Pediatric Nerve Blocks: An Evidence-Based Approach

Abstract

Successful injury management is often dependent upon optimal pain control. Many injuries do not require procedural sedation or systemic analgesia, and emergency clinicians have used peripheral nerve blocks for several decades for these injuries. Nerve blocks deliver anesthetic to the nerve that corresponds to the sensory innervation of the area where the wound or injury is located. In the pediatric setting, some nerve block modalities require modification to the approach and techniques commonly used in adult patients due to the age and weight of the child, the ability of the patient to cooperate, and the ability of the emergency clinician to observe pain response. Peripheral nerve blocks have a high rate of success for effective local anesthesia and a low rate of complications, making them an attractive option for analgesia in the management of some injuries. This evidence-based review summarizes the advantages and disadvantages of peripheral nerve blocks, reviews commonly used local anesthetics, describes the landmark technique for the most common nerve blocks used in pediatric emergency medicine, and presents literature on ultrasound-guided technology.

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CME Objectives

Upon completion of this article, you should be able to:
1. Choose the appropriate nerve block and anesthetic medication for a given injury/anatomic region.
2. Describe the general risks and benefits of nerve blocks and complications specific to certain nerve blocks.
3. Demonstrate the landmark technique for common nerve blocks performed in the pediatric emergency setting.
4. Appraise the utility of ultrasound guidance for nerve blocks in pediatric patients.

Prior to beginning this activity, see “Physician CME Information” on the back page.

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A 15-year-old previously healthy male presents to the emergency department via EMS after being assaulted in his neighborhood. The patient is in cervical spine immobilization and has blood-soaked gauze on his face. He is currently awake and complaining of pain in his face and left leg. He states that several people attacked him with fists and threw him onto an embankment. His vital signs are: heart rate, 110 beats/min; respiratory rate, 20 breaths/min; blood pressure, 131/79 mm Hg; oxygen saturation, 99% on room air; and temperature, 36.4°C. On primary survey, the patient has a clear airway with no blood or lesions noted in the oral cavity, clear breath sounds, and good air entry throughout. He has strong peripheral and central pulses, with a 2-second capillary refill. The patient is alert and oriented to person, place, and time, and he has a Glasgow Coma Scale score of 15. You undress him fully and evaluate him for further injuries. He has a 3-cm stellate laceration extending 5 mm from the inferior border of the right eyelid to the medial aspect of the zygomatic process. He also has a 4-cm laceration extending from the right aspect of the lower lip, crossing the vermilion border to the right lateral aspect of the chin. There is a deformity above the left knee, with swelling and increased pain when manipulating the extremity. The femoral, popliteal, and pedal pulses are palpable, and sensation and motor strength are intact distal to the injury. After completing all necessary evaluations and concluding that the patient is stable for injury repair, you discuss the plan with the patient and his family members who have just arrived. The patient’s mother informs you that he has previously had an anaphylactic reaction to sedation for a dental procedure. She prefers that you do not sedate her son because she is fearful of another medication reaction. You exit the room to gather supplies for the wound repair and to call the orthopedic surgery consult. You begin to wonder: What is the most efficient way to provide safe analgesia to this patient? Due to the extent of the injuries, should I sedate him for the repairs? Which nerve block techniques and anesthetic can I use to anesthetize these injuries? How much of this anesthetic can I use in this patient? What are the anatomical landmarks I should be aware of for nerve block techniques? Will using ultrasound guidance improve the success of the nerve block?

Peripheral nerve blocks are commonly used in patients with lacerations, fractures, and other injuries when pain is expected during the management of the condition. Compared to local infiltration, nerve blocks are thought to prevent further wound distortion and allow for improved analgesia; additionally, they require a lower volume of anesthetic, reducing the risk of systemic toxicity. Traditionally, nerve blocks are performed using landmark-based techniques, but these are subject to errors from anatomical variability. More recently, the use of ultrasound-guided peripheral nerve blocks has been described in the literature. This issue of Pediatric Emergency Medicine Practice discusses the indications, contraindications, techniques, and cutting-edge technology available for peripheral nerve blocks through an examination of the current literature.

Critical Appraisal Of The Literature

A literature search was performed using PubMed, using the search terms pediatric nerve blocks, regional blocks, ultrasound-guided nerve blocks, pediatric emergency nerve blocks, and peripheral blocks. A total of 369 articles from 1960 to the present were reviewed. The majority of the articles pertained to anesthesiology and chronic pain syndromes and were beyond the scope of this review. Abstracts were reviewed for relevance to the topic. Supporting articles were gathered from related articles and the reference lists of review articles. Textbooks pertaining to emergency medicine and anesthesia were used for the general guidelines of pediatric nerve blocks. Case reports, editorial views, and correspondence to the editors were largely excluded.

Pathophysiology

Familiarity with the actions and potential side effects of nerve blocks is imperative in choosing the appropriate anesthetic for use in these procedures. There are 2 broad classes of anesthetics: (1) amides and (2) esters. Amides are metabolized in the liver and bind to plasma protein. Children aged < 1 year lack the ability to metabolize these agents effectively, as they have decreased levels of plasma protein compared to adults, allowing for a larger fraction of unbound anesthetic and a higher potential for toxicity. Esters, on the other hand, are eliminated in the plasma by esterases. Compared to adults, infants have lower levels of plasma esterases; however, no clinical significance of this difference in levels has been reported. It is important to note that metabolic byproducts of esters are potentially allergenic substances. A review of commonly used amide and ester anesthetics is presented in Tables 1 and 2.
syndrome. Other diagnostic modalities can be used as adjuncts in further evaluating the injury. Sonography, plain radiographs, and computed tomography (CT) can be helpful in evaluating for the presence of a foreign body, fractures, fluid collection, or deep tissue and vascular involvement.

General indications for regional nerve blocks are injuries or pain in a region innervated by a particular nerve or group of nerves. This applies specifically when the dose of anesthetic needed to provide adequate local infiltration of a wound is greater than the maximum dose allowed for the child. Diagnoses in which nerve blocks should be considered are listed in Table 3. Nerve blocks can be achieved with a lower volume of anesthetic, leading to a lower risk of systemic toxicity. In addition, nerve blocks can be beneficial when local infiltration would create cosmetic distortion of the wound.

Absolute contraindications to peripheral nerve blocks include:

- The age and weight of the child
- Known drug allergies
- The type, location, and mechanism of injury
- The presence of systemic symptoms
- Family history of adverse reaction to anesthesia
- The ability of the patient to cooperate
- The ability of the emergency clinician to evaluate the child’s pain response
- The experience of medical personnel

### Physical Examination

The physical examination aids in determining the eligibility of the patient for a peripheral nerve block. The characteristics that should be reviewed include: (1) intact neurovascular examination distal to the injury, (2) evaluation of lacerations, (3) presence of a foreign body, (4) potential signs of serious underlying injuries such as fracture, infection, or deep tissue involvement, and (5) the risk of compartment syndrome.

### Table 1. Amide Anesthetics

<table>
<thead>
<tr>
<th>Type</th>
<th>Time of onset (min)</th>
<th>Duration of effect (h)</th>
<th>Maximum Dose</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lidocaine (0.5%-4%)</td>
<td>4-7</td>
<td>1.5</td>
<td>3-5 mg/kg (max: 300 mg)</td>
<td>• Excellent clinical efficacy and safety record</td>
</tr>
<tr>
<td>Lidocaine (0.5%-2%) with epinephrine</td>
<td>4-7</td>
<td>3.5</td>
<td>7 mg/kg (max: 500 mg)</td>
<td>• Refer to page 4 for use in end-arterial areas</td>
</tr>
<tr>
<td>Prilocaine 4% +/- epinephrine</td>
<td>1-2</td>
<td>1-2</td>
<td>6-8 mg/kg (max: 400 mg)</td>
<td>• Commonly used for dental procedures and in Bier block</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Component of lidocaine/prilocaine topical anesthetic</td>
</tr>
<tr>
<td>Bupivacaine (0.25%, 0.5%, 0.75%)</td>
<td>20</td>
<td>3-6</td>
<td>2 mg/kg</td>
<td>• Consider for longer procedures</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Has high toxicity potential</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Not recommended for use in patients aged &lt; 12 y</td>
</tr>
<tr>
<td>Ropivacaine (0.2%-1%)</td>
<td>20</td>
<td>3-6</td>
<td>2-2.5 mg/kg</td>
<td>• S-isomer of bupivacaine; pharmacokinetics are not affected by epinephrine</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• 70% less likely to cause cardiotoxic effects 8</td>
</tr>
<tr>
<td>Levobupivacaine</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>• Discontinued in the United States in 2003</td>
</tr>
<tr>
<td>Mepivacaine (1%, 1.5%, 2%, 3%)</td>
<td>4-7</td>
<td>3</td>
<td>5-6 mg/kg (children aged &lt; 3 y [or 13.6 kg], use concentration 0.5%-1.5%)</td>
<td>• Similar systemic toxicity when compared to lidocaine</td>
</tr>
</tbody>
</table>

### Table 2. Ester Anesthetics

<table>
<thead>
<tr>
<th>Type</th>
<th>Time of onset (min)</th>
<th>Duration of effect (h)</th>
<th>Maximum Dose</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloroprocaine (1%-3%)</td>
<td>6-12</td>
<td>1</td>
<td>11 mg/kg</td>
<td>• Use with/without epinephrine, with low concentrations, in pediatric patients</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Use in children aged &gt; 3 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• More commonly used for central neuraxial blocks 8</td>
</tr>
<tr>
<td>Cocaine (tetracaine-adrenaline-cocaine [TAC])</td>
<td>20-40</td>
<td>2</td>
<td>3 mg/kg</td>
<td>• Found in topical formulations</td>
</tr>
<tr>
<td>Procaïne</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>• Discontinued in the United States</td>
</tr>
<tr>
<td>Tetracaine 1% (lidocaine, epinephrine, tetracaine [LET])</td>
<td>&lt; 15</td>
<td>3</td>
<td>3 mg/kg</td>
<td>• Most commonly found in topical formulations along with lidocaine and epinephrine</td>
</tr>
</tbody>
</table>
blocks include: (1) a history of allergic reaction to the local anesthetic, (2) a risk of developing compartment syndrome in the distribution of the nerve block, (3) infection at the site of injection, and (4) coagulopathy. In patients with altered mental status, providers should consider alternative forms of analgesia or employ ultrasound guidance to ensure proper needle placement, since altered patients may not be able to communicate the presence of paresthesias during the procedure. Use of a clinical pathway is suggested to aid in determining the appropriateness of nerve blocks and other forms of analgesia in the management of injuries. (See the Clinical Pathway For Analgesia In Injured Children, page 10.)

### Treatment

**Possible Complications Of Nerve Blocks**

Complications related to peripheral blocks are generally rare but include intravascular injection of local anesthetic, allergic reaction to the anesthetic, bleeding or hematoma from vascular damage, infection, and mechanical or pressure-related damage to nerve tissue from needle manipulation in intraneural injection. The most serious complication of intravascular injection or overdose is local anesthetic systemic toxicity, which can manifest with seizures, cardiac arrest, and respiratory failure. A 2001 review article shows that the incidence of systemic toxicity is 7.5 per 10,000 uses, due mostly to inadvertent intravascular injection; it also reported an incidence of peripheral nerve damage of 1.9 per 10,000.\(^5\) A 1997 prospective study by Auroy et al of 21,278 patients receiving peripheral nerve blocks by anesthesiologists reported 3 episodes of cardiac arrest, 16 seizures, and 4 cases of neuropathy.\(^6\) Given the low—but possible—risk of systemic toxicity for nerve blocks requiring large doses of local anesthetic (generally, blocks proximal to the elbow or knee), it is recommended that patients be placed on a cardiac monitor.\(^7\)

Intraneural injection is a known risk of nerve blocks, and it can cause severe pain and may produce nerve injury.\(^2\) Neural damage is rare in regional anesthesia. The most likely mechanism of injury is by direct needle damage or pressure induced during anesthetic injection. Neuropraxia (an area of persistent numbness) is one of the most common complications from nerve blocks; however, these effects generally resolve over several weeks, and most patients regain normal function at 3 months.\(^5\)

A 1996 multicenter study reviewing more than 20,000 pediatric regional blocks performed by pediatric anesthesiologists reported a complication rate of approximately 1:1000 blocks but no long-term sequelae. Of those blocks, 9396 pediatric patients received peripheral nerve blocks with no complications reported.\(^8\) A follow-up study was published in 2010 and included approximately 30,000 regional blocks. Only 41 complications were noted, and there were no long-term sequelae. Most complications were noted with central blocks, which had a complication rate that was 6 times that of peripheral blocks.\(^9\) The safety profile of nerve blocks is well documented, and they carry a low risk of complications. The introduction of ultrasound-guided technology for peripheral nerve blocks has the potential to increase their safety even further.

### Epinephrine Use

In choosing a local anesthetic agent, it is always important to consider combining the anesthetic with epinephrine. In nerve blocks, the use of epinephrine can be advantageous due to its local vasoconstriction properties, which allows for decreased rates of systemic absorption, increased allowable dose of anesthetic, and prolonged duration of action of the anesthetic (compared to local infiltration).\(^2,10\)

Previously, local anesthetics with epinephrine were contraindicated for regions of end-arterial vascular supply, such as digits, nose, ears, and genitals. However, there have been no recent reports involving cases of ischemic complications following epinephrine use in digital blocks,\(^10,11\) and there have been no reported cases of finger gangrene or tissue necrosis since the commercial formulation of lidocaine with epinephrine was introduced in 1948. The reported cases prior to 1948 were likely due to errors in manual dilution and additional complications with infection and the use of tourniquets.\(^10\) A 2005 article reviewed 10,000 surgical cutaneous procedures of the nose and ear and noted zero complications due to epinephrine use with local anesthetic.\(^12\)

In summary, the evidence supports the use of local anesthetic with epinephrine in most situations, with the exception of genital blocks, where there is limited evidence to support using epinephrine.

### Calculating Dosages

When choosing a local anesthetic for a nerve block, we recommend careful dose calculation and proper infiltration techniques to decrease the risk of adverse reactions. The most widely used local anesthetic

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**Table 3. Diagnoses And Indications For Consideration Of Nerve Blocks**

<table>
<thead>
<tr>
<th>Diagnoses</th>
<th>Indications</th>
</tr>
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<tbody>
<tr>
<td>Laceration</td>
<td>Tissue exploration</td>
</tr>
<tr>
<td>Fracture</td>
<td>Foreign body</td>
</tr>
<tr>
<td>Dislocation</td>
<td>Injury manipulation</td>
</tr>
<tr>
<td>Orofacial pain</td>
<td>Amputation</td>
</tr>
<tr>
<td>Abscess</td>
<td></td>
</tr>
<tr>
<td>Burns</td>
<td></td>
</tr>
<tr>
<td>Circumcision</td>
<td></td>
</tr>
<tr>
<td>Priapism</td>
<td></td>
</tr>
<tr>
<td>Paraphimosis</td>
<td></td>
</tr>
</tbody>
</table>

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*Data adapted from references 5, 6, 7, 8, 9, 10, 11, 12.*
with the highest therapeutic safety margin is lidocaine. Lidocaine is available in concentrations of 0.5% to 4%. The concentration refers to the grams of medication per 100 mL of solution. For example, a 1% solution includes 1 gram of lidocaine in 100 mL of solution (10 mg/mL of lidocaine), which is essential information when calculating the maximum dose allowed for a child’s weight (5 mg/kg without epinephrine and 7 mg/kg with epinephrine). Other amide formulations offer a longer duration of action and should be considered when anesthesia is desired for >3 hours. Ester anesthetics are more common in topical formulations, and they can be used in conjunction with amide anesthetics. Dosage recommendations are listed in Tables 1 and 2 (page 3), and common anesthetic volumes can be seen in Table 4.

The following sections describe the anatomy and landmark techniques for some of the most commonly used nerve blocks, including the face and head, the upper extremity, the lower extremity, the Bier block, and the penis.

**Face And Head Nerve Blocks**

**Infraorbital Block**

**Anatomy:** The infraorbital nerve is the terminal branch of the second branch of the trigeminal nerve (V2). It exits through the infraorbital foramen, below the middle of the inferior rim of the orbit, and it can be easily palpated. It then divides into 4 branches that innervate the area below the lower eyelid to the lateral inferior portion of the nose, including the upper ipsilateral lip and vermilion border.

**Landmark Technique:** There are 2 approaches for the infraorbital block: intraoral and extraoral. The extraoral approach is less desirable due to the difficulty of achieving full anesthesia, the increased risk of damaging the facial vessels, and cosmetic concerns. Both approaches require palpation of the infraorbital foramen. In the intraoral approach, the needle is positioned parallel to the maxillary premolar and inserted towards the foramen. Caution must be taken to not extend posteriorly and superiorly towards the orbit as well as to avoid insertion of the needle or injection of anesthetic directly into the foramen.

A video of this procedure is available at: https://sites.google.com/site/emprocedures/facial-and-dental-nerve-blocks/infraorbital-nerve-block

**Supraorbital And Supratrochlear Blocks**

**Anatomy:** The supraorbital and supratrochlear nerves are terminal branches of the first branch of the trigeminal nerve (V1). The supraorbital nerve exits through the supraorbital foramen and innervates the anterior lateral forehead and scalp to approximately the coronal suture. The supratrochlear nerve exits just medial to the supraorbital nerve and innervates the medial forehead.

**Landmark Technique:** With the widespread use of topical anesthetics such as lidocaine-epinephrine-tetracaine (LET), the use of this block has decreased, but it can be considered for younger children with large lacerations that may result in a theoretical concern for overdose (since LET compounds often contain 3%-5% lidocaine solutions). The recommended technique is to lay a linear subcutaneous track of anesthetic at the level of the brow where the nerves will be flooded as they exit the foramina. (See Figure 1.)

A video of this procedure is available at: http://www.mainhealth.org/em_body.cfm?id=3244

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Table 4. Common Pediatric Regional Nerve Block Anesthetic Volumes

<table>
<thead>
<tr>
<th>Face and Head</th>
<th>Upper Extremity</th>
<th>Lower Extremity</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infraorbital: 1-3 mL</td>
<td>Digital: &lt;4 mL total&lt;br&gt;Wrist (radial): 5-10 mL&lt;br&gt;Wrist (median): 2-4 mL&lt;br&gt;Wrist (ulnar): 3-5 mL&lt;br&gt;Elbow (median): 5-15 mL&lt;br&gt;Elbow (radial): 5-15 mL&lt;br&gt;Elbow (ulnar): 5-10 mL&lt;br&gt;Brachial plexus: 5-10 mL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supraorbital: 1-3 mL</td>
<td>Femoral: 10-20 mL&lt;br&gt;Posterior tibial: 4-10 mL&lt;br&gt;Saphenous: 4-10 mL&lt;br&gt;Sural: 4-10 mL&lt;br&gt;Superficial peroneal: 4-10 mL&lt;br&gt;Deep peroneal: 2-3 mL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mental: 1-2 mL</td>
<td></td>
<td></td>
<td>Bier block: 10-20 mL&lt;br&gt;Penile: 1-3 mL</td>
</tr>
<tr>
<td>Auricular: 2-3 mL/track</td>
<td></td>
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</tbody>
</table>
Mental Block
Anatomy: The mental nerve is a continuation of the inferior alveolar nerve that innervates the lower lateral lip and the skin of the ipsilateral side of the mandible. It exits through the mental nerve foramen, which lies inferior to the second mandibular bicuspid.

Landmark Technique: There are 2 approaches for the mental block: intraoral and extraoral. In the intraoral approach, the needle is inserted adjacent to the second mandibular premolar in a 45° angle toward the mental foramen. Anesthetic is infiltrated adjacent to the foramen, not in the foramen, which may result in ischemic nerve damage. In the extraoral approach, a similar trajectory is used with the needle, except the needle is inserted through the prepared skin superior to the mental foramen. The anesthetic is injected above and around the mental foramen. (See Figure 2.)

A video of this procedure is available at: https://sites.google.com/site/emprocedures/facial-and-dental-nerve-blocks/mental-nerve-block

Great Auricular Nerve Block
Overview: Great auricular nerve blocks are beneficial for all wounds and injuries to the ear and, specifically, to the auricle of the ear. In this location, the skin is tightly adhered to the cartilage, making wound infiltration complicated and creating excessive distortion of the wound.

Anatomy: The great auricular nerve is a sensory nerve branch of the cervical plexus C3, supplying sensation to the mastoid and the external ear. The nerve branches at the level of the cricoid cartilage posterior to the belly of the clavicular head of the sternocleidomastoid and courses caudally. (See Figure 3.)

Landmark Technique: The clavicular head of the sternocleidomastoid muscle is identified, and a point at the level of the cricoid cartilage and C6 is marked. At this point, local anesthetic is injected superficially. (See Figure 3.) The injection is done superficially to avoid the jugular vein and carotid artery, which lie deep to these structures. Maintaining superficial infiltration also avoids a deep cervical plexus block, phrenic nerve block, or spinal accessory nerve block, which could cause Horner syndrome, hemidiaphragmatic paralysis, or trapezius paralysis, respectively.

An alternative approach to an auricular block is a simple diamond field block around the affected ear. Superficial infiltrations are done in a diamond pattern (or a rhombus shape) around the affected ear. The needle entry point is at the level of the angle of the mandible, extending posteriorly to a perpendicular line drawn from the posterior cartilage of the base of the ear. Infiltration is done posteriorly and anteriorly to the ear, terminating slightly above the superior portion of the auricle. (See Figure 4.)

Videos of these procedures are available online at: https://sites.google.com/site/emprocedures/facial-and-dental-nerve-blocks/auricular-block
Upper Extremity Nerve Blocks

Digital Blocks

Overview: Digital nerve blocks are commonly used for the repair of nailbed injuries, fractures, dislocations, or lacerations involving the digits beyond the metacarpophalangeal joint.

Anatomy: Four nerves innervate each digit: 2 run in the dorsal aspect, and 2 run in the palmar/plantar aspect. They are located at the 2, 4, 8, and 10 o’clock positions in relation to the bones. In the hand, digits 2, 3, and 4 require only palmar nerve block for proper distal phalanx and nailbed anesthesia. Digits 1 and 5 need both sets of nerves to be anesthetized for a proper digital block. In the toes, all 4 nerves should be blocked due to their sensory overlap.

Landmark Techniques: Various techniques have been described for digital blocks. The most ubiquitous technique is the dorsal approach, which involves placing the needle in the web space perpendicular to the plane of the hand. The needle insertion site is slightly distal to the metacarpal joint and approximately 3 mm proximal to the most distal portion of the web space. The needle is inserted approximately 5 mm, followed by slow injection of approximately 2 to 4 mL of local anesthetic, targeting the dorsal nerve. The needle is then advanced along the bone until the palmar skin begins to tent. The needle is slowly pulled back and, after aspiration to check for inadvertent intravascular placement, another 1 to 2 mL is injected, targeting the palmar nerve. The same technique is done on the opposite side of the target digit. (See Figure 5.)

Figure 5. Dorsal Approach Digital Block


A second approach is an isolated palmar nerve block, which can be performed for hand digits 2, 3, and 4 since the palmar nerves supply sensation to the palmar aspect and dorsal aspect distal to the proximal interphalangeal (PIP) joint on these digits. Palpate the metacarpal head of the desired digit and insert the needle at this site directly toward the bone. Inject approximately 1 to 2 mL of anesthetic at this point. The needle is then slightly withdrawn and angled at either side along the bone, approximately 5 mm. Another 1 to 2 mL of anesthetic is injected on either side, targeting the palmar nerves. A third technique is the superficial ring block. This begins similarly to the dorsal approach block, but the needle is withdrawn (without exiting the skin) and repositioned to aim across the dorsal aspect of the proximal phalanx to the adjacent web space and anesthetic is injected in that area. The needle is reinserted in the adjacent web space and anesthetic applied in a similar fashion. The theoretical benefit of this approach is that the pain of the second injection is decreased (as the skin is already anesthetized), but directing the needle across the dorsal aspect of the hand could puncture the extensor tendon.

A video on the traditional dorsal approach is available at: http://www.youtube.com/watch?v=z-QGqK7-3As

A more recently described fourth approach is the tumescent technique for digital blocks. It can be performed on any of the 5 digits and is a single-injection technique. Insert the needle at the base of the digit at the proximal crease on the palmar aspect, perpendicular to the skin surface. Inject local anesthetic subcutaneously until the palmar aspect achieves a tumescent state. Slightly more volume (typically 3 to 3.5 mL, total) is introduced to achieve tumescent state dorsally. Two studies have described the success rate of this procedure. (See Figure 6.)

Figure 6. Tumescent Digital Block

Wrist Blocks
Overview: The radial, median, and ulnar nerves supply sensory and motor innervation to the hand and can be blocked at the wrist. (See Figure 7.) Although their areas of innervation are well described, usually more than 1 nerve block is needed due to variable effectiveness of the block and extent of the injury. In addition, anatomical variability may require more than 1 nerve to be blocked. It is reported that 10% of the population has the ulnar/median nerve bifurcation at the third digit as opposed to the fourth digit. If anesthesia is desired for these digits, the use of the digital block techniques described earlier may be considered. Using ultrasound to identify and block the radial, median, and ulnar nerves provides the same sensory block in the hand and requires a lower amount of anesthetic per nerve (2-3 mL). \(^{18}\)

A video of this procedure is available at: http://www.youtube.com/watch?v=dtaHX6wfgA8

Wrist Block, Median Nerve
Anatomy: At the level of the proximal flexor crease, the median nerve runs between the flexor carpi radialis tendon and the palmaris longus tendon. The palmaris longus tendon may be absent in up to 20% of the population. The sensory component innervates the palmar area from the wrist to the thumb, digits 2 and 3, and the radial aspect of digit 4, including the nails to the dorsal aspect at the distal interphalangeal (DIP) joint.

Landmark Technique: Insert the needle perpendicular to the wrist at the level of the proximal flexor crease between the flexor carpi radialis tendon and the palmaris longus tendon or slightly ulnar to the flexor carpi radialis tendon. Advance the needle slowly until it penetrates the deep fascia of the flexor retinaculum and a slight “pop” is appreciated. \(^{14}\) Injection of the anesthetic begins deep and continues as the needle is withdrawn. (See Figure 8.)

Wrist Block, Radial Nerve
Anatomy: The radial nerve branches at the distal third of the forearm prior to entering the wrist and hand. At the level of the wrist, the radial nerve branches fan out, providing innervation to the dorsoradial aspect of the hand. These branches lie in the superficial fascia just deep to the skin. \(^{4}\) The sensory component innervates the dorsal aspect from the wrist to the DIP joint of digits 1, 2, and part of 3, and it does not include the nail of the first digit.

Landmark Technique: The commonly described technique involves identifying the radial artery and radial styloid. At the level of the styloid, a field block is obtained by depositing a continuous subcutaneous track of anesthetic along the dorsoradial aspect of the wrist surrounding the radial styloid. \(^{4,14}\)

Wrist Block, Ulnar Nerve
Anatomy: The ulnar nerve lies directly deep to the flexor carpi ulnaris tendon alongside the ulnar artery. At the level of the proximal flexor crease, the nerve and artery run on the radial side of the tendon; however, the ulnar nerve lies deep to the artery. \(^{2}\) The sensory component of the ulnar nerve innervates the palmar and dorsal aspects of digit 5 and the ulnar aspect of digit 4, including the nail.

Landmark Technique: The ulnar nerve and artery run together into the wrist, and at the level of the proximal flexor crease they lie deep to the flexor carpi ulnaris tendon. A lateral (rather than volar) approach helps avoid the artery because the ulnar nerve lies deep to the artery. The flexor carpi ulnaris tendon can be identified by palpating proximal to the pisiform bone as the patient flexes at the wrist against resistance. Insert the needle at the level of the proximal flexor crease on the ulnar lateral aspect of the wrist, directed horizontally under the flexor carpi ulnaris tendon. Advance the needle in a horizontal plane directed towards the ulnar bone. Inject 3 to 5 mL of local anesthetic as the needle is withdrawn. \(^{14}\) The cutaneous branches of the ulnar nerve run superficially from the lateral border of the flexor carpi ulnaris tendon to the dorsal midline. These can be anesthetized in subcutaneous fashion.

Elbow Blocks
Overview: The median, radial, and ulnar nerves can be blocked at the elbow for extensive injuries of the

Figure 8. Median Nerve Block At The Wrist
The brachial plexus is located in the forearm. All 3 nerves must be blocked for proper anesthesia due to the overlap of sensory innervation throughout the forearm. This makes the use of elbow blocks less common because of the higher risk of neuropathy. Injuries in the proximal forearm may require additional subcutaneous infiltration due to the cutaneous nerves. Due to variations in the depth and location of these nerves among children of different ages, ultrasound guidance is suggested to improve the efficacy of these blocks.

**Elbow Block, Median Nerve**

*Anatomy:* At the elbow, the median nerve runs medial to the brachial artery. It is located in the anteromedial space at the elbow.

*Landmark Technique:* In a flexed position, palpate the brachial artery anteriorly slightly proximal to the antecubital crease and medial to the biceps tendon. Once the artery is palpated, extend the elbow to 30° and insert the needle slightly medial to the artery and perpendicular to the skin. Insert the needle carefully to a depth about halfway to the underlying bone, injecting a volume of 5 to 15 mL after aspiration.

A video of this procedure is available at: [http://www.youtube.com/watch?v=2_ve-mNaYmI](http://www.youtube.com/watch?v=2_ve-mNaYmI)

**Elbow Block, Radial Nerve**

*Anatomy:* On the anterolateral aspect of the elbow, the radial nerve runs with the musculocutaneous nerve in the sulcus between the biceps tendon and the brachioradialis muscle.

*Landmark Technique:* Place the elbow in 90° flexed position. Have the patient contract the muscles isometrically. In the antecubital fossa, 1 cm proximal to the skin crease, palpate the sharp lateral edge of the biceps tendon and the medial edge of the brachioradialis muscle. This is the location of the radial nerve sulcus and the site of needle insertion. Ask the patient to relax the muscles prior to introducing the needle. The needle is positioned perpendicular to the skin and inserted approximately two-thirds of the distance to the underlying bone. After aspiration, 5 to 15 mL of anesthetic is injected into the space. There is a risk of radial artery puncture at this level, and ultrasound guidance has been recommended to decrease the risk of vascular puncture.

**Elbow Block, Ulnar Nerve**

*Anatomy:* At the elbow, the ulnar nerve is found at the ulnar groove located between the olecranon and the medial epicondyle.

*Landmark Technique:* Palpate the ulnar groove in the flexed elbow. A point approximately 1 to 2 cm proximal to the groove is the site of needle insertion. Insert the needle parallel to the course of the nerve in the direction of the ulnar groove. The ulnar nerve is prone to damage if it is blocked at the ulnar groove, as it is a very small compartment space, and injecting anesthetic into the area is likely to cause nerve ischemia and damage. If a paresthesia is induced, the needle must be repositioned to avoid intraneural injection. Approximately 5 to 10 mL of anesthetic is injected proximal to the ulnar groove. In adults, an ulnar nerve block at the elbow by landmark technique has been noted to have a failure rate of 10% to 30%. Ultrasound guidance allows the emergency clinician to track the nerve to a section proximal to the groove and directly visualize anesthetic spread in order to control compartment pressure.

**Axillary Block (Brachial Plexus)**

*Overview:* The axillary nerve block is the most commonly used approach of the brachial plexus blocks in the pediatric population. An axillary nerve block can be used for procedures of the forearm and hand, such as laceration repairs or fracture reduction. This procedure may be challenging in a patient where abduction at the level of the shoulder is compromised; however, the advantages of an axillary block include the simplicity of the anatomy and the low risk of complications. This procedure blocks the radial, median, and ulnar nerves. The musculocutaneous nerve, which innervates the lateral aspect of the forearm, requires a separate block.

*Anatomy:* The brachial plexus is located in the axilla and is comprised of the nerve roots for C5, C6, C7, C8, and T1. In children, the axillary sheath and axillary artery are easily palpated.

*Landmark Technique:* Position the patient with the arm abducted to a 90° angle. Palpate the axillary artery and insert the needle immediately adjacent and anterior to it. The needle is inserted in a 30° to 45° angle aimed towards the midpoint of the clavicle. Advancing the needle will result in sudden laxity of tissue as it enters the plexus sheath. Confirmation of location with a nerve stimulator or ultrasound is recommended, or aspiration should be performed to ensure the needle is not within a vessel. Inject local anesthetic into the plexus sheath, noting swelling. Remove the needle, and hold pressure in the area of needle insertion with adduction of the arm. This allows for proximal spread of the local anesthetic into the plexus sheath.

Videos of this procedure are available at: [http://www.youtube.com/watch?v=3MBmUFMoH7w](http://www.youtube.com/watch?v=3MBmUFMoH7w) and [http://www.youtube.com/watch?v=0N2PnkIDEIY](http://www.youtube.com/watch?v=0N2PnkIDEIY)

**Lower Extremity Nerve Blocks**

**Femoral Blocks**

*Overview:* Femoral nerve blocks have been described in the literature for over 50 years. When done appropriately, they are safe and can provide excellent analgesia in the setting of femoral shaft and neck fractures, especially when reduction is...
Clinical Pathway For Analgesia In Injured Children

Injury in 1-2 nerve distributions?

NO

Large area?
(Amount of anesthetic greater than the maximum allowable dose?)

NO

Allergy to anesthetic?

YES

Contraindication to procedural sedation and analgesia?

NO

Local infiltration of anesthetic for repair (Class II)

YES

Procedural sedation and analgesia for repair (Class II)

• Surgical and anesthesia consult
• Operating room for repair (Class II)

YES

Nerve block with ultrasound or nerve stimulator (if available) technique (Class III)

NO

Allergy or contraindication to anesthetic?

YES

Developmentally appropriate to evaluate paresthesia/sensation?

NO

Class Of Evidence Definitions

Each action in the clinical pathway section of Pediatric Emergency Medicine Practice receives a score based on the following definitions.

Class I
• Always acceptable, safe
• Definitely useful
• Proven in both efficacy and effectiveness

Level of Evidence:
• One or more large prospective studies are present (with rare exceptions)
• High-quality meta-analyses
• Study results consistently positive and compelling

Class II
• Safe, acceptable
• Possibly useful

Level of Evidence:
• Generally higher levels of evidence
• Non-randomized or retrospective studies: historic, cohort, or case control studies
• Less robust randomized controlled trials
• Results consistently positive

Class III
• May be acceptable
• Considered optional or alternative treatments

Level of Evidence:
• Generally lower or intermediate levels of evidence
• Case series, animal studies, consensus panels
• Occasionally positive results

Indeterminate
• Continuing area of research
• No recommendations until further research

Level of Evidence:
• Evidence not available
• Higher studies in progress
• Results inconsistent, contradictory
• Results not compelling

This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient’s individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

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required. It is important to note that this nerve block also affects motor function of the affected extremity.

**Anatomy:** The femoral nerve arises from the spinal lumbar nerves L1, L2, and L3, and it enters the thigh in the femoral triangle below the inguinal ligament. The femoral nerve runs adjacent and lateral to the femoral artery and vein. The femoral nerve courses distally in a fascial sheath that is contiguous with a nerve sheath located higher in the pelvis that contains the femoral, obturator, and lateral femoral cutaneous nerves. These 3 nerves supply the sensory innervation for the majority of the thigh and leg. Nerve block of all 3 nerves requires either a 3-in-1 block (inguinal perivascular block) or the fascia iliaca compartment block.²

**Femoral Nerve Block**

**Landmark Technique:** Place the patient in the supine position with the leg slightly abducted and externally rotated at the hip. Palpate the femoral artery approximately 1 to 2 cm below the inguinal ligament. The site of needle insertion will be just lateral to the femoral artery at that level. Continue to palpate the femoral artery with your nondominant hand as the needle is inserted lateral to the artery at a 90° angle or slightly cephalad to the skin. Advance the needle until a paresthesia is felt, indicating the needle is close to the nerve. Aspiration is essential to ensure the needle is not within a vessel, given the close proximity of the femoral vessels. Confirmation of the position can be done by nerve stimulation, but this is not recommended in a patient with a femur fracture, as muscle contraction will cause increased pain.

Using ultrasound to guide the femoral nerve block will improve precision of the block, but this requires a lateral approach at 45° to the skin in order to visualize the needle sonographically. Upon needle confirmation and aspiration, the local anesthetic can be injected. The volume and dose of local anesthetic used depends on the weight of the patient; however, for an adolescent, a volume of 10 to 15 mL of 1% to 2% lidocaine is typically recommended.¹⁴

The 3-in-1 block (inguinal perivascular block) is similar to the femoral nerve block, with the following modifications. Once the needle is within the femoral sheath, local anesthetic is injected. Distal pressure is maintained for at least 5 minutes after the injection to allow for cephalad spread of the local anesthetic. The 3-in-1 block has a high reported failure rate for successfully anesthetizing all 3 nerves. The femoral nerve is anesthetized 100% of the time (if the procedure is done correctly); however, the lateral femoral cutaneous and obturator nerves are anesthetized only 20% of the time.¹¹ Nonetheless, in the acute emergency setting, the main indication for a femoral block is for a femur fracture, which is well anesthetized with a primary femoral nerve block.

**Fascia Iliaca Compartment Block**

**Landmark Technique:** Palpate the patient’s anterior superior iliac spine and the lateral aspect of the pubic bone. Along the inguinal ligament, divide the distance from the anterior superior iliac spine and the lateral aspect of the pubic bone into thirds. Use a surgical marker to mark one-third of the distance, medially, between these 2 landmarks, just inferior to the inguinal ligament. Insert a needle at the injection point with a 90° angle to the skin. When the needle pierces the fascia lata, an initial “pop” sensation is felt. As the needle is advanced further through the fascia iliaca, a second “pop” will be felt, at which point the target compartment has been entered. Aspirate to confirm the needle is not in a vessel, and apply pressure 1 inch caudal to the injection site as local anesthetic is injected. Continue to apply distal pressure for 2 minutes after the injection.²¹

In a randomized study of 55 patients presenting to the pediatric ED with femur fractures, pain control was compared in patients receiving intravenous morphine versus a fascia iliaca compartment block. The study noted an 18% improvement in pain reduction at 30 minutes and a 15% reduction at 6 hours, favoring the fascia iliaca compartment block group.²¹ This study indicates that there is improved pain control for pediatric patients presenting with a femur fracture who receive a fascia iliaca compartment block.

Video demonstration is available at: [http://www.youtube.com/watch?v=w0SkxMRyZfM](http://www.youtube.com/watch?v=w0SkxMRyZfM)

**Ankle/Foot Blocks**

**Overview:** There are 5 peripheral nerves that divide the sensory innervation of the ankle and foot. Nerve blocks of the ankle are the preferred method for local anesthesia to this area due to the painful nature of direct infiltration of the foot.

Videos of ankle blocks are available at:
[http://www.youtube.com/watch?v=7PYreMxoKPo](http://www.youtube.com/watch?v=7PYreMxoKPo)
[http://www.youtube.com/watch?v=tcnPkfbpYl4](http://www.youtube.com/watch?v=tcnPkfbpYl4)

**Posterior Tibial Nerve**

**Anatomy:** This nerve is the major source of sensory innervation to the plantar aspect of the foot. It lies posteriorly to the posterior tibial artery between the medial malleolus and the Achilles tendon. (See Figure 9, page 12.) It branches into the medial and lateral plantar nerve to innervate the plantar aspect of the foot, including the digits.

**Landmark Technique:** Place the patient in a prone position with the foot slightly dorsiflexed. Palpate the posterior tibial artery slightly posterior to the medial malleolus. Insert the needle slightly superior and medial to the artery, directed at a 45° angle to the mediolateral plane of the leg until bony contact is made or a paresthesia is elic-
Other Blocks

Bier Block (Intravenous Regional Anesthesia)

**Overview:** This procedure is used to anesthetize an extremity by injecting anesthesia intravenously and containing the anesthetic within the extremity by use of a tourniquet. It has been used for extremity fracture reductions and for surgical procedures lasting < 90 minutes.³

**Technique:** This procedure requires 2 intravenous lines: an intravenous line in the extremity requiring anesthetic and a second intravenous line in a noninvolved location to provide medications and fluids, as needed. Two tourniquets are placed at the proximal portion of the extremity requiring anesthetic. Both tourniquets should have secure closure and reliable pressure gauges; regular blood pressure cuffs are not recommended, as they often leak and are not designed to hold pressures for prolonged periods of time. Traditionally, exsanguination of the extremity occurs by elevating it and wrapping it with an elastic bandage, starting distally and moving proximally. At this point, the proximal tourniquet is inflated to approximately 50 mm Hg above systolic pressure for an upper extremity procedure and approximately 100 mm Hg for a lower extremity procedure. After proper inflation, the 1.5 mg/kg of 0.5% lidocaine or 0.5% prilocaine is slowly infused via the intravenous line in the target extremity, and block is achieved in 5 to 10 minutes. If the initial dose does not provide adequate anesthesia, an additional 0.5 to 1 mg/kg can be infused. If the proximal tourniquet is causing pain, the distal tourniquet is inflated to the same setting and the proximal tourniquet is released. The distal tourniquet is now overlaying an anesthetized area and should not induce any pain. Once the surgical procedure is complete, the

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**Sural Nerve**

**Anatomy:** The sural nerve runs posteriorly on the lateral aspect of the ankle. It lies superficially between the lateral malleolus and Achilles tendon. (See Figure 9.) It supplies the sensory innervation of the lateral aspect of the foot, both dorsal and plantar.

**Landmark Technique:** Place the patient in a prone position with the foot slightly dorsiflexed. The block consists of a superficial band injection approximately 1 cm above the lateral malleolus between the lateral malleolus and the Achilles tendon.

**Superficial Peroneal Nerve**

**Anatomy:** At the level of the ankle, the superficial peroneal nerve consists of several branches that lie superficially between the lateral malleolus and extensor hallucis longus tendon.¹⁴ This nerve supplies the sensory innervation for the dorsum of the foot. (See Figure 10.)

**Landmark Technique:** Place the patient in a supine position with the foot in a neutral position. Identify the extensor hallucis longus tendon on the lateral anterior portion of the ankle. At the level of the ankle between the lateral malleolus and the extensor hallucis longus tendon, inject a superficial infiltration of local anesthetic in a band-like pattern.¹⁴

**Deep Peroneal Nerve**

**Anatomy:** At the level of the ankle, the deep peroneal nerve runs under the extensor hallucis longus tendon. This nerve supplies the sensation for the web space between digits 1 and 2. (See Figure 10.)

**Landmark Technique:** Place the patient in a supine position. At the level of the base of the medial malleolus, palpate the anterior tibial tendon and extensor hallucis longus tendons when the patient dorsiflexes the foot and the first toe, respectively. After depositing a subcutaneous wheal of anesthetic, place the needle between these 2 tendons, directed 30° laterally, and advance under the extensor hallucis longus tendon until there is contact with the tibia. Withdraw the needle slightly and inject local anesthetic.²,¹⁴ (See Figure 10.)

**Saphenous Nerve**

**Anatomy:** At the level of the ankle, the saphenous nerve runs parallel and superficial to the saphenous vein between the medial malleolus and tibialis anterior tendon. This nerve supplies the innervation to the medial foot and arch.

**Landmark Technique:** A subcutaneous injection of local anesthetic between the medial malleolus and the anterior tibial tendon produces a nerve block.²,¹³ (See Figure 10.)

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**Figure 9. Landmarks Of The Ankle**

- Posterior tibial artery
- Tibial nerve
- Sural nerve
- Achilles tendon
distal tourniquet is slowly released for 15 seconds and reinflated. This is repeated 3 to 4 times to release the local anesthetic in short intervals in order to decrease systemic complications.3

Potential Complications: Complications can result from systemic spread of local anesthetic. Lidocaine can cause neurotoxicity or procedure seizures if a large volume is released or if the tourniquet fails. Prilocaine has the potential of inducing methemoglobinemia in susceptible patients or when interactions occur with other medications. The use of bupivacaine is contraindicated due to its potential for cardiotoxicity.3

Penile Block Overview: This procedure is used for wound or injury to the shaft and tip of the penis. It is important to note that epinephrine should not be used with anesthetics for penile blocks because it can cause severe vasoconstriction and lead to tissue ischemia. Three techniques have been demonstrated to achieve a penile block: (1) subcutaneous ring block, (2) dorsal penile nerve block, and (3) subpubic block.3

Anatomy: The sensory innervation of the penis is supplied by the dorsal penile nerve, which branches off the pudendal nerve. The dorsal nerves course adjacent to the dorsal vessels and are surrounded by Buck’s fascia.3

Penile Block, Subcutaneous Ring Block Landmark Technique: A superficial infiltration of local anesthetic (without epinephrine) is injected circumferentially at the base of the penis. This is superficial to Buck’s fascia but provides adequate anesthesia to the area. This block is most often used for neonatal circumcisions.

Penile Block, Dorsal Penile Nerve Block Landmark Technique: At the base of the penis, the needle is inserted at the 10 o’clock and 2 o’clock positions. The needle is advanced into Buck’s fascia with careful aspiration to avoid the dorsal vessels. Local anesthetic is then injected around the dorsal nerves. Ultrasound can confirm needle position. This technique is often used for surgical or wound-repair procedures.

A video of this procedure is available at: http://vimeo.com/33647051

Penile Block, Subpubic Block Landmark Technique: The penis is positioned ventrally and the symphysis pubis identified. The needle insertion site is located lateral to the midline and caudal to the symphysis pubis. The needle is positioned perpendicular to the skin and aimed medially and caudally until Scarpa’s fascia is crossed. A sensation of resistance followed by laxity is felt as the needle is inserted through Scarpa’s fascia. Needle aspiration is required prior to injection of anesthetic. This procedure can be used instead of the dorsal penile approach if there is redundant tissue or single-needle insertion is desired.

Special Circumstances

The child may not tolerate the process of needle insertion due to developmental limitations or other reasons. It is preferable that the child be able to reliably communicate levels of pain or discomfort, but the lack of ability to communicate should not necessarily exclude the patient from undergoing a nerve block. In anxious children, it may be difficult to assess the effectiveness of nerve blocks because

Figure 10. Nerve Blocks At The Ankle

Images A and B show the transverse plane of the ankle structures shown in the image C cross-section.
they may perceive pressure in an anesthetized area as pain. The use of ultrasound can aid in performing effective nerve blocks in children who are unable to adequately communicate paresthesias or anesthesia. The emergency clinician can also attempt other methods of anxiety and pain control in these patients as an adjunct to peripheral nerve blocks. Additional strategies that may aid as adjuncts include the use of the following: (1) a child life specialist, (2) distraction modalities, (3) topical anesthetics or injection of a subcutaneous wheal of local anesthetic using a 29-gauge insulin syringe prior to injection of target nerves, and/or (4) anxiolytics such as midazolam and nitrous oxide.

Controversies And Cutting Edge

Use Of Ultrasound In Nerve Blocks
Ultrasound guidance of nerve blocks was introduced in 1994, and its benefits have been demonstrated in the pediatric setting since 2004. Since the introduction of ultrasound, several articles in the anesthesiology literature have substantiated the advantages of using ultrasound technology in pediatric nerve blocks. The advantages of ultrasound-guided peripheral nerve blocks include: (1) direct visualization of the anatomical structures, (2) real-time control of needle advancement, (3) assessment of the spread of anesthetic around the nerve, (4) decreased amounts of anesthetic required to achieve a nerve block, and (5) decreased number of complications.

Most nerve blocks performed in the pediatric emergency setting are superficial in nature and may be easily achievable by simple anatomical landmarks. However, ultrasound guidance can improve success of nerve blocks by providing real-time visualization of the nerve and its surrounding structures. The success rate of ultrasound-guided peripheral nerve blocks in the pediatric emergency setting has not been fully evaluated. The success rate in terms of direct nerve and structural visualization, time duration of the procedure, block effectiveness, and block onset is best described in the anesthesia and emergency medicine literature. Multiple clinical studies have demonstrated that ultrasound use allows accurate and direct visualization of superficial nerves, specifically in the pediatric population. In addition, the visualization of surrounding anatomical structures (such as vessels and tendons) provides the opportunity to deliver the appropriate amount of anesthetic and prevents intravascular or intraneural injection.

There is evidence to suggest that ultrasound guidance shortens both the time necessary to perform the block and the time to complete anesthesia. In 2 randomized controlled trials of 188 and 90 subjects, the authors reported a reduction in the time necessary to perform an ultrasound-guided axillary block compared to a nerve stimulator-guided axillary block. Several other retrospective and randomized controlled trials show a reduction in the procedure time with the use of ultrasound guidance. In a randomized controlled trial of 40 patients, ultrasound-guided infraclavicular blocks resulted in complete anesthesia within 9 minutes compared to 15 minutes in the nerve stimulation guidance control group.

The success rate of nerve block anesthesia with ultrasound guidance has also been compared to the nerve stimulation and landmark techniques. In a randomized controlled trial of 100 pediatric patients comparing the effectiveness of ilioinguinal and iliohypogastric blocks using ultrasound guidance versus the more traditional "fascial click" technique, there was an increased failure rate in the fascial click-guided group. The study reported a 96% success rate in the ultrasound group versus a 74% success rate in the fascial click group. In addition, 2 randomized controlled trials comparing the anesthetic dose for ultrasound-guided nerve blocks with conventional methods reported significantly lower doses and volume of anesthetic used in ultrasound-guided blocks compared to either nerve stimulator guidance or fascial click guidance. The literature also notes a significant increase in block duration, specifically in the pediatric population. In a randomized controlled trial of sciatic and femoral blocks, the ultrasound-guided group had a mean anesthesia duration of 508 minutes compared to 335 minutes in the nerve stimulation group (despite using a significantly lower volume of anesthetic in the ultrasound-guided group).

Overall, there is a paucity of pediatric literature on ultrasound-guided peripheral nerve blocks. However, the available studies demonstrate both statistical significance and clinical advantages when using ultrasound guidance for peripheral nerve blocks compared to more conventional methods.

Complications For Ultrasound-Guided Nerve Blocks
Complication rates of ultrasound-guided nerve blocks are comparable to those with conventional techniques. Several clinical trials comparing ultrasound guidance versus nerve stimulation guidance report an incidence of accidental vessel injury or bruising between 0 and 4%. In 3 studies, there was a significant decrease in vessel puncture in the ultrasound group. Similarly, the frequency of unintentional paresthesias during block performance is lower when using ultrasound guidance. In a Cochrane review of 17 randomized controlled trials of ultrasound-guided nerve blocks versus nerve stimulator-guided nerve blocks, the rates of complications were equally low and variable throughout the studies. They reported no major complications (including cardiorespiratory arrest, seizures, pneumothorax, or...
Needle Positioning Techniques
The position of the needle with respect to the probe is described in 2 main approaches: the in-plane technique and the out-of-plane technique. The in-plane approach refers to the needle placed within the ultrasound beam, parallel to the transducer. The needle is visualized as it is advanced through the skin to target structures, and it can be traced throughout its entire trajectory. The out-of-plane approach refers to placement of the needle perpendicular to the transducer. Only a segment of the needle is visualized at a given time. The needle cannot be viewed in its entirety, and it can be difficult to distinguish the shaft of the needle from the tip of the needle. Once the needle tip is abutting the desired nerve, the spread of local anesthetic can be directly visualized as an expanding collection of hypoechoic fluid surrounding the nerve. In general, direct contact with the nerve tissue should be avoided to prevent intraneural anesthetic injection. Circumferential hypoechoic fluid surrounding the nerve (also known as the “donut sign”) is considered an indication of adequate spread of local anesthetic around the nerve. (See Figures 11 and 12.)

A study involving 31 anesthesiologists reported a higher rate of accuracy in both expert and novice groups by using the in-plane approach, with no difference in the time to perform the block. However, evidence to support using the in-plane or out-of-plane approaches vary according to the type of nerve block. Although a detailed discussion in the use of ultrasound guidance in specific nerve blocks is beyond the scope of this review, we suggest the following websites as useful references for further information:

- http://www.usra.ca
- http://www.neuraxiom.com
- http://www.nysora.com

Figure 12. Post-Nerve Block Ultrasound Image

V indicates the vessel. Arrow points to the nerve. Note the infiltrated anesthetic, or “donut sign.”
Image courtesy of Sacha Duchicela, MD.

Figure 11. Pre-Nerve Block Ultrasound Image

V indicates the vessel. Arrow points to the nerve.
Image courtesy of Sacha Duchicela, MD.

Techniques And Approaches To Ultrasound-Guided Nerve Blocks
The use of ultrasound as a tool in the ED is limited by the experience of the operator. This also applies to ultrasound-guided regional anesthesia. Successful ultrasound-guided nerve blocks can be performed by optimization of image quality and use of proper needle technique.

Improving Image Quality
For peripheral nerve blocks, linear high-frequency transducers are generally used to locate the target nerve(s) and surrounding structures. Vessels, muscles, and bones are easily identifiable and can help confirm the correct anatomical location of the nerve. Sonographically, nerves are generally hyperechoic, with anechoic fascicles that are often described as having a honeycomb-like structure when viewed in the transverse axis. Nerves have a sonographic property called anisotropy, where they appear hyperechoic when the transducer is oriented perpendicular to the nerve but hypoechoic when oriented obliquely to the nerve. Nerves are often found adjacent to vascular structures that can be identified by using color or pulse wave Doppler modes. Optimizing views of the target nerve by adjusting the angle of the transducer and the depth and gain of the images will help improve the success rate of ultrasound-guided nerve blocks.
Use Of The Nerve Stimulator In Nerve Blocks
One of the challenges in performing successful pediatric nerve blocks is relying on surface landmarks, tactile appreciation, or induced paresthesias to confirm correct needle placement. Due to the range of anatomical variability in children of different ages, a nerve block may not only seem like a daunting task, but it may have a low success rate. In 1964, Greenblatt introduced the electric nerve stimulator, which allowed for increased success with regional nerve blocks such as the axillary plexus. However, several subsequent studies have demonstrated limitations to nerve stimulation, including it only being able to detect needle-nerve proximity (which could include an intravascular or intraneural location), unpleasant electrical stimulation, and harmful electrical paresthesia. This instrumentation is more widely used in anesthetized patients, and its use has not been demonstrated in the pediatric emergency setting.

Disposition
Discharge criteria are largely dependent on underlying medical conditions and associated injuries; however, some general principles apply after a peripheral nerve block. The anesthetized region must be neurovascularly intact, and all vital signs must be normal. The return of full sensation is not required for disposition for most nerve blocks (with the exception of lower extremity blocks). Since anesthetic effects last for several hours, it is not necessary to wait for full sensation to return before discharge. It is important to confirm that the nerve block did not cause intravascular or intraneural damage. Assessing proper vascular flow and sensory/motor function of the region distal to the peripheral block can provide clinical evidence that there was no vascular or neural damage. Patients with any lower extremity block must demonstrate ability to ambulate when clinically appropriate, as long as there are no further injuries preventing ambulation. These patients are given instructions for fall precautions and are assisted with ambulation at discharge. Documenting stable vital signs assists in evaluating for systemic reactions to the anesthetic. Every patient needs follow-up with a medical provider after undergoing a procedure that involves a nerve block. It is important that the medical provider evaluate for changes in sensation or movement of the anesthetized area as well as follow the injury as it heals over time. Parents of children with lacerations should be provided with appropriate wound care instructions, prophylactic antibiotics if needed, and follow-up for wound checks and suture removal. If the procedure involves a fracture reduction, follow-up with an orthopedic or plastic surgeon may be needed.

Summary
Pain control in injury management plays an important role in pediatric emergency medicine. Regional nerve blocks are widely underused in the pediatric population for a variety of reasons; however, when performed appropriately, they can provide adequate analgesia while having a very low risk of systemic toxicity. Nerve block techniques have been developed using anatomical landmarks, nerve stimulation, and ultrasound guidance. Regional pain management can be a challenge in children due to poor patient cooperation and anatomical variability, but when incorporated into a comprehensive pain management program including developmentally appropriate psychological approaches and pharmacologic adjuvants, nerve blocks allow for focused and efficient pain control, an increased safety margin, and more effective wound or injury management. In addition, while more studies are necessary in the pediatric population, the incorporation of ultrasound guidance for nerve blocks appears to increase the accuracy and success of nerve blocks in children.

Case Conclusion
The 15-year-old assaulted male was noted to have a closed displaced left femur fracture and multiple large lacerations on the right side of his face. You asked the nurse to place an IV to provide pain medication. You administered morphine 0.1 mg/kg IV, which improved his pain; however, upon manipulation for portable radiographs, the patient experienced significant pain. You decided to proceed with an ultrasound-guided femoral nerve block. The procedure was successful, and the patient was able to tolerate manipulation of his left leg and subsequent reduction and immobilization by orthopedic surgery with no additional sedation. A landmark-guided right infraorbital block and a right mental block allowed you to repair the facial wounds. The patient was admitted for observation and surgical repair of the femur fracture the following morning.
## Risk Management Pitfalls For Pediatric Nerve Blocks

1. “The child wouldn't tolerate the block procedure.”
   Children may not tolerate procedures due to high anxiety levels. Utilizing a child life specialist, distraction techniques, or anxiolytics may help the child tolerate the procedure.

2. “I couldn’t tell if the nerve was properly blocked because the child couldn’t communicate.”
   There are a variety of behavioral response assessments and pain scales that can help determine whether the patient is feeling discomfort or if the block has successfully anesthetized the area.

3. “I wasn’t sure of the correct method for the nerve block, so I decided to try local infiltration instead.”
   Taking the time to review the techniques for nerve blocks can potentially decrease the amount of anesthetic used, the time required to anesthetize the area, and the distortion caused by local infiltration.

4. “I sedated the girl with a femur fracture for portable radiographs because she couldn’t tolerate the manipulation.”
   Sedating a patient will not guarantee decreased pain with manipulation; however, a nerve block will anesthetize the area and allow for more appropriate imaging of an awake and alert patient in the radiology suite without the antecedent risks of procedural sedation. The duration of nerve blocks may also allow subsequent repair with a single dose of anesthetic compared to possible repeat doses of sedating medications.

5. “I decided to use lidocaine without epinephrine because it had a lower dose and therefore posed less risk of toxicity.”
   Epinephrine is recommended because it will allow for vasoconstriction in the area and a longer duration of anesthetic. If there is a dosing concern, then the concentration of anesthetic should be lowered and a nerve block should be considered.

6. “I didn’t do a nerve block because I was afraid I would puncture a vessel and cause further damage.”
   While it is possible to puncture a vessel while performing a nerve block, simple pressure to the area will create hemostasis and the procedure can be attempted again. Using ultrasound may assist in avoiding vessels and may decrease the rate of complications.

7. “Using the ultrasound machine requires too many hands. I did the nerve block by landmarks alone.”
   If there are no available personnel to assist in the procedure, simply reviewing the anatomy of the area with ultrasound may assist in the initial placement and direction of your needle.

8. “I didn’t do a nerve block because they have a high risk for causing permanent nerve damage.”
   Done properly, nerve blocks have a low rate of complications and can successfully produce analgesia and anesthesia.

9. “Nerve blocks can only be used for laceration repair.”
   Nerve blocks can be successfully used in the management of many types of injuries, including fracture and dislocation reduction, foreign body removal, incision and drainage of abscesses, and wound management.

10. “I tried to ‘spread out’ the maximum dose of anesthetic via local infiltration to repair this wound.”
    Inadequate analgesia caused by “spreading out” local infiltration can make proper injury repair more difficult. A smaller dose of anesthetic used in a nerve block can produce adequate anesthesia to aid in wound management.
References

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study will be included in bold type following the references, where available. The most informative references cited in this paper, as determined by the author, will be noted by an asterisk (*) next to the number of the reference.


21. Wathen JE, Gao D, Merritt G, et al. A randomized controlled trial comparing a fascia iliaca compartment nerve block to a...
traditional systemic analgesic for femur fractures in a pediatric emergency department. Ann Emerg Med. 2007;50(2):162-171. (Randomized study; 55 patients)


CME Questions

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1. Which type of local anesthetic can be harmful in a patient aged < 6 months?
   a. Amides
   b. Esters
   c. Neither amides nor esters
   d. Both amides and esters

2. Regional nerve blocks have been documented to have high rates of serious complications such as cardiorespiratory arrest, pneumothorax, seizures, or nerve damage.
   a. True
   b. False

3. Recent literature has suggested that the use of lidocaine with epinephrine in end-artery regions such as the digits, nose, and ears is likely to result in complications.
   a. True
   b. False

4. Peripheral nerve blocks are largely underused in pediatric emergency care because of:
   a. Uncooperative patients
   b. Anatomical variations
   c. Lack of success of the procedure
   d. Lack of experience by clinicians
   e. All of the above
5. Because of the location of the great auricular nerve, emergency clinicians must be cautious of which of the following?
   a. Horner syndrome
   b. Hemidiaphragm paralysis
   c. Trapezius muscle paralysis
   d. Disruption of the jugular vein and carotid artery
   e. All of the above

6. A femoral nerve block is a good choice of analgesia for femur fractures.
   a. True
   b. False

7. Which nerve block is adequate for a laceration involving the plantar surface of the foot?
   a. Sural nerve block
   b. Posterior tibial nerve block
   c. Deep peroneal nerve block
   d. Femoral nerve block

8. A teenager presents to the ED with a laceration between his first and second toe after attempting to pick up a knife with his toes in a dare. What is the most effective nerve block for this region?
   a. Sural nerve block
   b. Superficial peroneal nerve block
   c. Deep peroneal nerve block
   d. Femoral nerve block

9. Which type of penile nerve block requires insertion below Buck’s fascia?
   a. Dorsal penile nerve block
   b. Subcutaneous ring block
   c. Subpubic block
   d. None of the above

10. The in-plane needle technique is when the needle can be visualized in its entirety by the ultrasound window.
    a. True
    b. False