Writing Group of Chinese Expert Consensus on Ultrasound-Guided Pediatric Nerve Blocks in Children (2025 edition)
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Abstract

Ultrasound-guided nerve blocks in children have achieved significant progress in recent years, with improved safety and efficacy attributed to high-resolution ultrasound visualization. The widespread clinical adoption of ultrasound technology empowers clinicians to visualize pediatric neural structures and adjacent tissues clearly and individually, which permits real-time observation of local anesthetic spread, thereby markedly lowering complication risks inherent to conventional blind puncture techniques. This expert consensus is based on evidence-based medicine and clinical practical experiences, integrating the development history and current status of ultrasound-guided pediatric nerve block. It systematically elaborates on the anatomical characteristics of pediatric nerves and their impact on blocking techniques, clarifies the indications and contraindications of pediatric nerve block, and standardizes equipment preparation, drug formulation, and pediatric sedation protocols prior to nerve block administration. It also comprehensively explains the procedural steps and technical key points of nerve blocks at different regions, including probe selection, needle insertion pathways, and real-time monitoring of local anesthetic diffusion, and analyzes the potential main complications along with corresponding prevention and management strategies. Through in-depth discussions among the expert group, recommendations were formed based on jointly established criteria. The final consensus aims to provide practical guidance for the implementation of ultrasound-guided pediatric nerve blocks in clinical anesthesia and pain management, thereby promoting the more effective and safer application of ultrasound-guided pediatric nerve blocks in clinical practice, ultimately achieving the goal of reducing children's pain and accelerating postoperative recovery.

Keywords nerve block; ultrasound; children; expert consensus

Over the past decade, significant progress has been made in the application of nerve block techniques in pediatric anesthesia, greatly facilitated by the widespread use of ultrasound-guided visualization techniques[1]. With the increased clinical application of ultrasound-guided pediatric nerve blocks, numerous clinical studies have confirmed the significant advantages of this technique, including enhanced anesthesia safety and precision, reduced perioperative opioid consumption[2-3], promotion of early postoperative recovery of bowel function, shortened hospital stays, lowered overall medical costs, and improved satisfaction among patients and their families[4-5]. Recent research[6] also indicates that it can reduce perioperative pain sensitivity, stress response, and the incidence of delirium in children. Consequently, nerve block techniques have become a core component of perioperative multimodal analgesia and enhanced recovery after surgery (ERAS) protocols.

Since the advent of nerve block techniques, their development in the pediatric field has consistently lagged. Reasons include: the high technical difficulty of performing nerve blocks and poor compliance in children; the difficulty of meeting the needs of pediatric surgery with nerve blocks alone; the difficulty in assessing the effectiveness of nerve

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blocks; and cognitive biases regarding the perception of pain in children[7]. Therefore, pediatric surgeries have typically been performed under general anesthesia. Although most of these issues have been solved, the development of pediatric nerve block techniques still faces numerous challenges: First, the operational methods are mostly derived from adult practice, lacking technical standards tailored to children's physiological characteristics. Second, ultrasound guidance demands high levels of anatomical knowledge, technical skill, and equipment proficiency from the operator, leading to significant variability in skill levels and unbalanced regional development. Finally, clinical data on pediatric nerve blocks are scattered, making large-scale clinical trials challenging[8]. Given this context, developing a set of standards and consensus for pediatric nerve blocks based on existing clinical research and experience is of great significance for overcoming the current difficulties in ultrasound-guided pediatric nerve blocks, promoting technical dissemination, and advancing clinical research.

1. Consensus Development Methodology

1.1 Methods and Process for Consensus Development

This expert consensus has been registered in both Chinese and English on the International Practice Guideline Registry Platform (http://www.guidelines-registry.org, Registration Number: PREPARE-2025CN551), and the guideline protocol has been filed on this registration platform. The consensus development methods and procedures reference the principles and methods outlined in the WHO Handbook for Guideline Development (2nd Edition) and adhere to the standards set by the Appraisal of Guidelines for Research and Evaluation II (AGREE II) instrument. This consensus aims to provide scientific and standardized guidance for the clinical application of ultrasound-guided pediatric nerve blocks. To ensure the scientificity and authority of the consensus, a panel of experts from anesthesiology, pain medicine, and related fields was formed, with a dedicated working group responsible for literature search, data organization, and consensus writing. The final consensus content was determined through collective discussion and voting during meetings.

This consensus integrates existing research using systematic review or meta-analysis methods, based on the latest high-quality literature and clinical evidence. The quality of the consensus was assessed by the internationally accepted AGREE II instrument, covering six domains: scope and purpose, participants, rigorousness, clarity, applicability, and independence. The GRADE (Grading of Recommendations Assessment, Development and Evaluation) system was used for evidence assessment and grading of recommendation strength to ensure scientificity and transparency.

1.2 Target Population and Users

This consensus provides recommendations for the standardized clinical application of pediatric nerve block techniques. It is intended for reference by all physicians in anesthesiology, pain medicine, pediatrics, and perioperative specialties related to pediatric care.

1.3 Selection and Determination of Clinical Questions

This consensus focuses on five aspects of ultrasound-guided pediatric nerve blocks: characteristics, indications and contraindications, preoperative preparation, implementation methods and key points, and complications with their prevention and treatment.

1.4 Literature Evidence Search and Screening

The working group was responsible for literature search and data organization. Databases searched included PubMed, Embase, Web of Science, CNKI (China National Knowledge Infrastructure), and Wanfang Data. Included literature types comprised meta-analyses, systematic reviews, randomized controlled trials, non-randomized controlled trials, observational studies, and comparative studies. After initial abstract screening, 110 articles were ultimately included.

The English literature search strategy involved three sets of keywords. First set: pediatric/children; Second set: regional anesthesia/nerve block; Third set: upper limb/lower limb/trunk/complication/local anesthetic toxicity. Searches were performed using combinations of terms taken from these three keyword sets. The Chinese literature search strategy mirrored the English one.

1.5 Evidence Evaluation and Recommendation Methods

The consensus was reviewed collectively by the expert panel, while also incorporating input from external expert panels as important evidence-based basis. The GRADE system was used for evidence quality grading[9], integrating consideration of evidence strength, balance of benefits and harms, and patient preferences to formulate recommendations. Recommendation strength is classified as strong or weak, and evidence quality is graded as high, moderate, low, or very low, ensuring conclusions scientific and reliable.

1.6 Key Points Guide

Based on the evidence-based medicine of ultrasound-guided pediatric nerve blocks, combined with the characteristics of pediatric anesthesia and common issues, the recommendations of this consensus can be summarized into the following four key points.

(1) The application of nerve block techniques in the perioperative period for children provides definite benefits. Ultrasound guidance plays a significant role in advancing the development of pediatric nerve blocks.
(2) Pediatric nerve block techniques have a wide range of applications, and safety is a crucial factor in anesthetic selection and assessment.
(3) When formulating a pediatric nerve block plan, preparing for the procedure, and performing the block, full consideration must be given to the child's psychology and the specific characteristics of their anatomy.
(4) The incidence of complications from pediatric nerve blocks is low, and prevention is key.

2. Characteristics of Ultrasound-Guided Pediatric Nerve Blocks

2.1 Anatomical Characteristics of Pediatric Nerves and Clinical Implications

Pediatric nerves have smaller diameters, more superficial locations, denser arrangement with less fat tissue around, and less connective tissue in the endoneurium compared to adults[10]. High-frequency linear array probes (6–14 MHz) are preferred to clearly visualize the epineurium and fascicular structure. Myelination of pediatric nerves matures between 7–12 years of age. Before this, myelin sheaths are incomplete, facilitating the diffusion of local anesthetics (LAs). Consequently, even low-concentration LAs may lead to prolonged motor nerve block duration[11], requiring careful dose adjustment. Furthermore, children's bones are not fully ossified; epiphyses consist mainly of cartilage. Ultrasound can clearly visualize cartilage, epiphyses, and growth plates (which are difficult to see on X-ray). When performing nerve blocks, care should be taken to avoid cartilage and growth plates and to prevent the needle from contacting bone[12].

2.2 Physiological and Pharmacokinetic Characteristics of Children

Children have high cardiac output and a larger proportion of open cardiac sodium channels, resulting in higher LA affinity and systemic absorption. This results a higher risk of LA-induced cardiac toxicity, necessitating strict calculation of the total LA dose to avoid single overdose. The hepatic drug-metabolizing enzyme system for LAs does not reach near-adult levels until approximately 9 months after birth. Therefore, caution regarding drug accumulation is needed when administering repeated doses or continuous infusions of LAs[11].

2.3 Technical Specifications for Ultrasound-Guided Pediatric Nerve Block Imaging

A 25–30 mm high-frequency linear array probe can meet the imaging needs for superficial nerves in children. The in-plane needling technique allows visualization of the entire needle path and tip position, reducing the risk of injury to adjacent structures[11]. This is particularly appropriate when nerves or plexuses are located near vital structures such as the spinal cord, pleura, blood vessels, and peritoneum. During the procedure, keep the needle insertion angle shallow, dynamically adjust using ultrasound, and ensure a clear relationship between the nerve and needle tip. Optimize the image by adjusting gain, depth, and focus position to achieve clear contrast between the nerve and surrounding tissues (e.g., tendons, vessels), thus obtaining superior ultrasound images.

2.4 Clinical Benefits of Ultrasound-Guided Pediatric Nerve Blocks

Ultrasound-guided pediatric nerve blocks visualize anatomical structures, allowing real-time visualization of the needle's path, depth, and position relative to the nerve, as well as real-time observation of LA spread and distribution. This ensures adequate LA envelopment of the nerve, improves safety and accuracy, leads to faster block onset, reduces LA dose[13-15], and effectively decreases related complications[16-17]. Results from retrospective studies on ultrasound-guided regional anesthesia in children[18-19] show that, compared to no ultrasound guidance, ultrasound guidance results in higher success rates for regional anesthesia, longer duration of analgesia, improved early postoperative pain scores, significantly better pain management, and reduced postoperative analgesic requirements. The benefits of ultrasound guidance are even greater when applied to younger children[20].

Ultrasound-guided pediatric nerve blocks can reduce the dosage requirements for general anesthetics in children[21-22], helping to reduce stress response, increase circulatory stability, and lower perioperative mortality[23]. This technique also reduces the dosage of opioid drugs, thereby decreasing opioid-related adverse effects such as nausea, vomiting, and constipation, while significantly

lowering the risk of respiratory depression[15,22,24-25].

Ultrasound-guided pediatric nerve blocks can interrupt trauma-induced neuroendocrine stress, alleviate autonomic nervous system, hormonal, metabolic, and immune/inflammatory disturbance, effectively suppress the surgical stress response, and improve surgical outcomes[15,26]. When combined with general anesthesia, they improve surgical conditions, reduce intraoperative blood loss, shorten recovery time, promote smoother recovery, reduce the incidence and severity of postoperative delirium[27-31], facilitate early feeding and functional recovery, and play an important role in ERAS[24,32-33]. Continuous catheter placement for nerve blocks provides effective pain relief, enhancing the rehabilitation compliance of children[22,34], shortening hospital stays and potentially increasing the proportion of day surgery, ultimately reducing healthcare costs.

Recommendation 1: Evidence indicates that ultrasound-guided nerve block techniques hold significant value in perioperative ERAS protocols for children, with clinical benefits encompassing safety, efficacy, outcomes, and cost. (Evidence Level: High; Recommendation Strength: Strong)

3. Indications and Contraindications for Ultrasound-Guided Pediatric Nerve Blocks

3.1 Indications for Ultrasound-Guided Pediatric Nerve Blocks

Indications include anesthesia and perioperative analgesia for surgeries within the distribution area of the corresponding nerve. It can be used alone or in combination with other anesthetic methods. The appropriate approach and medication should be selected based on the child's condition and the surgical or pain area. Ultrasound-guided pediatric nerve blocks can be used alone for minor procedures (e.g., circumcision, superficial mass excision) or for high-risk children (e.g., susceptibility to malignant hyperthermia, difficult airway). It's a key component of multimodal analgesia. When combined with general anesthesia, it can reduce the dosage of general anesthetic drugs and opioids, thereby lowering the risks of postoperative nausea, vomiting and respiratory depression[35]. It also can be used for trauma analgesia, primarily for rapid pain relief during emergency fracture reduction or soft tissue injury[36].

3.2 Contraindications for Ultrasound-Guided Pediatric Nerve Blocks

Absolute contraindications include child's or parents' refusal, allergy to local anesthetics, and infection at the needle insertion site. Relative contraindications include systemic sepsis, coagulation disorders, progressive neurological disease, and pre-existing nerve injury[35]. For relative contraindications, a thorough analysis and assessment of the risks and benefits of performing the ultrasound-guided pediatric nerve block should be conducted based on the patient's condition. Before the procedure, the risks should be fully explained to the child and family. Only after obtaining the informed consent can the nerve block be performed with caution[37].

When coagulation function is abnormal or there is a positive history of a bleeding disorder, extra caution is recommended when performing nerve blocks[38]. When the International Normalized Ratio (INR) is >1.15, after appropriate risk-benefit analysis, superficial nerve blocks under ultrasound guidance may be performed, but deep nerve blocks (e.g., paravertebral, lumbar plexus) are not recommended[39].

Currently, there is no evidence that using ultrasound-guided pediatric nerve blocks increases the risk of acute compartment syndrome (ACS) in children or delays its diagnosis[39]. It is recommended that before surgery, the anesthesiologist conduct a detailed preoperative discussion with the surgeon and the child's family, informing them of the risk of ACS, which is a rare but serious complication[11,38]. The following practical guidelines are recommended to reduce or avoid the risk of ACS[38-39]:

(1) Use 0.1%–0.25% bupivacaine, levobupivacaine, or ropivacaine for single-injection nerve blocks, as these concentrations rarely mask ischemic pain and/or produce muscle weakness.
(2) For continuous infusions, limit the concentration of the aforementioned drugs to less than 0.1%.
(3) For patients undergoing tibial compartment surgery or other procedures at high risk for ACS, it is advisable to restrict the dose and concentration of local anesthetics used for sciatic nerve block catheters.
(4) Use local anesthetic adjuvants cautiously, as they may prolong block duration and enhance block effect.
(5) Closely monitor postoperative pain changes in high-risk patients for early identification of possible signs and symptoms of ACS.
(6) For patients with suspected ACS, measure compartment pressure immediately.

Recommendation 2: There is no evidence that using ultrasound-guided pediatric nerve blocks increases the risk of ACS in children or delays its diagnosis. The use of low-concentration local anesthetics (suggested concentration 0.1%–0.25% for single injection, <0.1%

for continuous infusion) helps reduce the possibility of masking the condition. (Evidence Level: Moderate; Recommendation Strength: Strong)

4. Preoperative Preparation for Ultrasound-Guided Pediatric Nerve Blocks

4.1 Operation Skills

4.1.1 Requirements for the Operator

Given that most of the experience in pediatric nerve block techniques comes from adults, operators need to meet the following criteria[36,40-41]: ① Experience with adult ultrasound-guided nerve block techniques, and knowledge of the differences in anatomy, physiology, and pharmacology between adults and children. ② Knowledge of ultrasound fundamentals and basic operational skills for ultrasound-guided pediatric nerve blocks. ③ Familiarity with complications related to pediatric nerve blocks, along with the basic knowledge and emergency response capabilities to manage them. ④ Ability to manage anxious children and communicate effectively and smoothly with families. ⑤ Nerve blocks performed on children under 6 months of age must be administered by well-trained and experienced anesthesiologists/pain physicians.

4.1.2 Recommended Operational Practices[36]

These practices help enhance procedural safety.

(1) Pre-scan the block area to identify local anatomy, recognize blood vessels and vital organs, and measure target depth.
(2) In the initial phase of the block, normal saline can be injected using hydrodissection to help open the space around the nerve or fascial plane before injecting the local anesthetic around the target nerve or into the fascial plane.
(3) It is recommended that two operators perform the procedure: one controlling the probe and needle position, and the other performing intermittent aspiration before injection to confirm negative aspiration for blood or air before injecting local anesthetic.

4.2 Patient Care

4.2.1 Preoperative Visit

During the preoperative visit, apart from collecting specialty information, assess whether the child meets the indications and has no contraindications. Evaluate the risks and benefits of the nerve block thoroughly based on the child's condition and type of surgery, selecting the most suitable block approach and medication. Special attention should be paid to the child's behavioral characteristics and the guardian's attitude. Children with decision-making capacity should be encouraged to participate in the informed consent discussion together with their parents[42].

4.2.2 Operating Environment

Ideally, the operating room should have a dedicated area for children where assessment and procedures can be performed. The use of brightly colored decorations and age-appropriate recreational activities can help reduce children's anxiety and fear upon entering the operating room. It is recommended to raise the room temperature to 25°C before the child enters and prepare warming blankets. The required environmental temperature for infants should reach 28°C to prevent hypothermia-induced cardiovascular complications or coagulation disorders[43].

4.2.3 Sedative Medications

Routine fasting is required for elective surgeries. Monitor ECG, blood pressure, pulse, and oxygen saturation. For preschool-aged children with an established intravenous (IV) line, IV midazolam 0.1–0.3 mg/kg, or ketamine 0.25–0.50 mg/kg, or esketamine 0.15–0.25 mg/kg can be administered. Alternatively, a slow IV infusion of dexmedetomidine 1μg/kg can be given. For children without a pre-established IV line requiring procedures under basal anesthesia upon entering the operating room, intramuscular ketamine 3 mg/kg can be given, or intranasal dexmedetomidine 0.5–2.0 μg/kg, or oral midazolam 0.5–1.0 mg/kg can be administered 30 minutes before surgery[44].

4.3 Ultrasound Equipment

Select the appropriate ultrasound probe based on the child's size and the block site. Generally, a high-frequency linear array probe is suitable for most pediatric nerve blocks (Figure 1). Peripheral nerves in children are relatively superficial; high-frequency linear probes provide better high-resolution images but have weaker penetration capabilities. A "hockey stick" probe, approximately 2.5 cm long, is suitable for smaller children. It has an open space on one side, allowing for a large operating area without block out the sight. It operates at higher frequencies than standard linear probes, offering excellent resolution and

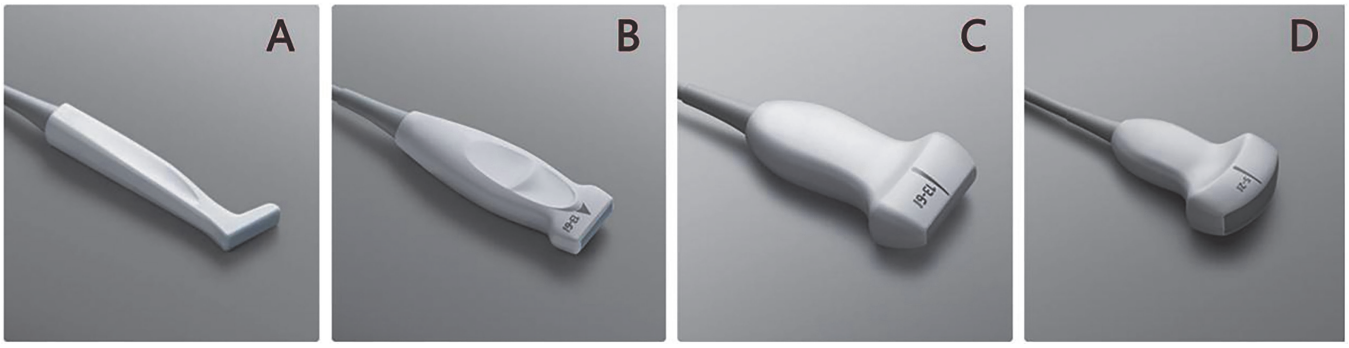


Figure 1 Ultrasound probes commonly used for nerve blocks in children
Note: A. 2.5 cm L-type high-frequency linear array probe. B. 2.5 cm high-frequency linear array probe. C. 3.5 cm high-frequency linear array probe. D. low-frequency covex array probe.

detail for superficial structures, making it particularly useful for guiding procedures requiring fine manipulation, such as those on the arm, neck, peripheral nerves, and distal vessels in children. For older or larger children undergoing deep nerve blocks (e.g., lumbar plexus, quadratus lumborum, paravertebral, erector spinae), a low-frequency convex array probe can be used, which helps widen the field of view to locate target nerves[37].

4.4 Other Operating Preparations

4.4.1 IV Access

Due to the small diameter of children's veins, their tendency to slide, the loose subcutaneous fat, and the poor compliance of young children, the difficulty of veinpuncture is increased. Ultrasound guidance can increase the success rate of veinpuncture and reduce complications.

4.4.2 Monitoring

At least, oxygen saturation and electrocardiogram monitoring should be conducted for the patient. For children under general anesthesia, end-tidal carbon dioxide partial pressure should also be monitored. All monitoring parameters should have alarm limits set according to age-specific standards. When the child is placed in a special position, care must be taken to avoid dislodging the face mask, laryngeal mask airway, or endotracheal tube[40].

4.4.3 Needle Selection

For children with smaller body sizes, excessively long needles can affect the flexibility of the operation. The puncture depth can be measured by ultrasound imaging, and an appropriate needle can be selected[45]. Using a short-bevel needle for puncture can reduce the incidence of nerve injury[46]; however, it is important to note that if a short-bevel needle does injure a nerve, the damage can be more severe.

4.5 Emergency Equipment and Medications

4.5.1 Emergency Equipment

Before performing a nerve block, emergency medications and equipment should be prepared. For children undergoing the procedure while awake or sedated, general anesthesia equipment should be ready, including laryngeal mask airways, laryngoscopes with various blade sizes (one large, one medium, one small), tracheal tubes (one large, one medium, one small) and tube cores, and appropriate face masks. The anesthesia machine should be checked and ready.

4.5.2 Resuscitation Medications

Resuscitation medications include epinephrine, benzodiazepines, and lipid emulsion. If seizures occur, administer a benzodiazepine [e.g., IV midazolam 0.05–0.1 mg/(kg·min)]. If this progresses to severe Local Anesthetic Systemic Toxicity (LAST), refer to the Pediatric Anesthesiology Society guidelines for lipid resuscitation therapy[37].

Recommendation 3: Anesthesiologists should be trained in ultrasound-guided pediatric nerve blocks. Procedures for children under 6 months of age should be performed by experienced physicians. Emergency resuscitation equipment and medications should be routinely prepared before administering anesthesia. (Evidence Level: High; Recommendation Strength: Strong)

4.6 Performing Nerve Blocks Under General Anesthesia or Sedation

Ultrasound localization and anesthesia administration techniques in children are largely consistent with those in adults, and most peripheral nerves are relatively superficial. However, pediatric anatomy is compact, with nerves located closer to certain vital structures than in adults, increasing the risk of injury compared to adults. Furthermore, children cooperate poorly with procedures, so performing nerve blocks while awake is associated with an increased incidence of complications[47]. The European Society of Regional Anaesthesia and Pain Therapy (ESRA)/ American Society of Regional Anesthesia and Pain Medicine (ASRA) published guidelines on pediatric regional anesthesia[38] recommending that children of all ages can and should undergo nerve blocks under general anesthesia or deep sedation.

Only when the child is under general anesthesia or deep sedation and there is no body movement response can the nerve block procedure be carried out. The children have significant individual variability in their responses to anesthetics, and are prone to respiratory depression, especially in the younger ones. Tracheal intubation or a laryngeal mask airway is generally required to maintain respiration. Anesthesia maintenance methods can be either simple inhalation of sevoflurane, total intravenous anesthesia, or combined intravenous-inhalation anesthesia. For older children, drug infusion rates can be determined based on sedation level and adverse effects under close monitoring of respiration and supplemental oxygen via face mask. Attention should also be paid to loose teeth, tonsil size, and cardiopulmonary function[44].

For deep nerves or difficult-to-visualize nerves, especially when performing lumbar plexus, sacral plexus, or other blocks in obese children, ultrasound imaging alone may not be sufficient to identify anatomical structures. Using a nerve stimulator in conjunction with ultrasound guidance may help confirm needle tip position and improve accuracy[48].

Recommendation 4: Performing ultrasound-guided pediatric nerve blocks under general anesthesia or deep sedation is safe; performing these blocks while awake is associated with an increased incidence of complications. (Evidence Level: High; Recommendation Strength: Strong)

4.7 Pre-Procedural Sterile Preparation

Strict aseptic technique must be followed before performing a nerve block. Clean the skin with a disinfectant such as chlorhexidine. Cover the ultrasound probe with a single-use sterile cover[49]. Between patients, the ultrasound probe and cable can be disinfected with an agent possessing antibacterial, antiviral, and antifungal properties[36].

The risk of infection is higher for continuous nerve block catheters (0–3%), and bacterial colonization of the catheter is common. The risk of infection is related to the catheter placement site and duration[50]. Therefore, for nerve blocks involving catheter placement or performed near the surgical field, strict sterile conditions are essential, including sterile gowns, gloves, masks, and a sterile field.

Recommendations from the Brazilian Society of Anesthesiologists (SBA) on how to reduce infection risk during operator preparation for regional anesthesia[51] include:

(1) Thorough hand washing significantly reduces the risk of cross-infection and is recommended before performing any regional anesthesia technique.
(2) Removing all jewelry (rings, watches, etc.) before hand washing reduces contamination risk.
(3) Sterile surgical gloves are recommended and should be considered a supplement to, not a substitute for, hand hygiene.
(4) Currently, insufficient data support the routine use of surgical gowns in regional anesthesia techniques.
(5) The use of surgical masks during regional anesthesia maximizes the preventive effect of the sterile barrier.
(6) Chlorhexidine-alcohol solution significantly reduces the risk of bacterial colonization of catheters and injection sites. Therefore, its use is recommended as the preferred disinfectant before regional anesthesia.

The latest research[52] indicates that for patients with a low risk of infection, a single superficial nerve block only requires the same level of disinfection as a vein puncture. However, the reliability of this conclusion needs further confirmation through more research.

Recommendation 5: The aseptic operation procedures should be strictly followed when performing nerve blocks, especially for deep nerve blocks and continuous catheter-based nerve blocks. (Evidence Level: High; Recommendation Strength: Strong)

5. Implementation Procedures and Key Points of Ultrasound-Guided Pediatric Nerve Blocks

5.1 Grading of Ultrasound-Guided Pediatric Nerve Blocks

Regional Anaesthesia-UK (RA-UK) has developed a graded recommendation protocols for nerve blocks based on the level of technical difficulty and the universal applicability

of the block region[41]. On this basis, and in accordance with the requirements of precision anesthesia, we have optimized the classification of the protocols (Table 1). The primary plan represents the most universally applicable method and is relatively easy for beginners to master. The advanced plan may be adopted when the primary plan fails to meet surgical requirements or when contraindications exist; these techniques are more challenging and are suitable for anesthesiologists with more experience.

Table 1 Grading of recommended protocols for ultrasound-guided pediatric nerve blocks

Block region	Primary Plan	Advanced plan
Upper limb		
Below shoulder	Axillary brachial plexus block	Supraclavicular brachial plexus block;infraclavicular brachial plexus block
Below elbow		Elbow blocks
Lower limb		
Hip	Femoral nerve block	Fascia iliaca block; Lumbar plexus block
Thigh and knee		Adductor canal block
Below knee	Sciatic nerve block of popliteal fossa	Ankle block
Trunk		
Chest wall	No recommendations	Erector spinae plane block ; paravertebral block; serratus anterior plane block
Abdomen,groin	Rectus sheath block; Lateral quadratus lumborum block; dorsal penile nerve block	Anterior quadratus lumborum block; transversus abdominis plane block; pudendal nerve block
Head and neck		
Anterior region of neck	Superficial cervical plexus block	No recommendations
Ear		Great auricular nerve block

5.2 Block Techniques and Key Considerations

5.2.1 Proximal Upper Extremity Nerve Blocks

The brachial plexus can be approached via the axillary, interscalene, supraclavicular, and infraclavicular approaches, all of which are applicable for pediatric upper extremity surgery. Shoulder surgery is uncommon in children; therefore, the interscalene approach is less frequently employed.

(1) Axillary Brachial Plexus Block

The child is placed in the supine position with the affected arm abducted to 90° and the elbow flexed. A high-frequency linear probe and an in-plane technique are utilized. The probe is positioned at the level of the pectoralis major muscle insertion on the humerus, perpendicular to the humerus (Figure 2). The probe is then fine-tuned proximally or distally along the humerus to obtain clear sonographic visualization of the axillary artery, axillary vein, and biceps brachii muscle. The radial, median, and ulnar nerves are located deep, anterior, and posterior to the axillary artery, respectively, although anatomical variations may be present in a minority of children. An in-plane technique is employed, and local anesthetic is injected around each individual nerve to enhance the success rate of the nerve block[53].

The vessels in the pediatric axillary region are superficially located and readily compressible under probe pressure; nevertheless, negative aspiration should be performed prior to each injection. Color Doppler imaging may be utilized for differentiation in children with abundant vasculature. The musculocutaneous nerve lies outside the axillary neurovascular sheath, between the biceps brachii and coracobrachialis muscles, and requires separate blockade; this can be accomplished by adjusting the needle direction within the same plane.

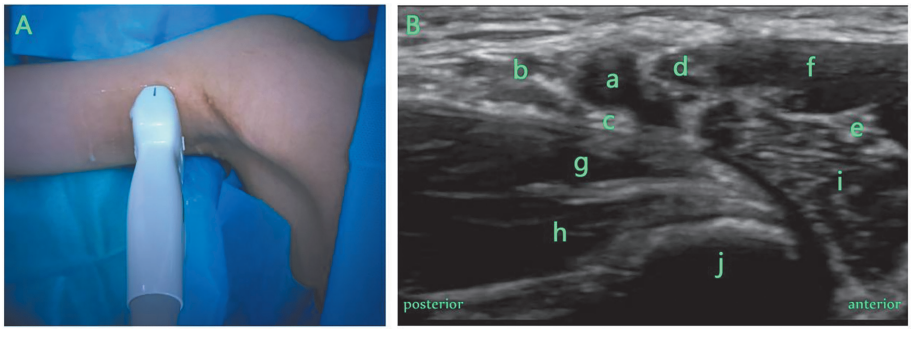


Figure 2 Ultrasound positioning and imaging of axillary brachial plexus block
Note: A. Position of the ultrasound probe. B. Ultrasound image of the axillary brachial plexus obtained with the probe positioned as shown in figure A. a—axillary artery; b—ulnar nerve; c—radial nerve; d—median nerve; e—musculocutaneous nerve; f—biceps brachiimuscle; g—the latissimus dorsi and teres major tendons; h—tricepsbrachiimuscle; i—brachiimuscle; j—brachialis muscle.

The axillary brachial plexus block is primarily indicated for analgesia during surgery from the mid-humeral level to the fingertips. Complications include nerve injury, intravascular injection, and hematoma formation.

(2) Interscalene Brachial Plexus Block

The child is placed in the lateral decubitus position with the affected side upward. A high-frequency linear probe and an in-plane technique are employed. The probe is placed at the level of the cricoid cartilage along the lateral border of the sternocleidomastoid muscle. The anterior and middle scalene muscles are visualized, with the C5, C6, and C7 nerve roots traversing this region[54]. The needle tip is advanced into the interscalene groove adjacent to the brachial plexus; following negative aspiration for blood and air, the local anesthetic is injected. Unilateral injection is performed, and the volume of local anesthetic should be minimized.

The interscalene brachial plexus block is indicated for analgesia of the shoulder, distal clavicle, acromioclavicular joint, and proximal humerus. Complications include phrenic nerve block, Horner's syndrome, recurrent laryngeal nerve palsy, vascular injury, and pneumothorax.

(3) Supraclavicular Brachial Plexus Block

The child is placed in the supine position. A high-frequency linear probe and an in-plane technique are utilized. The probe is placed parallel to the clavicle in the supraclavicular fossa. The honeycomb-appearing brachial plexus is identified lateral and superolateral to the subclavian artery. As the brachial plexus passes the subclavian artery, it lies in very close proximity to the pleura; therefore, the pleura and the complete needle tip must be clearly visualized during needle insertion to avoid inadvertent pleural puncture and subsequent pneumothorax.

The supraclavicular brachial plexus block is primarily indicated for analgesia of the shoulder and proximal humerus. Complications include pneumothorax, subclavian artery injury, and possible occurrence of Horner's syndrome and phrenic nerve block[34].

(4) Infraclavicular Brachial Plexus Block

The child is placed in the supine position. A high-frequency linear probe and an in-plane technique are employed. The probe is placed on the midclavicular line, and the axillary artery, brachial plexus cords, and pleura are scanned in the sagittal plane. In the parasagittal plane at the second segment of the axillary artery, the brachial plexus cords are visualized surrounding the cephalad, caudal, and dorsal aspects of the axillary artery; this represents the coracoid infraclavicular approach. In the oblique transverse plane at the first segment of the axillary artery, the brachial plexus cords (lateral, medial, and posterior cords) are visualized lateral to the axillary artery; this represents the costoclavicular approach.

The coracoid infraclavicular approach is the classic infraclavicular brachial plexus block approach, whereas the costoclavicular approach is a relatively novel approach. Compared with the supraclavicular approach, the costoclavicular approach is associated with a shorter procedure time and a lower risk of ipsilateral diaphragmatic paralysis[55-56]. The three cords lie in close proximity in the costoclavicular space with low anatomical variability, making this a reliable site for brachial plexus catheter placement. Positioning the catheter tip between the three brachial plexus cords provides excellent analgesia, and the distal end of the catheter lies within the "intermuscular tunnel" formed by the subclavius and serratus anterior muscles, reducing the risk of catheter displacement[57-59].

The costoclavicular brachial plexus block is primarily indicated for analgesia during surgery from the upper arm to the fingertips. Complications include vascular injury and pneumothorax.

5.2.2 Proximal Lower Extremity Nerve Blocks

Prior to the advent of ultrasound-guided nerve blocks, caudal epidural blockade was the primary method for analgesia in pediatric lower extremity surgery. The application of ultrasound-guided lower extremity nerve blocks not only enables unilateral limb anesthesia but also avoids the disadvantages associated with caudal blockade, including short duration and secondary urinary retention.

(1) Femoral Nerve Block

The child is placed in the supine position with the legs slightly separated and the affected limb mildly externally rotated. A high-frequency linear probe and an in-plane technique are utilized. The probe is positioned superior to the inguinal ligament (Figure 3). The femoral nerve enters the thigh deep to the inguinal ligament and lateral to the femoral artery[60]. Sonographically, the hyperechoic fascia lata and iliac fascia are visualized; deep to the inguinal ligament, the femoral artery and vein are identified, and lateral to the femoral artery, the femoral nerve appears as a fusiform or honeycomb-like structure. For little child, the inguinal ligament region is relatively narrow, and the needle trajectory using the in-plane technique may traverse the course of the lateral femoral cutaneous nerve. To avoid injury to the lateral femoral cutaneous nerve, this nerve should be scanned simultaneously prior to performing the block.

The femoral nerve block is indicated for anesthesia and analgesia during surgery involving the anterior thigh, knee, medial aspect of the lower leg, and medial aspect of the ankle[61]. Complications include femoral artery injury

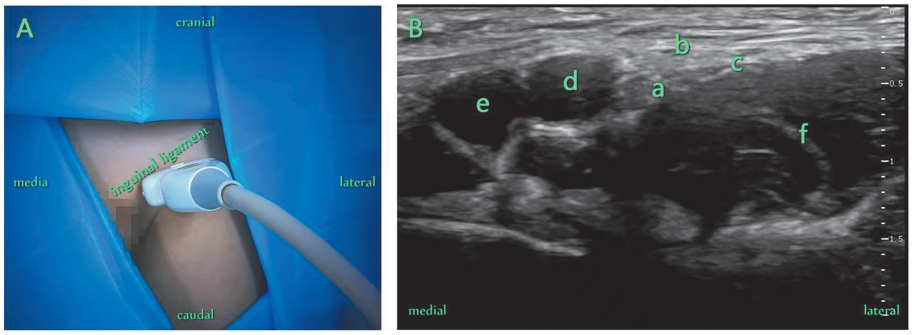


Figure 3 Ultrasound positioning and imaging of femoral nerve block
Note: A. Position of the ultrasound probe. B. Ultrasound image of the femoral nerve obtained with the probe positioned as shown in figure A. a—femoral nerve; b—fascia lata; c—fascia iliac; d—femoral artery; e—femoral vein; f—iliopsoas muscle.

and hematoma formation.

(2) Sciatic Nerve Block

The child is placed in the lateral decubitus position with the affected side upward. A high-frequency linear probe and an in-plane technique are employed; however, a low-frequency linear probe may be required for older or larger children when performing a high sciatic nerve block. The classic approach involves placing the probe along the line connecting the ischial tuberosity and the greater trochanter of the femur. Sonographically, deep to the gluteus maximus muscle lies the infragluteal space, within which the inferior gluteal artery can be identified. The sciatic nerve appears as a fusiform or triangular structure located lateral to the inferior gluteal artery. The sciatic nerve descends between the greater trochanter and the ischial tuberosity, courses along the posterior thigh deep to the biceps femoris muscle, and bifurcates into the tibial and common peroneal nerves proximal to the knee. Both the infragluteal region and the proximal popliteal fossa readily permit sonographic visualization and blockade of the sciatic nerve[34]. For the popliteal approach to sciatic nerve blockade, the probe is placed approximately 5 cm proximal to the popliteal skin crease; sonographically, the sciatic nerve is visualized in proximity to the popliteal artery and vein (Figure 4). Moving the probe distally along the course of the sciatic nerve, the nerve is observed to divide into the tibial and common peroneal nerve bundles.

The popliteal sciatic nerve block provides anesthesia and analgesia for the majority of the lower leg, ankle, and foot distal to the knee. The gluteal approach to sciatic nerve block usually permits simultaneous blockade of the posterior femoral cutaneous nerve, thereby providing anesthesia and analgesia for posterior thigh surgery.

(3) Lateral Femoral Cutaneous Nerve Block

The child is placed in the supine position. A high-frequency linear probe and an in-plane technique are utilized. The probe is positioned medial to the anterior superior iliac spine. The lateral femoral cutaneous nerve lies lateral to the superficial aspect of the sartorius muscle and appears as an ovoid or fusiform hyperechoic structure.

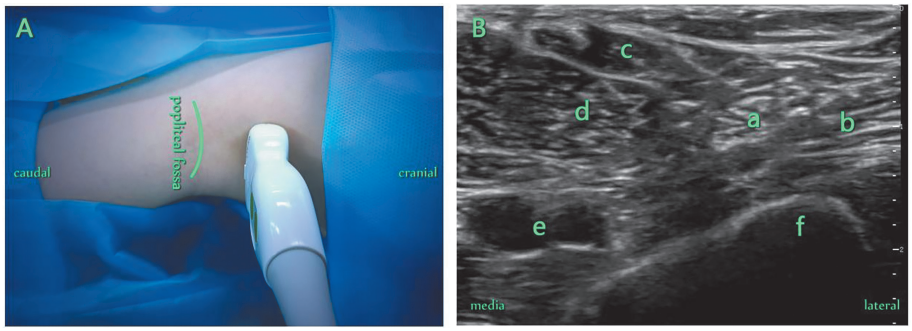


Figure 4 Ultrasound positioning and imaging of sciatic nerve block via popliteal fossa
Note: A. Position of the ultrasound probe. B. Ultrasound image of the sciatic nerve in the popliteal fossa obtained with the probe positioned as shown in figure A. a—sciatic nerve; b—biceps femoris muscle; c—semitendinosus muscle; d—semimembranosus muscle; e—popliteal artery and vein; f—femur.

The lateral femoral cutaneous nerve block is indicated for anesthesia and analgesia during surgery involving the lateral femoral region.

(4) Lumbar Plexus Block

The child is placed in the lateral decubitus position with the affected side upward, and the hip and knee joints are flexed. The lumbar plexus is located relatively deep, and the skin-to-plexus depth varies with body mass rather than age[62]. A low-frequency linear probe is generally selected; however, a high-frequency linear probe may be used in little children to achieve better image resolution. Pediatric muscle tissue contains fewer fibrous septa, resulting in greater contrast between hypoechoic muscle tissue and hyperechoic neural structures, thereby facilitating visualization of the lumbar plexus nerves. The psoas compartment is the common site for lumbar plexus blockade. In pediatric lumbar plexus blockade, the "Shamrock," "Trident," and "Three-Step" approaches are most commonly employed.

The Shamrock lumbar plexus block predominantly utilizes an in-plane approach. A pad is placed beneath the lower lateral abdomen to open the space between the 12th rib and the iliac crest. The probe is positioned on the lateral abdominal wall, immediately adjacent to the iliac crest. Sonographically, a shamrock-shaped configuration is visualized, composed of the lumbar transverse processes, erector spinae muscle, quadratus lumborum muscle, and psoas major muscle. Ventral to the transverse process, within the psoas compartment, the hyperechoic lumbar plexus is visualized.

The Trident lumbar plexus block predominantly employs an out-of-plane approach. The probe is placed on the sacrum with its long axis parallel to the posterior midline, and the transverse processes of the fourth and third lumbar vertebrae (L4 and L3) are counted in a cephalad direction. Sonographically, the transverse processes appear in a trident-like configuration; superficial to the transverse processes lies the erector spinae muscle, and between the superior and inferior transverse processes lies the psoas major muscle. Deep to the transverse process and within the psoas muscle, the hyperechoic lumbar plexus is visualized.

The Three-Step lumbar plexus block predominantly utilizes an in-plane approach. The L4 transverse process is first identified; the probe is then rotated 90° to obtain sonographic visualization of the spinous process, articular process, and transverse process in a three-step configuration. The probe is moved cephalad until the L4 transverse process disappears from view, revealing the superficial erector spinae muscle, quadratus lumborum muscle, intertransverse ligament, and the deep psoas major muscle. Deep to the intertransverse ligament, within the psoas compartment, the hyperechoic lumbar plexus can be identified.

The lumbar plexus block is indicated for anesthesia and postoperative analgesia during surgery involving the medial, anterior, and lateral thigh, as well as the knee.

The lumbar plexus block is classified as a deep nerve block with substantial procedural risks, requiring advanced skills and training. During needle insertion, inadvertent entry into the subarachnoid, epidural, or subdural space may occur, and injury to the lumbar plexus, blood vessels, or kidneys is also possible. Both American Society of Regional Anesthesia and Pain Medicine (ASRA) and European Society of Anaesthesiology (ESA) classify the lumbar plexus block as a "deep plexus block" and recommend adherence to the same coagulation standards required for neuraxial anesthesia[63-64].

5.2.3 Distal Upper and Lower Extremity Nerve Blocks

Distal nerve blocks of the upper and lower extremities may serve as supplementary analgesia when proximal limb blocks are incomplete, and may also be employed as primary anesthetic or analgesic techniques for distal limb surgery. The indications for distal upper and lower extremity nerve blocks are hand surgery and forefoot/toe surgery, respectively; the appropriate nerve block technique is selected based on the surgical field.

Although considerable anatomical variability exists in the peripheral nerve anatomy and innervation territories of the distal extremities, distal nerve blocks offer distinct advantages[53,65]: they enable more precise anesthesia while avoiding paralysis of the proximal limb; they are applicable in children in whom proximal blockade is technically difficult, such as those with limited upper extremity abduction; and they reduce local anesthetic requirements with potentially faster onset. Furthermore, pediatric nerve blocks are frequently combined with general anesthesia, effectively preventing ischemic discomfort reactions induced by intraoperative tourniquet application.

Pediatric distal limb nerve blocks are generally performed using small- to medium-sized high-frequency linear probe with an in-plane technique.

5.2.3.1 Distal Upper Extremity Nerve Blocks

(1) Radial Nerve Block

The child is placed in the supine position. For the mid-humeral radial nerve block, the probe is positioned over the radial groove on the lateral aspect of the mid-humerus, perpendicular to the humerus. Superficial to the humerus, between the triceps brachii and brachialis

muscles, a triangular or ovoid hyperechoic structure is visualized, representing the radial nerve.

For the elbow radial nerve block, the probe is placed on the lateral aspect of the elbow. Lateral to the brachialis muscle and superficial to the lateral epicondyle of the humerus, a hyperechoic structure is visualized, representing the radial nerve.

(2) Ulnar Nerve Block

The child is placed in the supine position. For the mid-humeral ulnar nerve block, the probe is positioned at the proximal-to-mid one-third of the humerus, medial to the belly of the biceps brachii muscle, perpendicular to the humerus. Posterior to the brachial artery, a hyperechoic structure is visualized, representing the ulnar nerve.

For the elbow ulnar nerve block, the probe is placed over the ulnar groove. Sonographically, the olecranon and the medial epicondyle of the humerus are visualized; between these two structures, a rounded ulnar nerve is identified.

(3) Median Nerve Block

The child is placed in the supine position. For the mid-humeral median nerve block, the probe is positioned at the proximal-to-mid one-third of the humerus, medial to the belly of the biceps brachii muscle, perpendicular to the humerus. Sonographically, the brachial artery is visualized; anterior to the brachial artery, a rounded structure is identified, representing the median nerve.

For the elbow median nerve block, the probe is placed between the brachial artery and the basilic vein. Sonographically, a rounded median nerve is visualized.

5.2.3.2 Distal Lower Extremity Nerve Blocks

(1) Common Peroneal Nerve and Its Branch Blocks

The child is placed in the lateral decubitus position with the affected side upward. Common peroneal nerve and its branch blocks are indicated for anesthesia and analgesia during surgery involving the lateral and posterior aspects of the lower leg and the dorsum of the foot. The common peroneal nerve divides into the superficial and deep peroneal nerves. Common sites for blockade include the mid-calf and ankle levels.

For superficial and deep peroneal nerve blocks at the calf level, the probe is placed on the lateral aspect of the lower leg at any level between the lateral malleolus and the fibular head. Anterior to the fibula, deep to the tibialis anterior and extensor digitorum longus muscles, the pulsatile anterior tibial artery is identified. The deep peroneal nerve is located in proximity to the anterior tibial artery and appears as an ovoid or fusiform structure; the superficial peroneal nerve lies superficial to the interface between the peroneal muscles and the extensor digitorum longus muscle and appears as an ovoid or fusiform structure.

For superficial peroneal nerve block at the ankle, the probe is placed at the level superior to the lateral malleolus. Superficial to the interface between the peroneal muscles and the extensor digitorum longus muscle, the superficial peroneal nerve is visualized.

For deep peroneal nerve block at the ankle, the probe is placed anterior to the ankle joint, slightly lateral. Sonographically, deep to the extensor digitorum longus and extensor hallucis longus muscles and superficial to the tibia, the pulsatile anterior tibial artery is visualized. At this level, the deep peroneal nerve has typically divided into medial and lateral terminal branches, located on either side of the anterior tibial artery.

(2) Tibial Nerve and Its Branch Blocks

The child is placed in the lateral decubitus position with the affected side upward. Tibial nerve and its branch blocks are indicated for anesthesia and analgesia during surgery involving the posterior aspect of the lower leg and the plantar surface of the foot. The tibial nerve divides into the posterior tibial nerve and the sural nerve; common sites for blockade include the calf and ankle levels.

For tibial nerve block at the calf level, the probe is placed on the posterior aspect of the lower leg at any level between the popliteal fossa and the ankle joint. Deep to the soleus muscle, the pulsatile posterior tibial artery and vein are identified; the tibial nerve is located in the vicinity of the posterior tibial vessels.

For posterior tibial nerve block at the ankle, the probe is placed along the line connecting the medial malleolus and the Achilles tendon. Between the flexor digitorum longus and flexor hallucis longus muscles, the pulsatile posterior tibial artery is identified; the posterior tibial nerve is located in the vicinity of the vessel.

For sural nerve block, the probe is placed at any level in the distal one-third of the posterior lower leg. Superficial to the soleus muscle and Achilles tendon, the small saphenous vein is identified; the sural nerve is located in the vicinity of the small saphenous vein.

5.2.4 Truncal Nerve Blocks

Truncal nerve blocks are indicated for surgery involving the thorax, abdomen, and perineum. Fascial plane blocks represent the commonly employed techniques for pediatric truncal nerve blockade. These techniques involve ultrasound-guided injection of local anesthetic into the target fascial plane, with blockade achieved through drug diffusion, thereby offering relatively straightforward procedural execution while avoiding direct needle puncture of neural structures.

The principal abdominal fascial plane block techniques include rectus sheath block, transversus abdominis plane (TAP) block, and quadratus lumborum block(QLB). The majority of fascial plane blocks serve solely as adjunctive techniques for perioperative analgesia and must be combined with general anesthesia[66]. Safety considerations in pediatric applications include the following: most fascial plane blocks are volume-dependent, necessitating heightened vigilance for local anesthetic systemic toxicity; the pediatric thoracoabdominal wall is relatively thin, requiring particular caution during needle insertion with continuous visualization of the complete needle shaft to avoid visceral injury.

(1) Rectus Sheath Block

The child is placed in the supine position with adequate exposure of the anterior abdominal wall. A high-frequency linear probe and an in-plane technique are utilized. The probe is positioned lateral to the linea alba at the umbilical level; sonographic visualization includes the anterior rectus sheath, rectus abdominis muscle, posterior rectus sheath, transversalis fascia, and peritoneum (Figure 5). The needle tip is advanced through the rectus abdominis muscle to the plane between the rectus abdominis muscle and the posterior rectus sheath; following negative aspiration for blood and air, local anesthetic is injected.

The rectus sheath block is indicated for anesthesia and analgesia during periumbilical surgery and midline vertical abdominal incisions[67]. The rectus sheath block is a safe and effective abdominal wall nerve block that reduces opioid requirements[68]. This technique has been demonstrated to provide superior postoperative analgesia compared with periumbilical local infiltration in pediatric umbilical hernia repair[69].

(2) Quadratus Lumborum Block

The child is placed in the lateral decubitus position with the affected side upward. A low-frequency linear probe or high-frequency linear probe is selected based on the required puncture depth. The probe is positioned at the level of the iliac crest along the posterior axillary line; deep to the transversalis fascia, the retroperitoneal fat is visualized anteriorly and the quadratus lumborum muscle posteriorly, with the psoas major muscle and vertebral transverse process located deep to the quadratus lumborum muscle (Figure 6).

The quadratus lumborum block is performed at three primary injection sites: the lateral point, posterior point, and anterior point, with local anesthetic deposited into the fascial planes between the quadratus lumborum muscle and the abdominal muscles, erector spinae muscle, and psoas major muscle, respectively. Intramuscular quadratus lumborum block refers to injection of local anesthetic directly into the quadratus lumborum muscle, thereby blocking the branches of the thoracolumbar spinal nerves coursing through this intermuscular space.

The lateral approach to quadratus lumborum block is indicated for anesthesia and analgesia during abdominal surgery, whereas the anterior approach is indicated for hip surgery[70]. Studies have demonstrated that the anterior approach to quadratus lumborum block provides superior postoperative analgesia compared with intramuscular quadratus lumborum block in pediatric abdominal surgery[71].

(3) Transversus Abdominis Plane (TAP) Block

The child is placed in the supine position. A high-frequency linear probe and an in-plane technique are employed. The most common approach is the lateral TAP block. The probe is positioned along the midaxillary line between the superior border of the iliac crest and the 12th rib; from superficial to deep, the external oblique, internal oblique, and transversus abdominis muscles are visualized, with the plane between the internal oblique and transversus abdominis muscles representing the transversus abdominis plane. This approach may be selected for

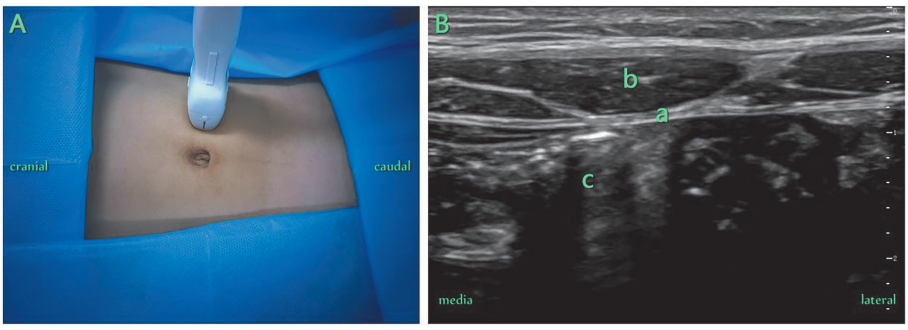


Figure 5 Ultrasound positioning and imaging of rectus sheath block

Note: A. Position of the ultrasound probe. B. Ultrasound image of the rectus sheath obtained with the probe positioned as shown in figure A. a—posterior sheath of rectus abdominis muscle; b—rectus abdominis muscle; c—abdominal cavity.

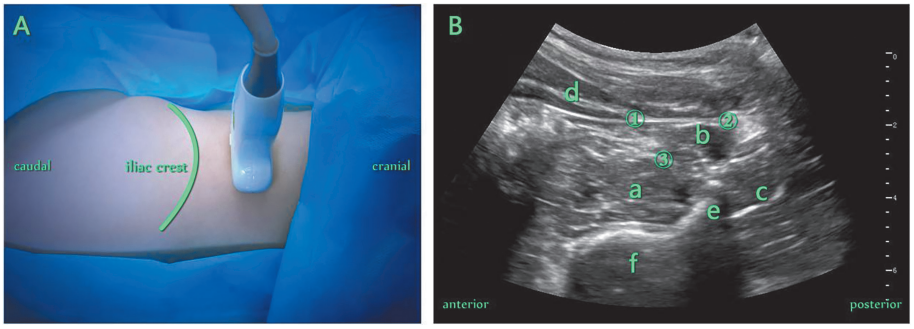


Figure 6 Ultrasound positioning and imaging of quadratus lumborum block
Note: A: Position of the ultrasound probe.B. Ultrasound image of the quadratus lumborum obtained with the probe positioned as shown in figure A. a—psoas muscle; b—quadratus lumborum muscle; c—quadratus lumborum muscle; d—abdominal muscle; e—transverse process; f—vertebral body; ① needle insertion site for lateral quadratus lumborum block; ②—needle insertion site for posterior quadratus lumborum block; ③—needle insertion site for anterior quadratus lumborum block.

children undergoing inguinal herniorrhaphy[72].

The posterior TAP block is performed at the Petit triangle, bounded by the iliac crest, posterior border of the external oblique muscle, and anterior border of the latissimus dorsi muscle, analogous to the lateral quadratus lumborum block. The child is placed in the lateral decubitus position with the affected side upward. The probe is positioned along the posterior axillary line between the costal margin and the iliac crest; the external oblique, internal oblique, transversus abdominis, and quadratus lumborum muscles are visualized. The target site is located anterior to the quadratus lumborum muscle and superficial to the transversalis fascia. This approach may be selected for children undergoing ureteral reimplantation[73].

The transversus abdominis plane block interrupts the abdominal wall nerves coursing through this plane to achieve analgesia of the abdominal wall region. Injection at different sites results in variations in both the extent and efficacy of blockade. The volume-dependent diffusion of local anesthetic is unpredictable, and inadequate dosing may result in block failure[74].

(4) Dorsal Penile Nerve Block

The child may be positioned supine or in the lithotomy position. A high-frequency linear probe is utilized. The probe is placed between the pubic symphysis and the base of the penis. In the superolateral aspect of the corpora cavernosa, deep to the fascia, the pulsatile dorsal penile artery is identified; the dorsal penile nerve is located in proximity to this artery. If the nerve is not clearly visualized, direct perivascular injection around the dorsal penile vessels may achieve equivalent analgesic efficacy.

This block is indicated for anesthesia and analgesia during circumcision and transurethral procedures. The technique is simple and safe[75-76]. Complications include arterial puncture and ischemic risk; solutions containing epinephrine must be strictly avoided[40].

5.2.5 Head and Neck Nerve Blocks

(1) Superficial Cervical Plexus Block

The child is placed in the lateral decubitus position with the affected side upward. A high-frequency linear probe and an in-plane technique are employed. The probe is positioned at the midpoint of the posterior border of the sternocleidomastoid muscle at the C4 level; the intermuscular space deep to the sternocleidomastoid muscle represents the target plane for blockade, and the circular or ovoid branches of the superficial cervical plexus may occasionally be visualized (Figure 7).

The superficial cervical plexus block is indicated for anesthesia and analgesia during cervical and upper thoracic surgery, and may be utilized in pediatric cochlear implantation and congenital muscular torticollis surgery. Complications include phrenic nerve block and vagus nerve block.

(2) Greater Auricular Nerve

The child is placed in the lateral decubitus position with the affected side upward. The probe is positioned over the surface of the sternocleidomastoid muscle; the external jugular vein is visualized sonographically. The greater auricular nerve lies superficial to the sternocleidomastoid muscle and posterior to the external jugular vein, typically appearing as a rounded or ovoid structure. The greater auricular nerve block is indicated for anesthesia and analgesia during earlobe surgery.

5.2.6 Continuous Peripheral Nerve Block

Single-injection peripheral nerve blocks typically fail to provide analgesia beyond 20 hours. Continuous peripheral

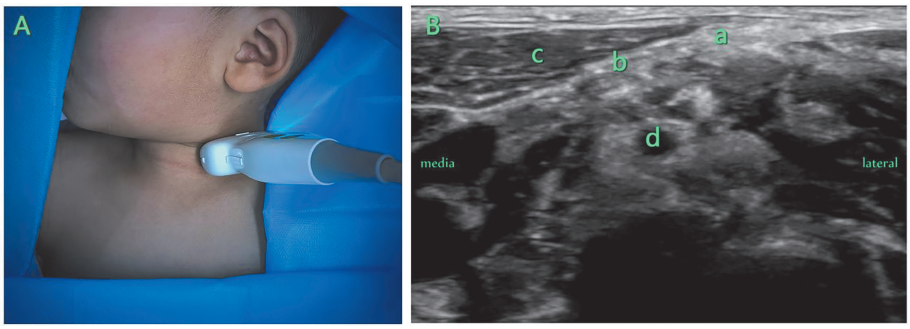


Figure 7 Ultrasound positioning and imaging of superficial cervical plexus block
Note: A. Position of the ultrasound probe.B. Ultrasound image of the superficial cervical plexus obtained with the probe positioned as shown in figure A. a—superficial cervical plexus; b—deep cervical fascia; c—sternocleidomastoid muscle; d—C5-nerve root.

nerve block (CPNB) has emerged as an effective modality capable of extending the analgesic duration of peripheral nerve blockade to 48–72 hours postoperatively[77]. Over the past decade, the utilization of CPNB in the pediatric population has progressively increased; moreover, the increased use of peripheral nerve catheters in pediatric anesthesia has been associated with a corresponding decrease in neuraxial anesthesia[78].

The literature demonstrates broad indications for CPNB, including: surgical procedures exceeding the analgesic duration provided by single-injection techniques; potential reduction in the incidence of phantom limb pain following amputation; management of chronic postoperative pain and complex regional pain syndrome; and pain management related to malignancy and chemotherapy[35,79].

Ultrasound guidance remains the gold standard for peripheral nerve catheter placement, with the in-plane technique employed to guide catheter advancement along the long axis of the nerve and accompanying vessels. The insertion and removal of peripheral nerve catheters should adhere to the same thromboprophylaxis guidelines as those for continuous neuraxial blockade[80]. The use of transparent dressings at the cutaneous catheter insertion site facilitates regular inspection. Minor catheter leakage that does not compromise effective analgesia does not necessitate catheter removal.

Recommendation 6: Ultrasound guidance is the gold standard for peripheral nerve catheter placement. Catheter insertion and removal should adhere to the same guideline standards as those for continuous neuraxial blockade. Complications associated with continuous peripheral nerve blockade (CPNB) are rare and generally mild. Subcutaneous tunneling techniques may reduce catheter-related complications. (Evidence Level: Moderate;Recommendation Strength: Weak)

5.3 Selection, Dosage of Local Anesthetics, and Use of Local Anesthetic Adjuvants

5.3.1 Selection and Dosage of Local Anesthetics

The maximum safe dose of 0.25% levobupivacaine is 2.5 mg/kg or 1 mL/kg. The use of 0.5–1.5 mg/kg of bupivacaine or ropivacaine enables successful and safe ultrasound-guided peripheral nerve blockade in children[81]. The recommended dosages of commonly used local anesthetics are summarized in Tables 2–3. For specific nerve blockade, the objective is to achieve circumferential spread of local anesthetic around the nerve, administering the recommended dose. For fascial plane blocks, the recommended volume should serve as the guiding parameter.

A study[82] utilizing data from the Pediatric Regional Anesthesia Network (PRAN) database analyzed 40,121 pediatric nerve block procedures and demonstrated that even for identical peripheral nerve blocks, local anesthetic dosage varied by up to 10-fold. Despite this substantial dosage variation, the incidence of local anesthetic systemic toxicity was only 0.005%, with no associated long-term adverse effects identified. The institution performing the nerve block was identified as the most significant factor influencing local anesthetic dosage[83].

Recommendation 7: The use of low-toxicity local anesthetics, such as ropivacaine and levobupivacaine, is recommended, with dosage calculated based on ideal body weight. (Evidence Level:High; Recommendation Strength: Strong)

Table 2 Recommended dosages of common local anaesthetics[84]

Local anaesthetics	Maximum allowable dose/(mg·kg^{-1})	Bolus for peripheral and truncal block		Infusion for continuous block	
		Mass concentration/ [g·(100 mL)$^{-1}$]	Volume/(mg·kg^{-1})	Mass concentration/ [g·(100 mL)$^{-1}$]	Rate/[mg·(kg·h)$^{-1}$]
Ropivacaine	2.5	0.2	0.5	0.2/0.1	0.4
Levobupivacaine	2.5	0.25	0.5	0.125	0.4

Note: The infusion rate should be halved in children below 1 year of age.

Table 3 Indications and dosing recommendations for commonly used paediatric regional blocks[41]

Common nerve block technique	Indication	0.2% Ropivacaine
Axillary brachial plexus block	Elbow open reduction and internal fixation, forearm and hand surgery	0.2–0.5 mL·kg^{-1} (up to 15 mL)
Femoral nerve block	Femoral fracture, slipped upper femoral epiphysis, femoral osteotomy	0.2–0.5 mL·kg^{-1} (up to 15 mL)
Popliteal sciatic nerve block	Tendon transfers/lengthening, lower limb trauma, tibial osteotomy, ankle arthroplasty, club foot repair	0.2–0.3 mL·kg^{-1} (up to 15 mL)
Rectus sheath block	Umbilical herniotomy, pyloromyotomy, open gastrostomy	0.1–0.3 mL·kg^{-1} (per side)
Lateral quadratus lumborum block	Inguinalherniotomy, open appendicectomy	0.5 mL·kg^{-1} (up to 20 mL per side)
Dorsal penile nerve block	Circumcision, distal hypospadias repair	0.1 mL·kg^{-1} (up to 5 mL both sides)

Note: When the same patient requires nerve blocks in two or more sites, the maximum dose specified in Table 2 shall serve as the limit for drug administration; the concentration of the local anesthetic shall be selected judiciously, and the dosage of the local anesthetic for each site shall be appropriately allocated.

5.3.2 Local Anesthetic Adjuvants

Local anesthetic adjuvants are defined as one or more medications administered concurrently with local anesthetics in the vicinity of peripheral nerves or nerve plexuses[85]. The purpose of adding adjuvants to local anesthetics is to prolong block duration and reduce general anesthetic requirements. In evaluating adjuvants, particular consideration must be given to whether the formulation is preservative-free, whether the overall safety profile is acceptable, and its potential toxicity[85].

Clinical studies investigating the addition of adjuvants to local anesthetics for pediatric nerve blockade have been conducted; however, no clear consensus exists regarding the clinical definition of prolonged postoperative analgesia or the assessment of benefits conferred by local anesthetic adjuvants[81]. Therefore, the use of local anesthetic adjuvants in pediatric nerve blockade should be approached with caution.

Studies have indicated that α2-adrenergic receptor agonists, when used as local anesthetic adjuvants, may prolong peripheral nerve block duration. Clonidine significantly prolongs block duration[86]; dexmedetomidine enhances the analgesic efficacy of local anesthetics, although this effect is limited to the initial 8 hours postoperatively[87]. Adverse effects include increased risk of bradycardia and enhanced sedative effects.

A study employing dexamethasone as an adjuvant[88] demonstrated sensory block duration of 9–19 hours (mean: 13.62 ± 3.02 hours), representing a 390-minute prolongation compared with the control group without adjuvant. Studies comparing the efficacy of perineural versus intravenous administration of dexamethasone have not established its superiority in either adult or pediatric populations.

Overall, clinical research data regarding the use of local anesthetic adjuvants in pediatric nerve blockade remain insufficient, and no other adjuvants have been demonstrated to improve postoperative analgesia.

5.4 Assessment of Anesthetic Efficacy

5.4.1 Local Anesthetic Spread Under Ultrasonographic Imaging

Direct ultrasonographic visualization of local anesthetic spread circumferentially around the nerve suggests a higher probability of block success.

5.4.2 Intraoperative and Postoperative Analgesic Consumption

Optimal nerve blockade provides more stable intraoperative hemodynamics, reduces intraoperative and postoperative opioid consumption, and facilitates enhanced recovery after surgery.

5.4.3 Postoperative Pain Assessment

Postoperative pain assessment scales constitute an important tool in the evaluation of pediatric nerve block efficacy[89-90]. It is recommended that age-appropriate assessment scales be selected based on the child's chronological age.

(1) Postoperative Pain Assessment in Children Aged 0–3 Years

The COMFORT/COMFORT-B scale[89-90] or the FLACC scale (Face, Legs, Activity, Cry, Consolability Scale)[89-90] is recommended.

(2) Postoperative Pain Assessment in Children Aged 4 Years

The Faces Pain Scale–Revised (FPS-R)[89-90] is recommended, in combination with the COMFORT/COMFORT-B scale or the FLACC scale. The FPS-R requires the child to independently rate pain intensity from 0 (no pain) to 10 (worst pain imaginable). Concurrently, the FPS-R provides six facial expression cartoon images (ranging from smiling to sad to crying) to visually represent the pain intensity corresponding to each score interval. During assessment, the child points to the scale or cartoon face that corresponds to their perceived pain level.

(3) Postoperative Pain Assessment in Children Aged 5–7 Years

The FPS-R is recommended.

(4) Postoperative Pain Assessment in Children Aged 7 Years and Above

The Visual Analogue Scale (VAS)[89-90], Numeric Rating Scale (NRS)[89-90], or FPS-R is recommended. The VAS is the most commonly employed unidimensional tool for measuring pain intensity. The scale consists primarily of a straight line, with one end representing "no pain at all" and the opposite end representing "pain as bad as it could be." The child marks the position on the line corresponding to their perceived pain intensity.

The NRS is accurate, concise, and was previously regarded by the American Pain Society as the gold standard for pain assessment. Multiple versions of the NRS exist, of which the NRS 0–10 version is the most commonly utilized. The child selects from four major categories comprising 11 scoring options (0–10): no pain (0), mild pain (1–3), moderate pain (4–6), and severe pain (7–10).

The aforementioned pain assessment scales are provided in the supplementary materials. It should be noted that utilizing chronological age as the sole indicator of a child's self-reporting capacity is likely to yield false-positive results. In clinical practice, the child's self-assessment capability must first be evaluated, as cognitive and linguistic abilities vary substantially among children of the same age.

Recommendation 8: The efficacy of pediatric nerve blockade may be assessed based on ultrasonographic imaging and intraoperative analgesic consumption; age-appropriate pain scales may provide relatively objective evaluation. (Evidence Level: Moderate; Recommendation Strength: Weak)

6. Complications and Prevention of Ultrasound-Guided Pediatric Nerve Blocks

6.1 Incidence of Complications in Pediatric Nerve Blocks

Pediatric nerve blocks have a high safety profile, with an incidence of complications ranging from 0.03% to 0.1%, which is one-sixth that of neuraxial anesthesia. The incidence of complications in infants under 6 months of age is four times higher than in children older than 6 months[38-39,91]. The incidence rates of the two most serious complications, i.e., nerve injury and local anesthetic systemic toxicity (LAST), are 0.02%–0.13% and 0.01%–0.05%, respectively[6].

6.2 Common Complications of Pediatric Nerve Blocks and Their Management

6.2.1 Local Anesthetic Systemic Toxicity (LAST)

As pediatric nerve blocks are often performed under general anesthesia or sedation, the signs and symptoms of LAST[92] may be masked, thereby increasing the risk of LAST[93]. The main manifestations of LAST in children are cardiovascular abnormalities. Early recognition relies entirely on close observation and assessment by the anesthesiologist[47,94]. Infants under 6 months of age are more susceptible to LAST, possibly due to differences in physiology and drug metabolism[47,82,95-96].

Early recognition of toxicity is crucial. The treatment of LAST depends on the severity of symptoms and the progression of the condition. Mild LAST symptoms are usually self-limiting. In such cases, conservative management includes stopping local anesthetic injection, administering oxygen, establishing intravenous access, preparing resuscitation equipment, reassuring the patient and family, and continuously monitoring until symptoms resolve. If mild symptoms persist or escalate, benzodiazepines may be used to prevent neurological symptoms such as seizures. If severe LAST develops, lipid resuscitation therapy (LRT) should be initiated according to the pediatric LAST management guidelines proposed by the Society for Pediatric Anesthesia (SPA) and the joint committee of ESRA/ASRA[92,94,97]. Specific measures from the pediatric LAST management guidelines are as follows:

(1) Stop injecting the local anesthetic and call for help and intralipid kit.
(2) Confirm or establish adequate IV access.
(3) Maintain the airway and give 100% oxygen. Consider the placement of endotracheal tube.
(4) Continuously monitor electrocardiogram (ECG), blood pressure (BP), oxygen saturation by pulse oximetry (SpO2).
(5) If seizures develop, administer a benzodiazepine (eg. midazolam 0.05–0.1 mg/kg IV), watch resultant hypotension.
(6) Avoid routine advanced cardiac life support (ACLS) doses of epinephrine. Treat hypotension with small IV epinephrine dose (MAX: 1 μg/kg)
(7) Drugs to Avoid: propofol, vasopressin, calcium channel blockers, and betablockers.
(8) Start IV intralipid therapy as follows: ① Initial bolus: IV 20% lipid emulsion = 1.5 mL/kg over 60 seconds; ② Maintenance infusion: IV 20% lipid emulsion = 0.25 mL/kg/min; ③ Repeat IV bolus every 3 to 5 min until circulation is restored (MAX cumulative total bolus dosing=4.5 mL/kg); ④ If cardiovascular instability persists, double infusion rate to 0.5 mL/kg/min. Continue maintenance infusion for 10 mins once hemodynamic stability is restored. Note: total intralipid dose should not exceed 10 mL/kg
(9) Recognize arrhythmias and/or cardiac arrest and initiate cardiopulmonary resuscitation (CPR)/pediatric advanced life support (PALS) protocols. REMEMBER: Continue chest compressions as intralipid must circulate to be effective. (May need prolonged compressions)
(10) 6-min mark: Consider alerting nearest cardiopulmonary bypass or extracorporeal membrane oxygenation (ECMO) center and intensive care unit if there is no return to spontaneous circulation to facilitate the transfer and maintenance of circulation until local anesthetic is metabolized.
(11) Monitor and correct acidosis, hypercarbia, and hyperkalemia as needed.

Recommendation 9: Early recognition of LAST is critical. In the event of severe toxicity, immediate lipid resuscitation therapy with 20% lipid emulsion should be initiated. Initial bolus: 1.5 mL/kg intravenously over at least 60 seconds; maintenance infusion: 0.25 mL/(kg·min); repeat intravenous bolus every 3–5 minutes until circulatory recovery; if circulatory instability persists, increase infusion rate to 0.5 mL/(kg·min); continue infusion for 10 minutes after hemodynamic stability is restored. The total dose of lipid emulsion should not exceed 10 mL/kg. (Level of evidence: High; Strength of recommendation: Strong)

6.2.2 Allergic Reactions

Ester local anesthetics can cause allergic reactions; allergic reactions to amide local anesthetics are extremely rare, with only isolated case reports[98]. Once a child develops symptoms related to an allergic reaction, prompt assessment and rapid diagnosis should be made. Treatment should be based on the severity grade of the reaction. For Grade I patients[99-100] presenting with skin and mucosal symptoms, the allergen should be removed immediately, and respiratory and circulatory support (e.g., oxygen) should be provided; epinephrine is generally not recommended. For patients with Grade II (moderate involvement of multiple organ systems) or higher allergic reactions, epinephrine should be the first-line treatment, along with measures to stabilize the respiratory and circulatory systems to save the patient's life[100-101].

6.2.3 Nerve Injury

Nerve injury presents as paresthesia and motor dysfunction[102-104]. According to PRAN data analysis, no permanent nerve injury was reported in any case, and the incidence of transient neurological dysfunction was 0.024%[47]. If an unexpected clinical outcome occurs, particularly persistent unexpected motor deficits following regional block, nerve injury should be highly suspected, and appropriate diagnostic and therapeutic measures should be taken immediately.

The widespread use of ultrasound has greatly improved the accuracy and success rate of blocks, but nerve injury cannot be completely avoided. The following preventive measures are currently recommended[104]:

(1) Carefully obtain a medical history before the procedure. For patients with pre-existing diffuse neuropathy or subclinical manifestations, nerve blocks should be avoided whenever possible. If required based on risk-benefit assessment, informed consent should be obtained.
(2) The paresthesia-seeking technique is not recommended for nerve blocks.
(3) Avoid using long-bevel needles[38].
(4) Use ultrasound guidance for precise localization. The in-plane technique is recommended. Clearly visualize the relationship between the needle tip and the target nerve. Inject around the nerve whenever possible to avoid direct needle-nerve contact and injury.

(5) If paresthesia, pain, or excessive resistance occurs during needle advancement or injection, stop needling or injecting immediately[105].
(6) Avoid using large-volume syringes for injection to prevent pressure-induced nerve injury due to false pressure feedback[106].
(7) Use the lowest effective concentration and dose of local anesthetic, and exercise caution when using adjuvants[107].
(8) Select appropriate surgical position. In particular, avoid position-related nerve compression injury in obese and underweight patients. Limit upper extremity abduction to ≤90°, use elbow protection pads to prevent local compression, and correctly apply tourniquets or compression bandages.
(9) Postoperative follow-up should monitor for possible nerve injury, and records should be kept to address potential disputes.

Currently, there is a lack of specific drugs that directly and efficiently promote neural structural regeneration and full functional recovery. Existing treatment strategies are mainly supportive and adjunctive. Options include[108-109]: ① Neuroprotective agents (e.g., glucocorticoids, vitamin B12) and physical therapy; transient nerve injury may resolve spontaneously. ② For local hematoma compressing the nerve, nerve transection, or severe axonal injury, surgical exploration may be necessary when indicated.

Recommendation 10: Preventive measures to avoid nerve injury during pediatric nerve blocks include: selecting an appropriate patient position; using ultrasound guidance; avoiding direct needle-nerve contact; using the lowest effective concentration and dose of local anesthetic; and stopping needling or injection immediately if excessive resistance or paresthesia occurs. (Level of evidence: High; Strength of recommendation: Strong)

6.2.4 Bleeding and Hematoma

Severe bleeding complications related to pediatric nerve blocks are rare, mainly because pediatric patients rarely receive perioperative anticoagulant therapy. In PRAN data, only one hematoma associated with bilateral paravertebral continuous catheter placement was reported[47]. For patients with coagulation disorders from any cause, neuraxial blocks and deep nerve blocks (paravertebral and lumbar plexus blocks) should be avoided[63,110]. An INR of 1.15 is recommended as the cutoff value; peripheral nerve blocks can be performed when INR <1.15[94]. 45 weeks postmen strual age should be managed according to protocols for known coagulopathies. During nerve block procedures, use ultrasound to clearly identify blood vessels and avoid inadvertent puncture. Observe local anesthetic spread under ultrasound, aspirate before injection, and inject in divided doses to ensure the drug is not intravascular. Apply appropriate compression to the puncture site after the procedure.

Recommendation 11: For patients with coagulation disorders from any cause, neuraxial blocks and deep nerve blocks should be avoided. An INR of 1.15 is recommended as the cutoff value; peripheral nerve blocks can be performed when INR <1.15. (Level of evidence: High; Strength of recommendation: Strong)

6.2.5 Infection

Infectious complications related to nerve blocks are rare. The risk of superficial or skin infection is approximately 0.5% (53/10,000), and symptoms are usually mild, with most not requiring antibiotic treatment. Infection following single-injection nerve blocks is rarely reported. The risk of infection is associated with longer duration of catheter use (>3 days) and the presence of more complications in the patient [American Society of Anesthesiologists (ASA) class III][104].

6.2.6 Complications Related to Continuous Peripheral Nerve Blocks (CPNB)

Complications of CPNB in children are infrequent and generally mild, primarily catheter-related mechanical issues and systemic drug effects such as nausea and vomiting[111].

In one study involving 2,074 CPNB catheter placements[95], 251 adverse events and complications were recorded, with an overall complication rate of 12.1% (10.7%–13.5%). The most common complications were catheter dysfunction, block failure, infection, and vascular puncture. No persistent neurological issues, severe infections, or LAST were reported. Catheter-related complications included minor leakage, which usually did not affect analgesic efficacy. Other common issues included catheter displacement and accidental removal. The incidence of local infection was low, mostly superficial inflammation, and was associated with the duration of catheter use[104]. Transcutaneous tunneling of the catheter may reduce bacterial colonization, but no data are available regarding its effect on reducing infection risk[94].

The most common systemic reactions are nausea and vomiting. Pruritus, urinary retention, and constipation

occur at very low rates. No permanent nerve injury has been observed[111-112].

7. Conclusion

This consensus represents the first expert guideline in China specifically formulated for the clinical practice of ultrasound-guided pediatric nerve blocks. Based on available evidence-based medical literature, the working group integrated relevant domestic and international research progress and clinical experience to formulate recommendations aimed at providing practical guidance for the implementation of ultrasound-guided pediatric nerve blocks in clinical anesthesia and pain management. However, limited by the current state of research on ultrasound-guided pediatric nerve blocks, this consensus has the following limitations: First, clinical evidence for some recommendations is insufficient; medical professionals are advised to use this consensus in conjunction with their clinical judgment. Second, some recommendations lack support from large-sample research data, and there is a lack of data on nerve blocks in infants under 6 months of age, as well as long-term follow-up regarding the safety of pediatric nerve blocks. Finally, a comprehensive training and certification system for pediatric nerve block techniques has not yet been established, making it difficult to quantitatively assess operator qualifications and experience. This consensus generally reflects the current status and level of clinical research on pediatric nerve block techniques. Future high-quality clinical studies, data analyses, and long-term observations are needed to strengthen the evidence chain and enhance the guiding value of this consensus. The expert team will regularly update the consensus to reflect the latest research progress and clinical practice outcomes.

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References

1. Pinto N, Sawardekar A, Suresh S. Regional anesthesia: Options for the pediatric patient. *Anesthesiol Clin.* 2020;38(3):559–75. doi:10.1016/j.anclin.2020.05.005
2. Hamill JK, Rahiri JL, Liley A, Hill AG. Rectus sheath and transversus abdominis plane blocks in children: A systematic review and meta-analysis of randomized trials. *Paediatr Anaesth*. 2016;26(4):363–71. doi:10.1111/pan.12855
3. Kendall MC, Alves LJC, Suh EI, McCormick ZL, De Oliveira GS. Regional anesthesia to ameliorate postoperative analgesia outcomes in pediatric surgical patients: An updated systematic review of randomized controlled trials. *Local Reg Anesth*. 2018;11:91–109. doi:10.2147/lra.S185554
4. Hall-Burton DM, Hudson ME, Grudziak JS, Cunningham S, Boretsky K, Boretsky KR. Regional anesthesia is cost-effective in preventing unanticipated hospital admission in pediatric patients having anterior cruciate ligament reconstruction. *Reg Anesth Pain Med*. 2016;41(4):527–31. doi:10.1097/aap.0000000000000410
5. Arena S, Di Fabrizio D, Impellizzeri P, Gandullia P, Mattioli G, Romeo C. Enhanced recovery after gastrointestinal surgery (eras) in pediatric patients: A systematic review and meta-analysis. *J Gastrointest Surg*. 2021;25(11):2976–88. doi:10.1007/s11605-021-05053-7
6. Barnett NR, Hagen JG, Kattail D. Pediatric regional anesthesia and acute pain management: State of the art. *Best Pract Res Clin Anaesthesiol*. 2024;38(2):135–44. doi:10.1016/j.bpa.2024.05.003
7. Dumbarton TC. Regional anesthesia in complex pediatric patients: Advances in opioid-sparing analgesia. *Can J Anaesth*. 2024;71(6):727–30. doi:10.1007/s12630-023-02616-x
8. Mathew A, Kerolus K, Bitonti N, Guzman A, Moore R, Bergese S. Back to the future: Historic insights and recent innovations in pediatric regional anesthesia. *J Clin Med*. 2024;13(22):doi:10.3390/jcm13226704
9. Guyatt GH, Oxman AD, Vist GE, et al. Grade: An emerging consensus on rating quality of evidence and strength of recommendations. *Bmj*. 2008;336(7650):924–6. doi:10.1136/bmj.39489.470347.AD
10. Teo EL, Strouse PJ, Chhem RK. Musculoskeletal ultrasonography in children. *Can Assoc Radiol J*. 2002;53(1):14–21.
11. Merella F, Canchi-Murali N, Mossetti V. General principles of regional anaesthesia in children. *BJA Educ*. 2019;19(10):342–48. doi:10.1016/j.bjae.2019.06.003
12. Hryhorczuk AL, Restrepo R, Lee EY. Pediatric musculoskeletal ultrasound: Practical imaging approach. *AJR Am J Roentgenol*. 2016;206(5):W62–72. doi:10.2214/ajr.15.15858
13. Boretsky KR. Regional anesthesia in pediatrics: Marching forward. *Curr Opin Anaesthesiol*. 2014;27(5):556–60. doi:10.1097/aco.0000000000000106
14. Marhofer P, Harrop-Griffiths W, Kettner SC, Kirchmair L. Fifteen years of ultrasound guidance in regional anaesthesia: Part 1. *Br J Anaesth*. 2010;104(5):538–46. doi:10.1093/bja/aeq069
15. Bosenberg A. Benefits of regional anesthesia in children. *Paediatr Anaesth*. 2012;22(1):10–8. doi:10.1111/j.1460-9592.2011.03691.x
16. Tsui BC, Suresh S. Ultrasound imaging for regional anesthesia in infants, children, and adolescents: A review of current literature and its application in the practice of neuraxial blocks. *Anesthesiology*. 2010;112(3):719–28. doi:10.1097/ALN.0b013e3181c5e03a
17. Lönnqvist PA. Is ultrasound guidance mandatory when performing paediatric regional anaesthesia? *Curr Opin Anaesthesiol*. 2010;23(3):337–41. doi:10.1097/ACO.0b013e328339276f
18. Suresh S, Schaldenbrand K, Wallis B, De Oliveira GS, Jr. Regional anaesthesia to improve pain outcomes in paediatric surgical patients: A qualitative systematic review of randomized controlled trials. *Br J Anaesth*. 2014;113(3):375–90. doi:10.1093/bja/aeu156
19. Splinter WM, Thomson ME. Somatic paravertebral block decreases opioid requirements in children undergoing appendectomy. *Can J Anaesth*. 2010;57(3):206–10. doi:10.1007/s12630-009-9239-y
20. Guay J, Suresh S, Kopp S. The use of ultrasound guidance for perioperative neuraxial and peripheral nerve blocks in children: A cochrane review. *Anesth Analg*. 2017;124(3):948–58. doi:10.1213/ane.0000000000001363
21. Dadure C, Veyckemans F, Bringuier S, Habre W. Epidemiology of regional anesthesia in children: Lessons learned from the european multi-institutional study apricot. *Paediatr Anaesth*. 2019;29(11):1128–35. doi:10.1111/pan.13741
22. Bosenberg AT. Regional anaesthesia in children: An update. *Southern African Journal of Anaesthesia and Analgesia*. 2014;19(6):282–88. doi:10.1080/22201173.2013.10872942
23. Dohlman LE, Kwikiriza A, Ehie O. Benefits and barriers to increasing regional anesthesia in resource-limited settings. *Local Reg Anesth*. 2020;13:147–58. doi:10.2147/lra.S236550
24. Brindle ME, McDiarmid C, Short K, et al. Consensus guidelines for perioperative care in neonatal intestinal surgery: Enhanced recovery after surgery (eras(®)) society recommendations. *World J Surg*. 2020;44(8):2482–92. doi:10.1007/s00268-020-05530-1
25. Association of Paediatric Anaesthetists of Great Britain and Ireland. Good practice in postoperative and procedural pain management, 2nd edition. *Paediatr Anaesth*. 2012;22 Suppl 1:1–79. doi:10.1111/j.1460-9592.2012.03838.x
26. Lönnqvist PA. Regional anaesthesia and analgesia in the neonate. *Best Pract Res Clin Anaesthesiol*. 2010;24(3):309–21. doi:10.1016/j.bpa.2010.02.012
27. Richman M, Berman JM, Ross EM. Regional anesthesia use in pediatric burn surgery: A descriptive retrospective series. *Cureus*. 2021;13(10):e19063. doi:10.7759/cureus.19063
28. Moningi S, Patki A, Padhy N, Ramachandran G. Enhanced recovery after surgery: An anesthesiologist's perspective. *J Anaesthesiol Clin Pharmacol*. 2019;35(Suppl 1):S5-s13. doi:10.4103/joacp.JOACP_238_16
29. Bugada D, Ghisi D, Mariano ER. Continuous regional anesthesia: A review of perioperative outcome benefits. *Minerva Anestesiol*. 2017;83(10):1089–100. doi:10.23736/s0375-9393.17.12077-8
30. Li T, Dong T, Cui Y, Meng X, Dai Z. Effect of regional anesthesia on the postoperative delirium: A systematic review and meta-analysis of randomized controlled trials. *Front Surg*. 2022;9:937293. doi:10.3389/fsurg.2022.937293
31. Somaini M, Sahillioğlu E, Marzorati C, Lovisari F, Engelhardt T, Ingelmo PM. Emergence delirium, pain or both? A challenge for clinicians. *Paediatr Anaesth*. 2015;25(5):524–9. doi:10.1111/pan.12580
32. Kim HS, Kim CS, Kim SD, Lee JR. Fascia iliaca compartment block reduces emergence agitation by providing effective analgesic properties in chil-

dren. *J Clin Anesth*. 2011;23(2):119–23. doi:10.1016/j.jclinane.2010.08.007
33. Mesnil M, Dadure C, Captier G, et al. A new approach for peri-operative analgesia of cleft palate repair in infants: The bilateral suprazygomatic maxillary nerve block. *Paediatr Anaesth*. 2010;20(4):343–9. doi:10.1111/j.1460-9592.2010.03262.x
34. Merella F, Mossetti V. Ultrasound-guided upper and lower extremity nerve blocks in children. *BJA Educ*. 2020;20(2):42–50. doi:10.1016/j.bjae.2019.11.003
35. Cucchiaro G, Craig K, Marks K, Cooley K, Cox TKB, Schwartz J. Short- and long-term results of an inpatient programme to manage complex regional pain syndrome in children and adolescents. *Br J Pain*. 2017;11(2):87–96. doi:10.1177/2049463717695695
36. White W, Bellman L, Liu YT. Ultrasound-guided pediatric nerve blocks in the emergency department: An evidence-based update. *Pediatr Emerg Med Pract*. 2022;19(5):1–32.
37. Wan L, Wang Y, Wang G, et al. Expert consensus on ultrasound-guided regional block/analgesia. In: Huang YG, Deng XM, eds. *Chinese Anesthesiology Guidelines and Expert Consensus (2020).* People's Medical Publishing House; 2022:336–346
38. Lönnqvist PA, Ecoffey C, Bosenberg A, Suresh S, Ivani G. The european society of regional anesthesia and pain therapy and the american society of regional anesthesia and pain medicine joint committee practice advisory on controversial topics in pediatric regional anesthesia i and ii: What do they tell us? *Curr Opin Anaesthesiol*. 2017;30(5):613–20. doi:10.1097/aco.0000000000000508
39. Ivani G, Suresh S, Ecoffey C, et al. The european society of regional anaesthesia and pain therapy and the american society of regional anesthesia and pain medicine joint committee practice advisory on controversial topics in pediatric regional anesthesia. *Reg Anesth Pain Med*. 2015;40(5):526–32. doi:10.1097/aap.0000000000000280
40. Ponde VC, Rath A, Singh N. Expert's tips on regional blocks in neonates and infants. *Anesth Pain Med (Seoul)*. 2024;19(Suppl 1):S73-s86. doi:10.17085/apm.23164
41. Pearson AME, Roberts S, Turbitt LR. New blocks on the kids: Core basic nerve blocks in paediatric anaesthesia. *Anaesthesia*. 2023;78(1):3–8. doi:10.1111/anae.15876
42. Yentis SM, Hartle AJ, Barker IR, et al. Aagbi: Consent for anaesthesia 2017: Association of anaesthetists of great britain and ireland. *Anaesthesia*. 2017;72(1):93–105. doi:10.1111/anae.13762
43. Disma N, Veyckemans F, Virag K, et al. Morbidity and mortality after anaesthesia in early life: Results of the european prospective multicentre observational study, neonate and children audit of anaesthesia practice in europe (nectarine). *Br J Anaesth*. 2021;126(6):1157–72. doi:10.1016/j.bja.2021.02.016
44. Chinese Society of Anesthesiology Task Force on Sedation during Regional Anesthesia. Consensus on sedation during regional anesthesia. *Chin J Anesthesiol.* 2017;37(1):12–20. doi:10.3760/cma.j.issn.0254-1416.2017.01.003
45. Ponde V, Puri K, Osazuwa M, et al. Principles of regional anaesthesia in children. Anaesthesia Tutorial of the Week. Published November 22, 2022. Accessed November 15, 2026. https://resources.wfsahq.org/wp-content/uploads/atow-485.pdf
46. Hewson DW, Bedforth NM, Hardman JG. Peripheral nerve injury arising in anaesthesia practice. *Anaesthesia*. 2018;73 Suppl 1:51–60. doi:10.1111/anae.14140
47. Walker BJ, Long JB, Sathyamoorthy M, et al. Complications in pediatric regional anesthesia: An analysis of more than 100,000 blocks from the pediatric regional anesthesia network. *Anesthesiology*. 2018;129(4):721–32. doi:10.1097/aln.0000000000002372
48. Gadsden JC. The role of peripheral nerve stimulation in the era of ultrasound-guided regional anaesthesia. *Anaesthesia*. 2021;76 Suppl 1:65–73. doi:10.1111/anae.15257
49. Disinfection of ultrasound transducers used for percutaneous procedures: Intersocietal position statement. *J Ultrasound Med*. 2021;40(5):895–97. doi:10.1002/jum.15653
50. Bomberg H, Bayer I, Wagenpfeil S, et al. Prolonged catheter use and infection in regional anesthesia: A retrospective registry analysis. *Anesthesiology*. 2018;128(4):764–73. doi:10.1097/aln.0000000000002105
51. Azi LMTdA, Fonseca NM, Linard LG. Sba 2020: Regional anesthesia safety recommendations update. *Brazilian Journal of Anesthesiology (English Edition)*. 2020;70(4):398–418. doi:10.1016/j.bjane.2020.04.015
52. Yoshida K, Kakinouchi K. Does a single ultrasound-guided peripheral nerve block always require a full aseptic technique? *Reg Anesth Pain Med*. 2024;49(10):775. doi:10.1136/rapm-2023-104931
53. Marhofer P. Upper extremity peripheral blocks. *Techniques in Regional Anesthesia and Pain Management*. 2007;11(4):215–21. doi:10.1053/j.trap.2007.09.002
54. Taenzer A, Walker BJ, Bosenberg AT, et al. Interscalene brachial plexus blocks under general anesthesia in children: Is this safe practice?: A report from the pediatric regional anesthesia network (pran). *Reg Anesth Pain Med*. 2014;39(6):502–5. doi:10.1097/AAP.0000000000000166
55. Guzel M, Bingul ES, Salviz EA, Senturk E, Cosgun MF, Savran Karadeniz M. Comparison of ultrasound-guided supraclavicular and costoclavicular brachial plexus blocks in pediatric patients: A randomized clinical trial. *J Anesth*. 2023;37(2):186–94. doi:10.1007/s00540-022-03143-7
56. Carioca F, Silva M, Bispo C, Mafra J, Cenicante T. Costoclavicular brachial plexus block in paediatric anaesthesia: A retrospective pilot study. *J Clin Anesth*. 2021;69:110113. doi:10.1016/j.jclinane.2020.110113
57. Karmakar MK, Sala-Blanch X, Songthamwat B, Tsui BC. Benefits of the costoclavicular space for ultrasound-guided infraclavicular brachial plexus block: Description of a costoclavicular approach. *Reg Anesth Pain Med*. 2015;40(3):287–8. doi:10.1097/aap.0000000000000232
58. Li PF, Guo X, Hong SM. Efficacy of ultrasound-guided modified brachial plexus block at costoclavicular space for forearm surgery. *Chin J Anesthesiol.* 2022;42(2):203–206. doi:10.3760/cma.j.cn131073.20211214.00217
59. Wang WT, Tu YB, Yi ZG, et al. Research progress on ultrasound-guided costoclavicular space brachial plexus block in pediatric patients. *J Clin Anesthesiol.* 2024;40(4):424–428. doi:10.12089/jca.2024.04.017
60. Oberndorfer U, Marhofer P, Bosenberg A, et al. Ultrasonographic guidance for sciatic and femoral nerve blocks in children. *Br J Anaesth*. 2007;98(6):797–801. doi:10.1093/bja/aem092
61. Turner AL, Stevenson MD, Cross KP. Impact of ultrasound-guided femoral nerve blocks in the pediatric emergency department. *Pediatric Emergency Care*. 2014;30(4):227–29. doi:10.1097/pec.0000000000000101
62. Kirchmair L, Enna B, Mitterschiffthaler G, et al. Lumbar plexus in children: A sonographic study and its relevance to pediatric regional anesthesia. *Anesthesiology*. 2004;101(2):445–50. doi:10.1097/00000542-200408000-00026
63. Horlocker TT, Vandermeuelen E, Kopp SL, Gogarten W, Leffert LR, Benzon HT. Regional anesthesia in the patient receiving antithrombotic or thrombolytic therapy: American society of regional anesthesia and pain medicine evidence-based guidelines (fourth edition). *Reg Anesth Pain Med*. 2018;43(3):263–309. doi:10.1097/AAP.0000000000000763
64. Hsu DT. Delayed retroperitoneal haematoma after failed lumbar plexus block. *Br J Anaesth*. 2005;94(3):395; author reply 95–6. doi:10.1093/bja/aei519
65. Keplinger M, Marhofer P, Moriggl B, Zeitlinger M, Muehleder-Matterey S, Marhofer D. Cutaneous innervation of the hand: Clinical testing in volunteers shows high intra- and inter-individual variability. *Br J Anaesth*. 2018;120(4):836–45. doi:10.1016/j.bja.2017.09.008

66. Lonnqvist PA. Fascial plane blocks in children-scientifically supported or not? *Paediatr Anaesth*. 2024;34(1):13–18. doi:10.1111/pan.14752
67. Winnie L, Kao YH, Liao CC, Tamura T, Chang ML, Hsieh KY. Comparative analgesic efficacies of ropivacaine and bupivacaine for postoperative rectus sheath block in paediatric abdominal surgery: A meta-analysis of randomized controlled trial and retrospective cohort studies. *Pain Res Manag*. 2021;2021:5535730. doi:10.1155/2021/5535730
68. Claxton HL, Nevins EJ, McCallum I. Comparison of the effectiveness of thoracic epidural and rectus sheath catheter as analgesic modalities following laparotomy: A systematic review and meta-analysis. *J Perioper Pract*. 2023;33(11):332–41. doi:10.1177/17504589221086130
69. Gurnaney HG, Maxwell LG, Kraemer FW, Goebel T, Nance ML, Ganesh A. Prospective randomized observer-blinded study comparing the analgesic efficacy of ultrasound-guided rectus sheath block and local anaesthetic infiltration for umbilical hernia repair. *Br J Anaesth*. 2011;107(5):790–5. doi:10.1093/bja/aer263
70. Ueshima H, Otake H, Lin JA. Ultrasound-guided quadratus lumborum block: An updated review of anatomy and techniques. *Biomed Res Int*. 2017;2017:2752876. doi:10.1155/2017/2752876
71. Hussein MM. Ultrasound-guided quadratus lumborum block in pediatrics: Trans-muscular versus intra-muscular approach. *J Anesth*. 2018;32(6):850–55. doi:10.1007/s00540-018-2563-z
72. Abu Elyazed MM, Mostafa SF, Abdullah MA, Eid GM. The effect of ultrasound-guided transversus abdominis plane (tap) block on postoperative analgesia and neuroendocrine stress response in pediatric patients undergoing elective open inguinal hernia repair. *Paediatr Anaesth*. 2016;26(12):1165–71. doi:10.1111/pan.12999
73. Bryskin RB, Londergan B, Wheatley R, et al. Transversus abdominis plane block versus caudal epidural for lower abdominal surgery in children: A double-blinded randomized controlled trial. *Anesth Analg*. 2015;121(2):471–8. doi:10.1213/ANE.0000000000000779
74. Suresh S, Taylor LJ, De Oliveira GS, Jr. Dose effect of local anesthetics on analgesic outcomes for the transversus abdominis plane (tap) block in children: A randomized, double-blinded, clinical trial. *Paediatr Anaesth*. 2015;25(5):506–10. doi:10.1111/pan.12550
75. Teunkens A, Van de Velde M, Vermeulen K, et al. Dorsal penile nerve block for circumcision in pediatric patients: A prospective, observer-blinded, randomized controlled clinical trial for the comparison of ultrasound-guided vs landmark technique. *Paediatr Anaesth*. 2018;28(8):703–09. doi:10.1111/pan.13429
76. Fujiwara T, Kagawa T. Ultrasound-guided dorsal penile nerve block in children: In-plane technique. *Paediatr Anaesth*. 2023;33(6):499. doi:10.1111/pan.14660
77. Antony S, Gurnaney H, Ganesh A. Pediatric ambulatory continuous peripheral nerve blocks. *Anesthesiol Clin*. 2018;36(3):455–65. doi:10.1016/j.anclin.2018.05.003
78. Rochette A, Dadure C, Raux O, Troncin R, Mailhee P, Capdevila X. A review of pediatric regional anesthesia practice during a 17-year period in a single institution. *Paediatr Anaesth*. 2007;17(9):874–80. doi:10.1111/j.1460-9592.2007.02217.x
79. Rathmell JP, Kehlet H. Do we have the tools to prevent phantom limb pain? *Anesthesiology*. 2011;114(5):1021–24. doi:10.1097/ALN.0b013e31820fc80d
80. Morgan J, Checketts M, Arana A, et al. Prevention of perioperative venous thromboembolism in pediatric patients: Guidelines from the association of paediatric anaesthetists of great britain and ireland (apagbi). *Paediatr Anaesth*. 2018;28(5):382–91. doi:10.1111/pan.13355
81. Suresh S, Ecoffey C, Bosenberg A, et al. The european society of regional anaesthesia and pain therapy/american society of regional anesthesia and pain medicine recommendations on local anesthetics and adjuvants dosage in pediatric regional anesthesia. *Reg Anesth Pain Med*. 2018;43(2):211–16. doi:10.1097/AAP.0000000000000702
82. Suresh S, De Oliveira GS, Jr. Local anaesthetic dosage of peripheral nerve blocks in children: Analysis of 40 121 blocks from the pediatric regional anesthesia network database. *Br J Anaesth*. 2018;120(2):317–22. doi:10.1016/j.bja.2017.10.019
83. Taenzer AH, Herrick M, Hoyt M, et al. Variation in pediatric local anesthetic dosing for peripheral nerve blocks: An analysis from the pediatric regional anesthesia network (pran). *Reg Anesth Pain Med*. 2020;45(12):964–69. doi:10.1136/rapm-2020-101720
84. Ponde V. Recent trends in paediatric regional anaesthesia. *Indian J Anaesth*. 2019;63(9):746–53. doi:10.4103/ija.IJA_502_19
85. Desai N, Albrecht E. Local anaesthetic adjuncts for peripheral nerve blockade. *Curr Opin Anaesthesiol*. 2023;36(5):533–40. doi:10.1097/ACO.0000000000001272
86. Lundblad M, Trifa M, Kaabachi O, et al. Alpha-2 adrenoceptor agonists as adjuncts to peripheral nerve blocks in children: A meta-analysis. *Paediatr Anaesth*. 2016;26(3):232–8. doi:10.1111/pan.12825
87. Tafoya SP, Tumber SS. The use of multimodal perineural adjuvants in pediatric peripheral nerve blocks: Technique and experiences. *Cureus*. 2022;14(3):e23186. doi:10.7759/cureus.23186
88. Mikjunovikj-Derebanova L, Kartalov A, Kuzmanovska B, et al. Epinephrine and dexamethasone as adjuvants in upper extremity peripheral nerve blocks in pediatric patients. *Pril (Makedon Akad Nauk Umet Odd Med Nauki)*. 2021;42(3):79–88. doi:10.2478/prilozi-2021-0038
89. Turco A, Cerulo M, Del Conte F, et al. Correlation between flacc scale score and analgesic requirement in children undergoing minimally invasive surgery. *Pediatr Med Chir*. 2023;45(1):doi:10.4081/pmc.2023.288
90. Choi S, Yoon SH, Lee HJ. Beyond measurement: A deep dive into the commonly used pain scales for postoperative pain assessment. *Korean J Pain*. 2024;37(3):188–200. doi:10.3344/kjp.24069
91. Ecoffey C, Lacroix F, Giaufré E, Orliaguet G, Courrèges P. Epidemiology and morbidity of regional anesthesia in children: A follow-up one-year prospective survey of the french-language society of paediatric anaesthesiologists (adarpef). *Paediatr Anaesth*. 2010;20(12):1061–9. doi:10.1111/j.1460-9592.2010.03448.x
92. Lönnqvist PA. Toxicity of local anesthetic drugs: A pediatric perspective. *Paediatr Anaesth*. 2012;22(1):39–43. doi:10.1111/j.1460-9592.2011.03631.x
93. Singaravelu Ramesh A, Boretsky K. Local anesthetic systemic toxicity in children: A review of recent case reports and current literature. *Reg Anesth Pain Med*. 2021;46(10):909–14. doi:10.1136/rapm-2021-102529
94. Ecoffey C, Bosenberg A, Lonnqvist PA, Suresh S, Delbos A, Ivani G. Practice advisory on the prevention and management of complications of pediatric regional anesthesia. *J Clin Anesth*. 2022;79:110725. doi:10.1016/j.jclinane.2022.110725
95. Walker BJ, Long JB, De Oliveira GS, et al. Peripheral nerve catheters in children: An analysis of safety and practice patterns from the pediatric regional anesthesia network (pran). *Br J Anaesth*. 2015;115(3):457–62. doi:10.1093/bja/aev220
96. Polaner DM, Taenzer AH, Walker BJ, et al. Pediatric regional anesthesia network (pran): A multi-institutional study of the use and incidence of complications of pediatric regional anesthesia. *Anesth Analg*. 2012;115(6):1353–64. doi:10.1213/ANE.0b013e31825d9f4b
97. Society for Pediatric Anesthesia. Pedi Crisis Checklist: Critical Events Checklists. Formatted June 2020; revised Jan 2025. Accessed November 15, 2026. https://pedsanesthesia.org/checklists/
98. Panesar SS, Javad S, de Silva D, et al. The epidemiology of anaphylaxis in europe: A systematic review. *Allergy*. 2013;68(11):1353–61. doi:10.1111/all.12272

99. Volcheck GW, Mertes PM. Local and general anesthetics immediate hypersensitivity reactions. *Immunol Allergy Clin North Am*. 2014;34(3):525–46, viii. doi:10.1016/j.iac.2014.03.004
100. Dodd A, Turner PJ, Soar J, Savic L, representing the UKPAN. Emergency treatment of peri-operative anaphylaxis: Resuscitation council uk algorithm for anaesthetists. *Anaesthesia*. 2024;79(5):535–41. doi:10.1111/anae.16206
101. Garvey LH, Dewachter P, Hepner DL, et al. Management of suspected immediate perioperative allergic reactions: An international overview and consensus recommendations. *Br J Anaesth*. 2019;123(1):e50-e64. doi:10.1016/j.bja.2019.04.044
102. Jeng CL, Rosenblatt MA. Intraneural injections and regional anesthesia: The known and the unknown. *Minerva Anestesiol*. 2011;77(1):54–8.
103. Sondekoppam RV, Tsui BC. Factors associated with risk of neurologic complications after peripheral nerve blocks: A systematic review. *Anesth Analg*. 2017;124(2):645–60. doi:10.1213/ane.0000000000001804
104. Wan L, Wang Y, Wang G, et al. Expert consensus on prevention and treatment of peripheral nerve block complications. In: Huang YG, Deng XM, eds. *Chinese Anesthesiology Guidelines and Expert Consensus (2020).* People's Medical Publishing House; 2022:244–253.
105. Krol A, Vala A, Phylactides L, Szarko M, Reina MA, De Andres J. Injection pressure mapping of intraneural vs. Perineural injections: Further lessons from cadaveric studies. *Minerva Anestesiol*. 2018;84(8):907–18. doi:10.23736/s0375-9393.18.12230-9
106. Quadri C, Saporito A, Capdevila X. Real-time continuous monitoring of injection pressure at the needle tip for peripheral nerve blocks: Description of a new method. *Anaesthesia*. 2018;73(2):187–94. doi:10.1111/anae.14041
107. Krishna Prasad GV, Khanna S, Jaishree SV. Review of adjuvants to local anesthetics in peripheral nerve blocks: Current and future trends. *Saudi J Anaesth*. 2020;14(1):77–84. doi:10.4103/sja.SJA_423_19
108. Pulos N, Shin EH, Spinner RJ, Shin AY. Management of iatrogenic nerve injuries. *J Am Acad Orthop Surg*. 2019;27(18):e838–e48. doi:10.5435/jaaos-d-18-00510
109. Wan L, Wang Y, Wang G, et al. Expert consensus on prevention and treatment of local anesthetic systemic toxicity. In: Huang YG, Deng XM, eds. *Chinese Anesthesiology Guidelines and Expert Consensus (2020).* People's Medical Publishing House; 2022:235–243.
110. Kietaibl S, Ferrandis R, Godier A, et al. Regional anaesthesia in patients on antithrombotic drugs: Joint esaic/esra guidelines. *Eur J Anaesthesiol*. 2022;39(2):100–32. doi:10.1097/eja.0000000000001600
111. Simić D, Stević M, Stanković Z, et al. The safety and efficacy of the continuous peripheral nerve block in postoperative analgesia of pediatric patients. *Front Med (Lausanne)*. 2018;5:57. doi:10.3389/fmed.2018.00057
112. Vij N, Singhal NR, Trif D, et al. Continuous epidural analgesia versus continuous peripheral nerve block in unilateral lower extremity pediatric orthopedic surgery: A matched case comparison study. *Cureus*. 2023;15(6):e40412. doi:10.7759/cureus.40412