by a loss of resistance technique similar to epidural placement. A “pop” may be felt as the needle penetrates the paravertebral space. At this point, a drop of sterile fluid

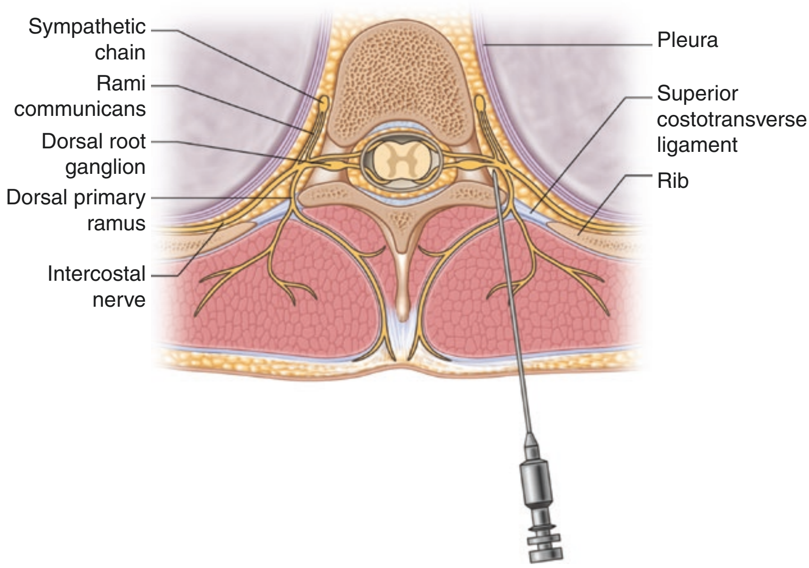

Fig. 15.6 Paravertebral block

is placed at the needle hub and the patient is given a deep breath to rule out intrapleural placement. A 22-gauge blunt needle is then used to inject 0.5 mL/kg of local anesthetic for unilateral blockade. Ropivacaine 0.2% or bupivacaine 0.25% is typically used. A Touhy needle can be used to thread a catheter for continuous techniques. Typical infusion rates are 0.25 mL/kg/h in children and 0.2 mL/kg/h in infants of 0.1–0.125% local anesthetic.

The proximity of this block to the epidural space leads to the possibility of inadvertent epidural or spinal blockade resulting in hypotension or rarely a "high spinal" [172, 173]. Other complications include vascular or pleural puncture and pneumothorax [174, 175]. A 10.7% failure rate in adults and 6.2% in children was demonstrated in one series of 367 patients by Lönnqvist and others [176]. However the use of bilateral paravertebral technique doubled the likelihood of accidental vascular puncture (9% vs. 5%) and with an eightfold increase in pleural puncture and pneumothorax complications (3% vs. 0.4%) when compared with unilateral blocks [177].

Transversus Abdominis Plane Block

As a landmark-based technique, the transversus abdominis plane block (TAP) has provided excellent analgesia in adults undergoing lower abdominal surgery including hernia repair, appendectomy, abdominal hysterectomy, and caesareans [178–182]. Application to the pediatric population, in which landmarks are difficult or impossible to palpate, has been eased by the use of US [9, 183–189]. The TAP block is especially useful in cases where neuraxial blockade is contraindicated [184]. A TAP block may substitute for the ilioinguinal/iliohypogastric block and can also provide analgesia for more superior abdominal incisions from laparotomy or laparoscopy. Incisional pain can be well controlled but the block is less effective for visceral pain [9, 183–190].

The anterolateral abdominal wall is innervated by the anterior rami of T_7-L_1 and include the ilioinguinal, iliohypogastric, intercostal, and subcostal nerves (Fig. 15.7) [191]. These nerves travel in the intercostal space before entering the abdominal wall between the internal oblique and transversus abdominis muscles. This plane serves as the target for the TAP block. The landmark technique involves locating the lumbar triangle of Petit. The base of the triangle lies on the highest point of the iliac crest and the apex is at the costal margin. Anterior and posterior borders include the external oblique muscle and latissimus dorsi muscle, respectively. A blunt 22-gauge 2-in. needle is inserted in this location and passes through the external oblique muscular fascia,

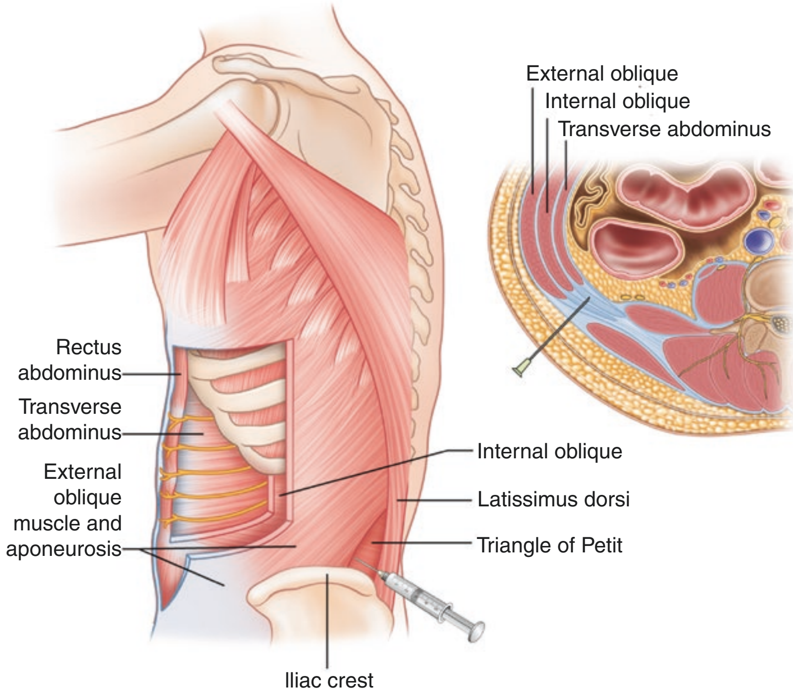

Fig. 15.7 TAP block

then the internal oblique muscular fascia (Fig. 15.7). After these two fascial "pops" are appreciated, local anesthetic is injected following negative aspiration with obvious care not to exceed toxic levels. A bilateral TAP block may be used for midline incisions or procedures involving both sides [9, 182, 183, 185–189, 192, 193].

Aside from real-time visualization, US offers a distinct advantage for this block in the pediatric population as the triangle of Petit is difficult to ascertain in children and loss of resistance through less developed internal and external oblique muscles can be difficult to appreciate [191, 194]. Placement of the US probe in the transverse plane above the iliac crest usually provides excellent visualization of the external and internal obliques fascial planes, transversus abdominis fascial plane, and peritoneal plane although the US probe may need to be directed more medially in some patients. Local anesthetic is deposited following negative aspiration as the needle tip is visualized deep to the internal oblique fascial plane. Spread within the internal oblique and transversus abdominis fascial plane confirms accurate placement. An US-guided Tuohy needle can be used to place a continuous catheter 2–3 cm beyond the needle tip if prolonged analgesia is required [9, 186, 187].

Complications are similar to those reported with ilioinguinal blockade including peritoneal perforation and femoral nerve palsy [182, 192, 195]. The catheter-based technique has a theoretical risk of infection. There are no reported complications with the US-guided technique [9, 182, 185–189, 192].

Ilioinguinal/Iliohypogastric Block

Analgesia for inguinal hernia repair, hydrocelectomy, and orchiopexy is provided by an ilioinguinal/iliohypogastric block [41, 79, 196, 197]. Originating from the lumbar plexus, the ilioinguinal and iliohypogastric nerves pass superficial to the transversus abdominus near the anterior superior iliac spine (Fig. 15.8). These nerves can be blocked at this site before separating. The iliohypogastric nerve supplies skin over the lower anterior abdominal wall, while the ilioinguinal supplies skin over the scrotum or labium majoris.

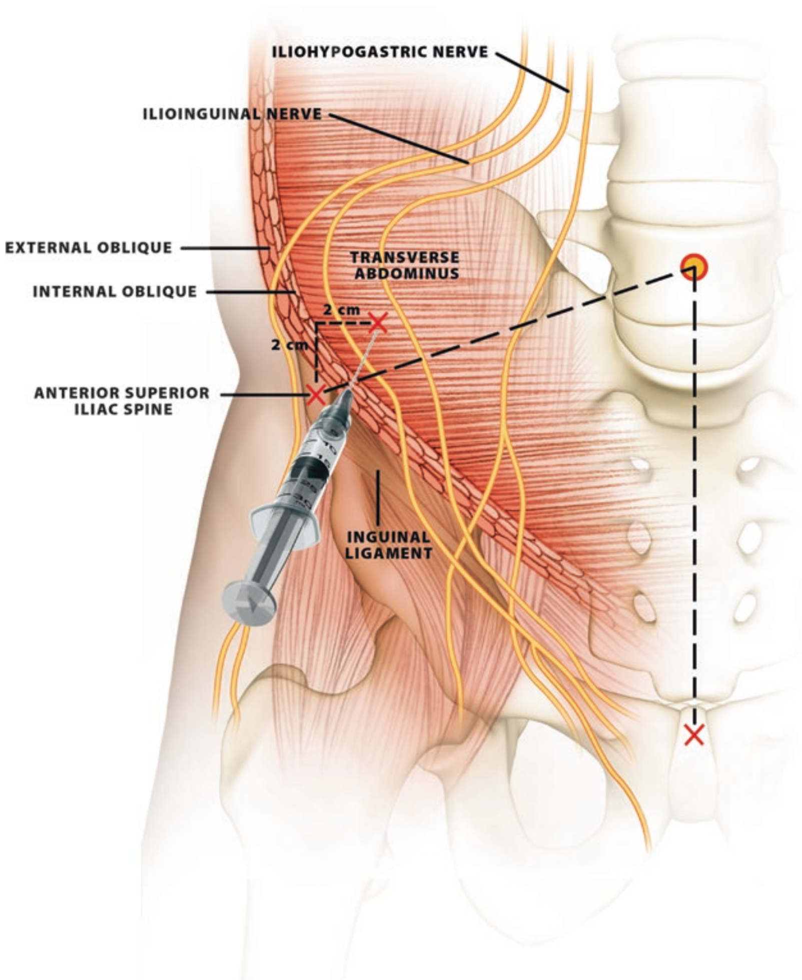

Fig. 15.8 Ilioinguinal/iliohypogastric block

A blunt 22–25 gauge needle is inserted 1 cm superior and 1 cm medial to the anterior superior iliac spine (ASIS) (Fig. 15.8). A field block is then performed directing the needle parallel to the muscle wall in the direction of the ASIS. The needle is withdrawn while injecting anesthetic and redirected toward the inguinal ligament with care not to puncture the ligament. Penetration of the oblique muscles results in a characteristic "pop" after while local anesthetic is again injected. The block can also be performed post surgically by the surgeon under direct vision. Bupivacaine 0.25% or ropivacaine 0.2% or 0.5% are typically used.

Ultrasound guidance involves direct visualization of the nerve or nerves by placement of the probe just medial to the superior aspect of the ASIS. An out-of-plane technique is typically employed as the nerves' proximity to the ASIS can make the in-plane technique challenging [198]. At this location, the nerves are typically less than 1 cm deep and run between the internal oblique and transversus abdominus muscle.

Serious complications are rare and include small bowel or colonic perforation [199]. Transient femoral blockade resulting in motor weakness of the quadriceps can occur in up to 5% of patients if the local anesthetic tracks inferior to the inguinal ligament [200].

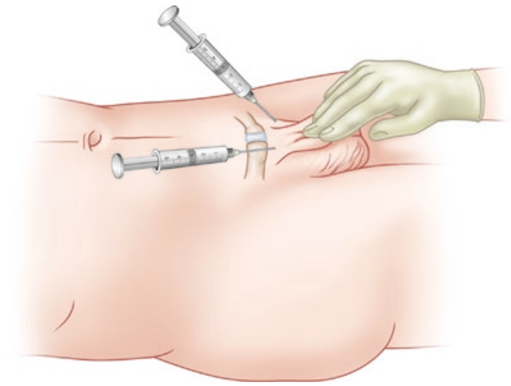

Fig. 15.9 Penile nerve block

Penile Nerve Block

Arising from the sacral plexus, innervation of the distal two-thirds of the penis is supplied by branches of the pudendal nerve known as dorsal nerves. The nerves are surrounded by Buck's fascia and are near dorsal vessels (Fig. 15.9). Various techniques exist for anesthetizing these nerves for intraoperative and postoperative pain secondary to circumcision and uncomplicated hypospadias repair. They include application of topical cream, subcutaneous ring block, dorsal nerve block, and suprapubic nerve block [124, 201–203]. Studies have shown the subcutaneous ring block to be more effective than the other techniques [201, 203].

Application of topical cream is the simplest method and has been employed because of its ability to penetrate intact foreskin [203, 204]. As absorption may be increased through mucous membranes, care must be taken to use the minimum amount necessary. Subcutaneous ring block involves placing a skin wheal of local anesthetic circumferentially around the base of the penis [205]. Injection of local anesthetic to the penis bilaterally at the symphysis pubis is known as the dorsal penile block. With downward traction of the penis, a 25-gauge needle is directed medially and caudally until Buck's fascia is penetrated at 10:30 and at 1:30 until a characteristic "pop" is felt. Frequent aspiration is necessary due to the close proximity of the dorsal vessels at this location [206–209].

Most sources recommend the avoidance of epinephrine with these blocks as vasoconstriction can theoretically result in necrosis [210, 211]. A volume of 0.1 mL/kg of bupivacaine 0.25–0.5% or ropivacaine 0.2% is typically used and provides approximately 4–6 h of analgesia. Complications include hematoma formation resulting in necrosis, intravascular injection, and tissue edema affecting surgical conditions [101, 205, 212]. Recent studies examined the role of US and found improved efficacy with the block [213–217].

Caudal Block

Although regional block needles are used in the performance of the pediatric caudal block, a number of studies advocate the use of styletted, short-beveled 22-guage needles [218–220], as the styletted needle may reduce the risk of introduction of a dermal plug into the caudal space [219]. The approach to the caudal canal is dependent upon proper angle of the needle as parallel insertion to the sacrum is required through the sacrococcygeal membrane (Fig. 15.10). Final needle placement is dependent upon a "pop" as the blunt needle pierces the sacrococcygeal membrane. Aspiration should be performed prior to injection of the local anesthetic solution. A test-dose including epinephrine (0.5 mcg/kg) helps identify that the needle is not in the intravascular or intraosseous space (Fig. 15.10 bottom cartoon). During injection, the lack of subcutaneous swelling is a helpful sign of proper needle placement. Relaxation of the anal sphincter also predicts successful blockade [221].

Extension of the Caudal Catheter into the Lumbar or Thoracic Regions

Caudal catheters were used in the past in adults, but lost their popularity with the development of lumbar and thoracic approaches to the epidural space [222]. However, there has been a recent resurgence in caudal catheter epi-

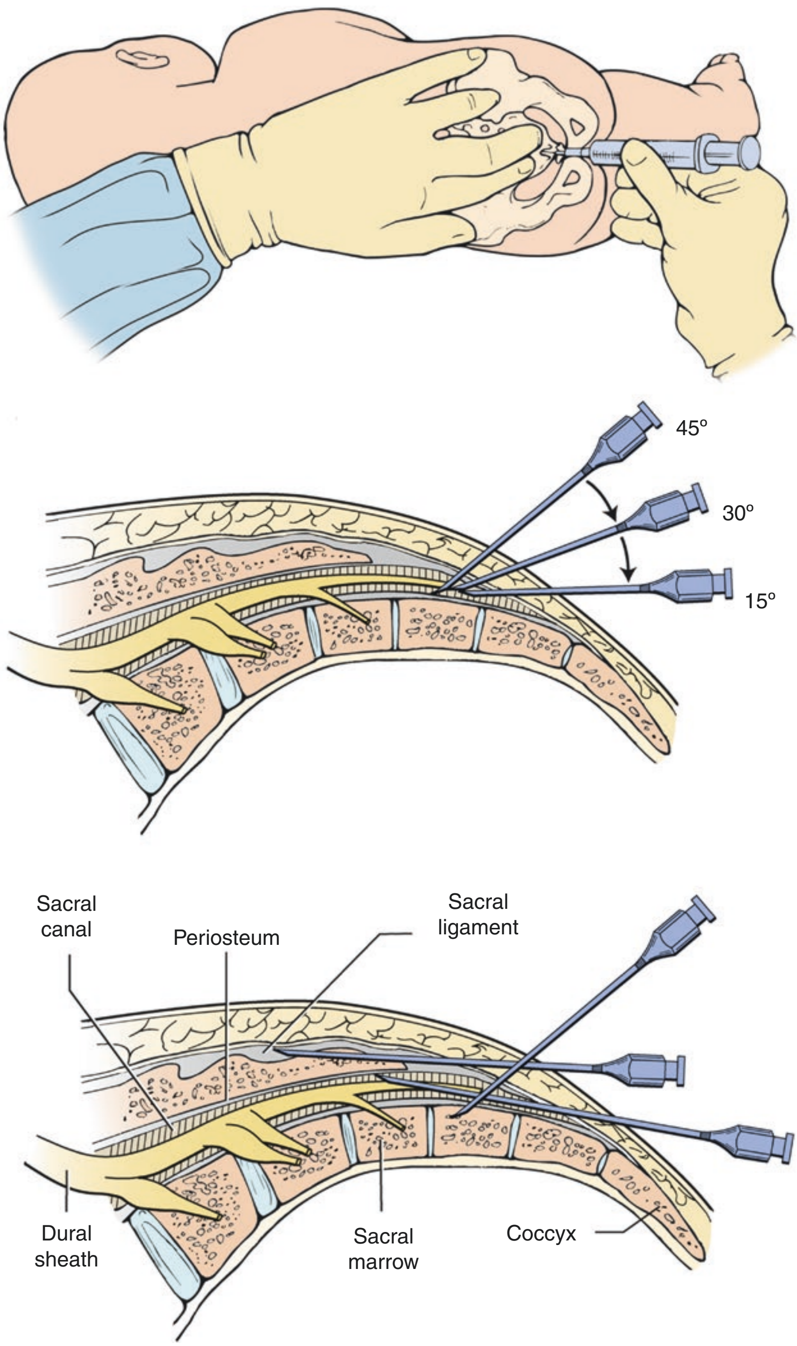

Fig. 15.10 Caudal block

dural placement in neonates and in infants as they can be used to facilitate the surgical anesthetic and be a component of a postoperative analgesia regimen. A recent large review of the Pediatric Regional Anesthesia Network in over 18,000 caudal blocks reported a 1.9% complication rate due to block failure, blood aspiration, and intravascular injection. There were no permanent sequelae reported [65]. The caudal canal in neonates can allow easy access to the lumbar and thoracic segments with minimal resistance in passage of the catheter [222–226]. However, in older patients, the addition of fibrous and fatty tissue and development of septal membranes in the epidural space, can impede caudal catheter advancement [227, 228].

Summary

The benefits of regional analgesia in the management of postoperative pain are clearly recognized. Despite many reported advantages, the use of peripheral nerve blocks in perioperative care for children continues to be underutilized. Although these regional techniques are safe, they are not without risk [85, 99, 229]. The application of ultrasonography should decrease some of these risks [34, 61, 70, 99, 230]. Regional anesthesia can be an important component to multi-modal analgesia [217, 231, 232]. Certainly the role of the parents regarding postoperative instructions is important in the transition of analgesic regimens as the regional block wanes [233]. However, these postoperative analgesia instructions should not be significantly different than what is currently employed for pediatric patients following general anesthesia. In any perioperative plan of care, the risks and benefits of any technique lie with the skill and experience of the caregiver. Nevertheless, regional anesthesia is an effective method of providing postoperative analgesia in the pediatric patient.

Review Questions

1. Opiate metabolic clearance rates in newborns are:
   (a) Increased when compared to older children
   (b) Unchanged when compared to older children or adults
   (c) Decreased when compared to adults
   (d) Decreased when compared to older children
2. Complications of great auricular nerve blocks in children are:
   (a) Intravascular injection of the carotid artery
   (b) Intravascular injection of the internal jugular vein
   (c) Horner's syndrome
   (d) All the above
3. The use of interscalene blocks under general anesthesia are contraindicated in children
   (a) True
   (b) False
4. Paravertebral blockade is indicated in children undergoing:
   (a) Renal surgery
   (b) Thoracic surgery
   (c) Cholecystectomy
   (d) Inguinal surgery
   (e) a, b, c
   (f) All the above
5. Penile nerve blocks in children can be most effective with:
   (a) Application of topical ELMA
   (b) Subcutaneous ring block
   (c) Doral nerve block
   (d) Suprapubic nerve block
6. Caudal nerve blocks in children:
   (a) Regional nerve block needles with echogenic features improve placement
   (b) Risk intraosseous injection of local anesthetic solution
   (c) Styletted needles may reduce risk of dermal plug into the caudal space
   (d) a and b
   (e) a and c
   (f) b and c
   (g) a, b, and c
7. Extending caudal catheters into the lumbar or thoracic regions in newborns risk permanent neurologic sequelae.
   (a) True
   (b) False
8. Complications of ilioinguinal/iliohypogastric nerve blocks include:
   (a) Small bowel perforation
   (b) Colon perforation
   (c) Quadriceps motor weakness
   (d) All the above

Answers

1. a
2. d
3. b
4. f
5. b
6. f
7. b
8. d

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