The growing use of regional anesthesia in infants, children, and adolescents has increased the popularity of peripheral nerve blocks in children. This review enumerates some of the more common peripheral nerve blocks used in this population and provides an easy approach to these blocks for common surgical procedures. A brief description of anatomy, followed by common indications with techniques often used for these blocks, along with potential adverse effects, will be discussed (Table).

### Head and Neck Blocks

Head and neck blocks can be performed on pediatric patients for postoperative pain control. Postoperative pain relief for several common head and neck procedures in children can be provided using simple landmark techniques. One advantage of using nerve blocks is the ability to reduce the incidence of postoperative nausea and vomiting (PONV) while providing adequate analgesia in the postoperative period.\(^1\) Several reviews of the anatomy and techniques in head and neck blocks have been published that provide a quick reference for these procedures.\(^2\)

#### Supraorbital Nerve Block

**Anatomy:** Derived from the V1 branch of the trigeminal nerve as it exits the supraorbital foramen. The foramen easily can be detected by palpation or recognized by its presence in the midline at the level of the mid-pupillary line. The nerve supplies the frontal area anterior to the coronal suture and is a pure sensory nerve.

**Indications:** Frontal craniotomy, ventriculo-peritoneal shunts, plastic surgery, and dermatologic procedures.\(^3\,^4\)

**Technique:** Using a 30-G needle, the skin over the area of the supraorbital foramen is injected subcutaneously (Figure 1). This will provide analgesia anterior to
the coronal suture on the side of the block placement.

**Adverse effects:** Hematoma at the site of the injection.

**INFRAORBITAL NERVE BLOCK**

**Anatomy:** Derived from the maxillary division of the trigeminal nerve, the terminal branches of V2 form an arborization of sensory nerves that supplies the upper lip, tip of the nose, and parts of the maxillary area. The nerve exits at the base of the orbit. The nerve location can be mapped externally using the midpupillary area as the marker for localization of the infraorbital foramen. A formula has been derived for the position of the infraorbital foramen; external landmarks using anatomical markings also have been used.\(^5,6\)

**Indications:** This block can be used effectively for management of pain following cleft lip repair, as well as for nasal septal surgery.\(^7-9\) One study of infants demonstrated the efficacy of this block, as well as its ability to encourage adequate feeding.\(^8\)

**Technique:** The infraorbital nerve is superficially sensory and therefore easy to access. After the surface landmarks are determined, the nerve can be accessed from an external extraoral approach or through an internal

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**Head and Neck**

**Upper Extremity**

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intraoral approach (Figure 2). Although controversy exists as to which approach is easier and safer, data demonstrate the superiority of the intraoral approach.\textsuperscript{10} We routinely use the intraoral approach to the infraorbital nerve for postoperative pain relief. The lip is everted and a 27-G needle is inserted intraorally toward the infraorbital foramen. After aspiration, 0.5 to 1.5 mL of 0.25% bupivacaine is used to provide analgesia. It is important to massage the area after injection of the local anesthetic to allow adequate spread of the solution.

**Adverse effects:** A hematoma may form at the site of injection if adequate pressure is not applied after needle insertion. Dysesthesia or paresthesia may occur in rare cases but typically are short lived and do not cause permanent nerve damage.

**Occipital Nerve Block**

**Anatomy:** The greater occipital nerve, a branch of C2, supplies the posterior occiput along with the lesser occipital nerve. The nerve is located lateral to the midline and the occipital artery.\textsuperscript{11} The nerve is superficial in its location here and easily can be accessed.

**Indications:** Occipital neuralgia, craniotomy, frame placement for stereotactic surgery.\textsuperscript{3,12,13}

**Technique:** This block generally is performed using a landmark technique. The occipital protuberance is palpated, the pulsation of the occipital nerves is localized, and a superficial injection of 0.25% bupivacaine is placed subcutaneously (Figure 3). Gentle massage of the area is carried out to spread the local anesthetic solution.

**Adverse effects:** With the potential for intravascular injection, careful aspiration is suggested prior to injection of local anesthetic.

**Superficial Cervical Plexus Block**

**Anatomy:** The superficial cervical plexus derives from the cervical nerve roots C2, C3, and C4. The plexus wraps around the belly of the sternocleidomastoid muscle and divides into 4 main branches: the greater auricular nerve, the lesser occipital, transverse cervical, and the supraclavicular branch. When blocked, these sensory nerves provide analgesia to the postauricular area, the pinna, the anterior portion of the neck, and the skin over the shoulder. The nerve is located easily at the level of the cricoid and at the border of the sternocleidomastoid.

**Indications:** Tympanomastoid, thyroid, airway,\textsuperscript{1} and reconstructive ear surgery.\textsuperscript{14-16}

**Technique:** It is important to identify the posterior border of the sternocleidomastoid. At the level of C6, a transverse line bisecting the muscle is identified. A skin wheal is placed in the subcutaneous area after sterile preparation of the site (Figure 4). A volume of 0.5 to 2 mL of local anesthetic solution can provide adequate analgesia for up 12 hours following mastoid surgery without the PONV that are associated with opioids often used to control postoperative pain.

**Adverse effects:** Potential for deep cervical plexus injections and injection into the vascular structures located close to the nerve bundle.
Upper Extremity Blocks

Peripheral regional anesthesia is of great utility in children undergoing surgery on the upper extremities. There are various techniques in completing brachial plexus blockade, including axillary, interscalene, supraclavicular, and infraclavicular approaches. The use of ultrasound guidance allows for real-time visualization of anatomical structures; however, some centers prefer nerve stimulation to guide peripheral nerve blockade. Although the axillary block is the most commonly performed brachial plexus block in children, advances in the use of ultrasonography may enhance the appeal of other techniques.

**AXILLARY APPROACH**

**Anatomy:** The axillary approach blocks the radial, median, and ulnar nerves. Although anatomic variation may exist, the radial nerve lies posterior to the axillary artery and the ulnar nerve is anterior and inferior to the artery. The location of the median nerve has considerable variation and is usually anterior and superior to the axillary artery. The musculocutaneous nerve usually lies between the coracobrachialis and biceps muscles.

**Indications:** Surgical procedures on the elbow, forearm, or hand. We prefer it mainly for procedures on the hand. The axillary approach is among the most common routes to the brachial plexus in children.

**Technique:** Ultrasound-guided axillary blocks in children are not well described in the literature. Techniques used in adults can be duplicated in children. An in-plane method can be employed, with the ultrasound probe placed transverse to the humerus. Multiple injections with needle redirections allow for circumferential spread of local anesthetic around each nerve (Figure 5). The close proximity of the axillary artery and vein to the nerves may necessitate multiple punctures to avoid intravascular injection. The shallow depth of these structures requires careful advancement of the needle under direct ultrasound guidance.

**Adverse effects:** Complications include infection at the site of skin puncture, axillary tenderness, hematoma, intravascular injection, and nerve damage. The advanced use of ultrasound guidance for real-time visualization may reduce the risk for intravascular injection and nerve damage.

**INTERSCALENE APPROACH**

**Anatomy:** The anatomical boundaries allow for blockade of the trunks of the brachial plexus lying between the anterior and middle scalene muscles. Ultrasonography enables direct visualization of the C5, C6, and C7 nerve roots between the anterior and middle scalene muscles.

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**Figure 4.** Subcutaneous injection to provide superficial cervical plexus blockade.

**Figure 5.** Ultrasound image of the brachial plexus from the axillary approach. A. The median, ulnar, and radial nerves (dotted circles). B. The musculocutaneous nerve (dotted circle with arrows).
**Indications:** The interscalene block often is used to provide analgesia for patients undergoing surgery on the shoulder and proximal upper arm. It also can be used for catheter placement for postoperative pain control. The interscalene block is rarely used in children due to the potential risks for pneumothorax, vertebral artery injection, intrathecal injection, as well as the low incidence of isolated shoulder surgery in this population.

**Technique:** The ultrasound probe typically is placed at the level of the cricoid cartilage at the posterolateral aspect of the sternocleidomastoid muscle in the transverse oblique plane. Lateral to the subclavian artery and vein and posterior to the sternocleidomastoid muscle are the anterior and medial scalene muscles. Within this interscalene groove is a hyperechoic structure composed of the neurovascular bundle of the C5, C6, and C7 nerve roots (Figure 6). Using a combined ultrasound-guided, nerve-stimulating technique, an insulated needle can be advanced and local anesthetic delivered to surround the brachial plexus at this level.

**Adverse effects:** Pneumothorax and vertebral artery and intrathecal injection. Successful blockade is accompanied by hemidiaphragmatic paralysis, recurrent laryngeal nerve block, and Horner syndrome that should not be mistaken for complications.

**SuprACLavicular Approach**

**Anatomy:** At this level, the trunks and divisions of the plexus are superior and lateral to the subclavian artery. The first rib is located immediately posterior and medial to the brachial plexus.

**Indications:** The suprACLavicular block provides analgesia for most upper extremity procedures, particularly the upper arm and elbow. It generally provides a predictable and immediate block after local anesthetic injection. In children who require neurovascular testing following surgery, the suprACLavicular block has been performed safely in the postanesthesia care unit following such testing.

**Technique:** Limited techniques in the pediatric population have been described. An ultrasound probe can be placed in the coronal-oblique plane immediately lateral to the upper border of the clavicle. The subclavian artery is visualized as the hypoechoic pulsatile structure (Figure 7). Using an in-plane approach, a needle can be advanced superior and lateral to the subclavian artery and above the first rib. Navigating the needle in a lateral-to-medial fashion, the needle can be directed to avoid vascular structures and intraneural injection. As an alternative the out-of-plane approach to the suprACLavicular plexus using ultrasound guidance also can be successful.

**Adverse effects:** In addition to the risks associated with other brachial plexus blocks, suprACLavicular block carries an increased risk for pneumothorax, as the lung parenchyma lies just medial and posterior to the brachial plexus at the level where the block is completed. Visualization of the tip and shaft of the needle with ultrasonography may reduce the risks.

**InfraคลAVicular Approach**

**Anatomy:** The brachial plexus cords are located medial and inferior to the coracoid process. In addition, the axillary artery and vein are deeper and medial to the cords, and the pectoralis major and minor lie superficial to the neurovascular bundle. The lateral cord of the plexus can be visualized on the ultrasound as a hyperechoic structure. The medial cord is difficult to identify on ultrasound as it lies between the axillary artery and vein, and posterior cord often is not visible, as it lies deep to the axillary artery.

**Indications:** The intraCLavicular block often is used to provide analgesia for the upper arm and elbow. It is particularly useful for placing a catheter in the posterior cord for major reconstructive procedures of the upper extremities.

**Technique:** Marhofer et al described their use of the ultrasound-guided intraCLavicular block in children.
using the lateral approach. The ultrasound probe was placed transversely below the clavicle to visualize the brachial plexus. Using an out-of-plane technique, a needle was inserted 1 cm inferior to the probe and aimed at the lateral aspect of the brachial plexus. Spread of local anesthetic was then visualized surrounding the plexus. De José Maria et al placed the probe parallel to the clavicle in a parasagittal plane and inserted the needle cephalad to the probe.

Adverse effects: The infraclavicular approach carries similar risks to those of the supraclavicular approach. Pneumothorax remains possible, as the cervical pleura is medial to the plexus where the block is placed. Therefore, a lateral approach is preferred for this block.

Lower Extremity Blocks

Multiple regional anesthesia techniques can be used for children undergoing surgery on the lower extremities, including the lumbar plexus, femoral, and sciatic nerve blockade. These procedures may be performed with the aid of nerve stimulation and ultrasound guidance.

Lumbar Plexus Block

Anatomy: The lumbar plexus is located deep to the paravertebral muscles and may be embedded in the psoas muscle, making this block technically difficult in older children. The technique can provide analgesia to the major branches of the lumbar plexus, including the femoral, genitofemoral, lateral femoral cutaneous, and obturator nerves.

Indications: Surgical procedures on the hip, knee, or foot.

Technique: The patient is placed in the lateral decubitus position, whereupon the iliac crest and spinous processes are identified. Using ultrasound guidance, the transverse processes of L4 or L5 are identified. The psoas major muscle and plexus lie beneath the erector spinae and/or quadratus lumborum muscles. As a result, they often are best visualized in the transverse view. The lumbar plexus may be difficult to see in older children because the psoas major is similarly echogenic. When using nerve stimulation, Twitches of the paravertebral muscles can be elicited on insertion of the needle. Upon approach to the plexus, twitching of the quadriceps is anticipated to confirm proximity.

Adverse effects: Inadvertent epidural injection is possible because the lumbar plexus is located within deep structures lateral to the spinous processes. Infection at the site of skin puncture, hematoma, and local anesthetic toxicity also may occur.

Femoral Nerve Block

Anatomy: The femoral nerve originates from nerve roots L2, L3, and L4 and when blocked provides surgical anesthesia and analgesia for the anterior thigh extending to the knee. Located lateral to the femoral artery, this landmark is easily palpable on examination and can easily be visualized with ultrasound. Other blocks of the lumbar plexus at this level include the fascia iliaca and 3-in-1 blocks; however, data are lacking for the use of ultrasound to achieve these blocks in pediatric patients.

Indications: Surgical procedures on the anterior thigh and the knee, including anterior thigh biopsy and knee arthroscopy.

Technique: With the patient supine, the femoral artery is identified within the inguinal crease. When using nerve stimulation, an insulated needle is advanced to obtain a twitch of the quadriceps muscles as indicated by patellar movement. Thigh movements indicate stimulation of the sartorius muscle and should not be accepted in place of quadriceps stimulation. The femoral artery, vein, and nerve can be visualized with ultrasound (Figure 8). An in- or out-of-plane approach is used to direct needle placement to the femoral nerve and surround it with local anesthetic.

Adverse effects: The proximity of the femoral nerve to major vascularity increases the potential for vessel puncture and formation of hematomas. No direct evidence currently exists to demonstrate that ultrasound guidance reduces the incidence of vessel puncture. Other possible adverse effects include infection at the site of needle insertion and nerve injury.

Sciatic Nerve Block

Anatomy: The sciatic nerve is formed by nerve roots L2, L3, and L4 and when blocked provides surgical anesthesia and analgesia to the knee and may be blocked at points from the subgluteal, anterior thigh, or popliteal approaches. In children, the sciatic nerve may be blocked at points from the subgluteal, anterior thigh, or popliteal approaches.

Indications: Most surgical procedures of the foot and ankle, as well as for knee surgery in combination with the femoral nerve block. Successful continuous nerve blockade with catheter placement has been described in children.
**Technique:** For approaching the sciatic nerve from the infragluteal region, position the child in the lateral decubitus position with the hip and knee flexed. Ultrasound use enables visualization of the nerve between the greater trochanter and the ischial tuberosity within the gluteus maximus muscle. Both in- and out-of-plane approaches have been described with success. Nerve stimulation may be used by itself or in conjunction with ultrasound guidance; if so, twitches of the hamstring, calf, foot, and toe should be expected.

The sciatic nerve can be blocked more distally using the popliteal fossa approach. With the patient prone, the ultrasound probe is placed above the popliteal crease. The popliteal artery and vein are visualized and the sciatic nerve is seen adjacent to these vessels (Figure 9). Moving distally, the tibial and common peroneal nerves are seen separating and another option may be to block these nerves at this location. Nerve stimulation may elicit calf, foot, or toe twitches at this location. Alternatively, the popliteal fossa may be approached posteriorly as the patient lies in the supine position with hip and knee flexed.

**Adverse effects:** Complications include infection at the site of skin puncture, hematoma, and local anesthetic toxicity. When the popliteal fossa approach is used, the proximity of the popliteal artery and vein make vessel puncture possible.

**Truncal Blocks**

**TRANSVERSUS ABDOMINIS PLANE BLOCK**

**Anatomy:** The transversus abdominis plane (TAP) is a potential space that exists between the internal oblique and the transversus abdominis muscle. The thoracolumbar nerve roots (T8 to L1) run in this space.

**Indications:** Blockade of this plexus provides analgesia for the anterior abdominal wall and has been described in adults. Our institution has extensive experience with the TAP block and has used it to provide analgesia for chronic neuropathic abdominal wall pain as well as for many surgical procedures on the abdomen.

**Technique:** A simple step-by-step approach has been described for performing the TAP block in infants and children. A linear transverse high-frequency probe is placed on the abdomen immediately lateral to the umbilicus. The rectus sheath is identified. The probe is then moved laterally to delineate the three layers of the abdominal wall: the external oblique, the internal oblique, and the transversus abdominis (Figure 10). A needle is inserted into the plane between the internal oblique and the transversus abdominis. Injection of local anesthetic solution will create an elliptical opening of the potential space. If this opening is not perceived, it is imperative to hydrodissect with small injections of local anesthetic solution or saline until the plane is reached.

**Adverse effects:** The potential exists for intravascular injections during a TAP block because of the proximity of abdominal vasculature, although such complications are rare. When intravascular injection occurs, a hematoma may appear where the needle enters the abdominal wall.

**ilioinguinal Nerve Block**

**Anatomy:** The ilioinguinal and iliohypogastric nerves, which supply the groin area, are derived from the L1 nerve root of the thoracolumbar plexus and run in the TAP.

**Indications:** Hernia repair, groin surgery.

**Technique:** A linear, high-frequency ultrasound probe is used for this procedure. The probe is placed on the highest point of the iliac crest with the axis facing the umbilicus. A needle is inserted in-plane toward the ilioinguinal and iliohypogastric nerves, which are located between the internal oblique and the TAP (Figure 11). After aspiration, 1 to 2 mL of local anesthetic solution is injected into the space. Pharmacodynamic studies have demonstrated the efficacy of lower doses of local anesthetic for managing postoperative pain in children undergoing ultrasound-guided ilioinguinal nerve blocks.
Conclusion

Regional anesthesia is gaining popularity in infants and children. The addition of ultrasound guidance has broadened the potential indications and improved the efficacy of nerve blocks in this population of patients. Improved education through hands-on workshops—offered at the American Society of Anesthesiologists, the Society for Pediatric Anesthesia, and the American Society of Regional Anesthesia and Pain Medicine—as well as the availability of numerous published studies and review articles describing the use of these techniques, can help clinicians best perform these blocks in their practices.

References