Chapter 4
Regional Analgesia and Its Role in the PICU

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Introduction

In the past few decades, regional anesthesia has had an increasing role in the management of pain in the pediatric intensive care unit. This has been concurrent with the expansion of regional anesthesia in the pediatric operating room, but the utility of regional anesthesia in the ICU is by no means confined to postoperative patients. In this chapter we will review the history of pediatric regional anesthesia, discuss the safety of and the risks associated with these techniques, and describe some of the benefits of regional anesthesia particularly with regard to the ICU patient. The chapter will conclude with an overview of the various regional anesthesia techniques currently in use, with some of their indications.

History

While widespread adoption of peripheral regional anesthesia techniques for pediatric patients has lagged behind their use in adults, children have been the recipients of neuraxial regional techniques since their origin. In 1898, the first group of six patients in whom Augustus Bier attempted spinal anesthesia included two children. As the twentieth century progressed, case series describing the use of spinal anesthesia in children increased. Caudal anesthesia was first described for pediatric urologic surgery in the 1930s. Epidural anesthesia was described not long after, with thoracic epidurals reportedly being used in Russia as early as the 1970s; by the 1980s pediatric epidural catheters were in wide use. Progress toward the general use

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of peripheral nerve blocks in children was slower, although case reports of their use for pediatric patients with chronic pain were published in the mid-1980s [1].

The first large-scale description of the use of pediatric regional anesthesia was published in 1996 by the French-Language Society of Pediatric Anesthesiologists (ADARPEF) [2]. At that time, the 38 participating hospitals reported an approximate 60:40 distribution of neuraxial versus peripheral regional techniques. Fifteen years later, the 2010 report from the same organization demonstrated an inversion of this distribution, with over 60% of patients receiving peripheral nerve blocks [3]. The Pediatric Regional Anesthesia Network shows a similar distribution in their 2018 review of over 100,000 blocks, with a near 50:50 distribution of central to peripheral nerve blocks [4]. The increasing incidence of peripheral nerve blocks in children is thought to be due to the increasing use of ultrasound guidance, which allows for exact localization of the needle or catheter with respect to surrounding structures, improved block success, and decreased complications [5].

Safety and Risks of Regional Anesthesia

The first case series description of spinal anesthesia resulted in 100% headaches, nausea, and vomiting for all eight patients, including the two pediatric patients in the series [1]. Fortunately, in the 120 years since then, the safety profile of regional anesthesia has improved considerably. Several large-scale studies of the complications of regional anesthesia in pediatric patients have been published; in all the large datasets published, the incidence of harm to pediatric patients with regional anesthesia has been reassuringly low. The American Society of Regional Anesthesia (ASRA) and the European Society of Regional Anesthesia (ESRA) have issued joint communications on the topic of pediatric regional anesthesia, affirming its safety and providing guidance on various controversies in block performance [6].

The French-Language Society of Pediatric Anesthesiologists (ADARPEF) published large-scale prospective studies in 1996 and again in 2010. The 2010 publication described over 31,000 blocks from over 47 reporting institutions, with a complication rate of <0.9/1000 procedures [3]. A higher complication rate was noted for infants less than 6 months and for central versus peripheral blocks. No fatalities were recorded and no long-lasting neurologic sequelae were reported in this study.

Similar results have been reported by the Pediatric Regional Anesthesia Network (PRAN), a US-based consortium of 21 institutions who have collected a database of over 100,000 pediatric regional blocks. In their 2018 publication, they report on these blocks, half of which were peripheral nerve blocks [4]. This study also showed a very low rate of complications, similar to that reported by ADARPEF, with no deaths and no sequelae lasting longer than 3 months. Table 4.1 shows the adverse events described in the consortium's 2015 study of peripheral nerve blocks [7].

A few particular areas of controversy exist when considering the use of pediatric regional anesthesia. The most contentious for many years was the placement of either neuraxial or peripheral nerve blocks in a heavily sedated or anesthetized

Table 4.1 Incidence of specific adverse events in PRAN database

Complication	Incidence
Catheter malfunction (dislodgement, occlusion)	7.3%
Abandoned or block failure	1.3%
Catheter-related infection	0.9%
Vascular (blood aspiration, hematoma)	0.9%
Excessive motor block	0.6%
Difficult catheter removal	0.1%
Others (foot swelling, muscle spasm, dizziness, burning sensation, adverse drug reaction, nausea and vomiting, contact dermatitis)	1%

Modified and used with permission from Walker et al. [7]

child. The concern from adult anesthesiologists was that children under anesthesia or sedation would not be able to report pain or paresthesias, which could arguably increase the incidence of nerve injury. Data from both APARDEF and PRAN have shown no increase in complications in anesthetized children receiving nerve blocks, and the joint ASRA/ESRA statement has confirmed that placement of blocks under general anesthesia or sedation is the standard of care for children and states that this method may in fact be safer than placing blocks on unsedated children [6].

The question of when to perform regional anesthesia on a patient who is anticoagulated is quite pertinent in the intensive care population. Bleeding complications are more problematic for neuraxial versus peripheral blocks, since the risk of neurologic catastrophe is increased with bleeding near the spinal cord. The American and European Societies of Regional Anesthesia review this topic regularly, updating their recommendations as new anticoagulant medications arise and as new data becomes available about the relative risk of bleeding complications with various regional and interventional pain procedures [8]. In general, the recommendation is to avoid neuraxial blocks in patients with altered coagulation; if anticoagulation can be briefly reversed or held to allow for placement of a block, then that can be considered.

Another question which provokes controversy is whether regional anesthesia could mask the onset of compartment syndrome in an injured extremity. Compartment syndrome develops in an injured limb after injury such as trauma, prolonged malposition during surgery, fracture with casting, and ischemia-reperfusion. These insults, if not recognized and treated within a few hours, can result in elevated pressure in a closed muscle compartment, decreased circulation, ischemia, and eventual nerve and muscle necrosis. Conventional wisdom several decades ago was that the dense sensory block achievable with regional anesthesia would mask the increasing pain which indicates the development of increased pressure in a limb compartment. The ASRA/ESRA consensus recognizes that this diagnosis is difficult to make with or without nerve block in preverbal or nonverbal children. The societies' consensus is that there is no evidence indicating that regional anesthesia masks the development of compartment syndrome. In at-risk patients, a less dense block might be used, but the most important factor in recognition of compartment syndrome is recognition of patients at risk and close monitoring [9].

One hazard of regional anesthesia safety which cannot be overlooked is that of local anesthetic systemic toxicity (LAST); it should be recognized as a possibility by anyone taking care of a child who has received a nerve block. The PRAN database reports an incidence of LAST of 0.76/10,000, with the majority of cases in infants under 6 months of age. This may be due to a combination of reduced protein binding of local anesthetics in this age group and reduced drug clearance by infants [4]. These physiologic differences in infant local anesthesia pharmacokinetics are reflected in ASRA/ESRA guidelines for local anesthesia dosing in infants [10]. LAST is more often seen in bolus administration of local anesthetic, as opposed to steady-state infusions. A study of >200,000 adult patients receiving blocks for orthopedic surgery over a 14-year period yielded a LAST incidence of 0.18% [11]. In the same study, the authors described a decreasing incidence of severe complications of LAST such as seizure and cardiac arrest, which was likely due to an increased recognition of the role of lipid therapy to treat LAST. Lipid resuscitation is now recognized as a first-line therapy for the treatment of LAST, and lipid emulsion should be stocked in any area where blocks are performed [12].

Benefits of Regional Anesthesia

The first and most important benefit of regional anesthesia is its provision of high-quality, site-specific pain control. As every PICU physician is aware, pain is one of the more distressing aspects of a patient's experience in an intensive care unit, with 50% of patients reporting moderate to severe pain during their time in the PICU. Untreated pain has detrimental effects, not only psychologically, but by causing a host of hormonal, metabolic, and inflammatory issues which can impede recovery. Additionally, up to a third of ICU patients will develop chronic pain after their ICU stay either from postsurgical pain or otherwise [13, 14]. In many of these cases, regional anesthesia has a role to play in their relief, and it is argued that regional anesthesia may still be underutilized in the ICU.

A number of meta-analyses have demonstrated the superior pain relief which can be afforded to patients with regional techniques. A 2016 Cochrane review of 15 studies reported that for patients with an epidural catheter after open abdominal surgery, their VAS pain score was reduced compared to patients receiving systemic pain medications up to postoperative day #3 [15]. A 10-year cumulative literature review by block type similarly showed an overall improvement in both pain scores and patient satisfactions with peripheral nerve blocks versus other methods of pain relief [16]. In some patient series in this review, their satisfaction with their pain control approached 100%, and they stated that they would choose that method of pain control again in the future.

One of the great advantages of regional anesthesia in contrast with systemic pain medications is the lack of systemic side effects. Opioids, nonsteroidal anti-inflammatory medications, and acetaminophen all have deleterious effects on various organ systems which are accentuated with long-term use. Opioids in particular have come under intense scrutiny recently, with many concerns raised for the potential of long-term opioid abuse arising in patients who have been exposed to them in the hospital environment. Regional anesthesia, which allows opiate-sparing pain relief, has been embraced as a possible means to reduce this problem [17].

Another area where regional anesthesia has an increasingly significant role is in the early mobilization of PICU patients. A key factor in assisting pediatric PICU patients to regain normal sleep-wake cycles and be able to participate with efforts to increase mobility is the provision of adequate analgesia with minimal sedative side effects [18]. With its lack of sedating or delirium-promoting side effects, regional anesthesia can be a valuable adjunct to these efforts.

In addition to excellent pain control, there is a growing body of evidence that the use of regional techniques can reduce perioperative complications when compared to systemic pain medication regimens. While many of the studies in this area have focused on the adult patient, the conclusions are in many cases translatable to the pediatric population. Guay's 2016 Cochrane review noted reduced time to extubation, incidence of myocardial infarction, incidence of respiratory failure, and time to ICU discharge in patients with epidurals after open abdominal aortic aneurysm repair [15]. In another review, the same authors noted reduced time to recovery of gastrointestinal function after abdominal surgery with use of epidurals [19]. A meta-analysis of 125 studies of patients with epidural after surgery found that patients with epidurals had a reduced incidence of mortality, and epidurals were associated with a beneficial effect on major pulmonary, cardiac, and gastrointestinal symptoms [20]. These myriad benefits are likely due to a combination of factors. Fewer side effects of opioids, such as sedation which can compromise efforts to extubate and constipating side effects of opioids, are certainly one factor. Another is the known reduction in the hormones associated with the perioperative stress response in patients with epidurals. The improved pain relief and decreased surgical stress response provided by regional anesthesia may also allow patients to more comfortably participate in postoperative respiratory physiotherapy, which can speed time to extubation. Together these can add up to a powerful benefit for critically ill patients.

The evidence for benefits of peripheral nerve blocks on postoperative outcomes other than pain has lagged behind the evidence for neuraxial blockade, in part because peripheral techniques have only recently become widespread. While there may be no direct effects on the success of surgical procedure, the use of regional anesthesia to promote early mobilization and physical therapy is now well-established. Several protocols detailing the use of regional anesthesia for Enhanced Recovery After Surgery (ERAS) have been published for orthopedic procedures, allowing for reduced morbidity and length of hospital stay [21].

One aspect of regional anesthesia which is of increasing utility to the physician treating critically ill children is the use of regional anesthesia for palliative purposes. While systemic analgesic therapy has been a mainstay of palliative care for many years, there is a growing recognition of the utility of regional anesthesia in this patient population. Many of the systemic side effects of pain medication, such as oversedation, pruritis, and constipation, can be relieved by the use of regional pain techniques. Additionally, regional techniques may provide good pain relief in patients for whom systemic therapies are no longer effective due to either disease progression or tolerance and tachyphylaxis [22]. In any of these cases, a thoughtful exploration of the potential methods to treat a child at the end of life will be necessary to determine if a regional procedure and its potential risk is in congruence with overall goals of care.

Some Common Blocks

Central Neuraxial Blocks

The central neuraxial blocks consist of spinal, epidural, and caudal blocks, with caudal blocks representing the largest proportion in younger children, transitioning to lumbar epidurals as the predominant neuraxial block in older children [4]. Both caudal and epidural blocks access the epidural space surrounding the spinal cord, either by access through the sacral hiatus in the case of the caudal block or percutaneously at any of the lumbar or thoracic vertebral interspaces. These blocks have traditionally been placed without image guidance, relying on the experienced operator's feel for a "pop," or loss of resistance to a saline or air-filled syringe on entry to the epidural space. Currently both fluoroscopy and ultrasound have been described to assist with block placement, and these may be invaluable in the case of patients with challenging anatomy [23, 24].

All of the central neuraxial blocks provide excellent pain relief for thoracic, abdominal, pelvic, and lower extremity pain. Figure 4.1 describes epidural catheter placement for a variety of surgical interventions. It should be noted that particularly in infants, the epidural space can be accessed by the caudal approach, and a catheter can be advanced even to the thoracic levels under fluoroscopic guidance. Infusion rates can be titrated to allow for ambulation, or even for a "band" of analgesia at an operative level, although it is quite possible with these blocks that the area affected may be greater than what is necessary. Adjuncts such as low-dose opiates or alpha-2 agonists may be added to potentiate pain relief or to increase the length of time a single-shot block may last.

Upper Extremity Blocks

There are nearly as many approaches to the brachial plexus as there are nerves coming from it (see Fig. 4.2). Axillary, infraclavicular, interscalene, and supraclavicular approaches are described, with the supraclavicular being the most commonly reported in the PRAN database [25]. Nerves all along the upper extremity from the finger to the neck can be targeted by ultrasound depending on the area which needs surgical analgesia, or vasodilation in the case of microvascular surgery [26]. Catheters can be placed for long-term pain relief, which has proven particularly helpful for pain relief and mobility after shoulder surgery [27].

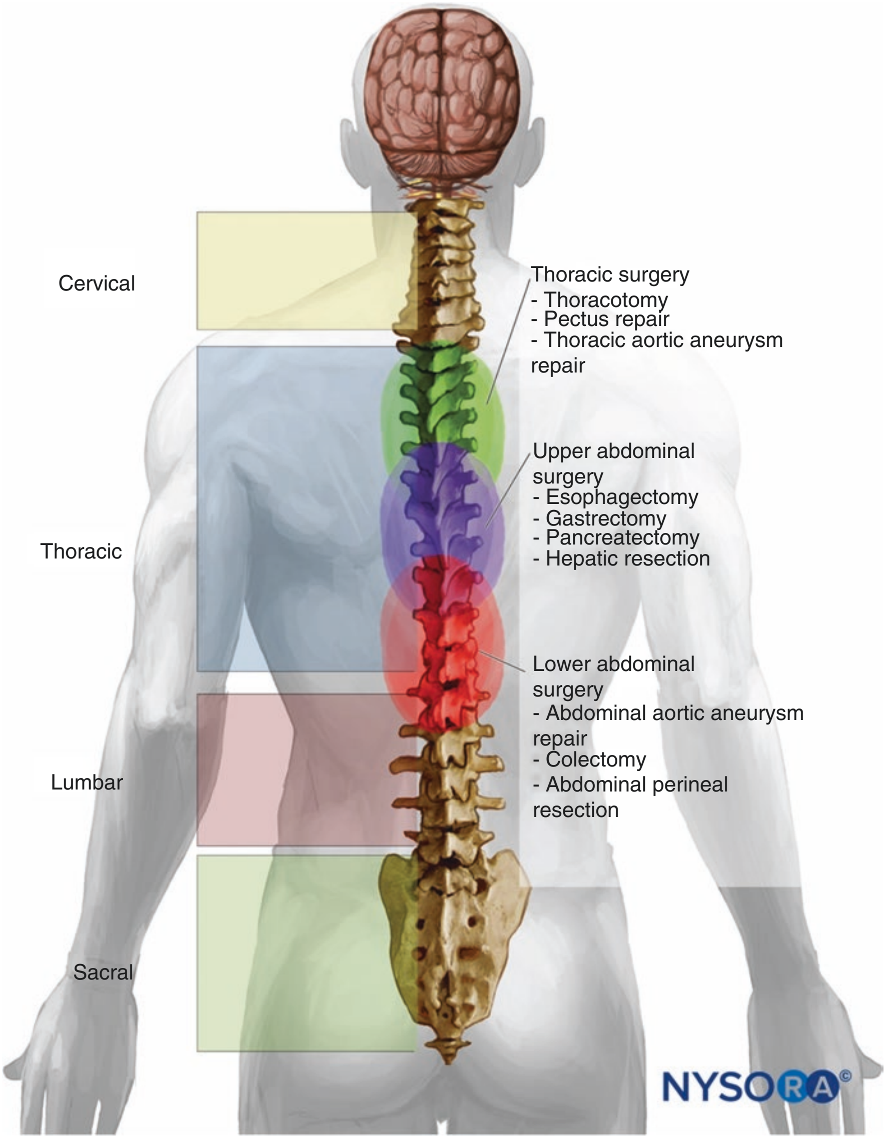

Fig. 4.1 Level of catheter placement in surgeries performed with epidural anesthesia and analgesia. (Source: nysora.com, used with permission)

A few potential complications are possible depending on the block performed, particularly for those targeting the brachial plexus. Horner's syndrome is not uncommon, and patients should be counseled that this will recede as the block wears off. More potentially concerning is hemidiaphragm paralysis, which can be potentially dangerous in patients with compromised respiratory function. Pneumothorax is a

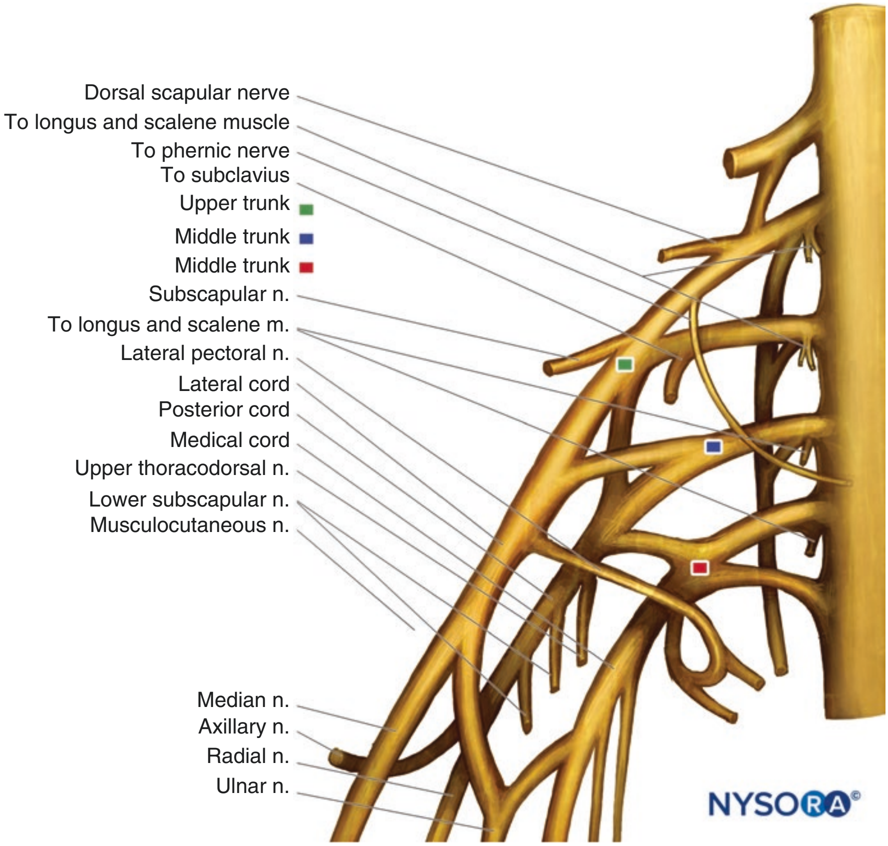

Fig. 4.2 Brachial plexus. (Source: nysora.com, used with permission)

possibility, although ultrasound guidance will hopefully minimize the chance of this complication [27].

Truncal Blocks

Truncal blocks provide analgesia to the chest, abdomen, and pelvis without the need for accessing the central neuraxis. This can be particularly useful in coagulopathic patients, in whom the risk for epidural hematoma may be unacceptably high, but is also useful when only a particular area of analgesia is desired without as high a chance of spread to nontarget areas. The most common blocks in this category include the TAP (transversus abdominis plane) block, ilioinguinal/iliohypogastric block, and rectus sheath block, with additional techniques being described on a regular basis. The paravertebral block can be thought of as transitional case between the central neuraxial block and the blocks of the abdominal and thoracic wall,

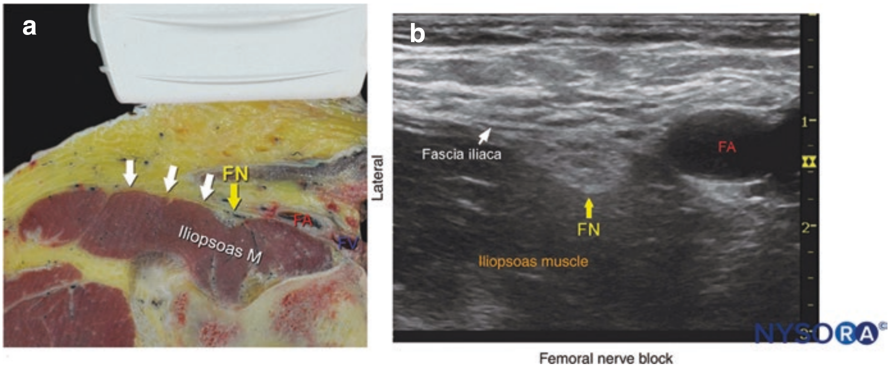

Fig. 4.3 (**a**) Cross-sectional anatomy of the femoral nerve (FN) at the level of the femoral crease. The FN is seen on the surface of the iliopsoas muscle covered by fascia iliaca (white arrows). The femoral artery (FA) and femoral vein (FV) are seen enveloped within their own vascular fascial sheath created by one of the layers of fascia lata. (**b**) Sonoanatomy of the FN at the femoral triangle. (Source: nysora.com, used with permission)

providing generally unilateral analgesia at the level of injection in the intervertebral foramen. Ultrasound guidance enhances both the rate of block success and minimizes complications such as intravascular injection, pneumothorax, and bowel perforation [25, 28].

Lower Extremity Blocks

Much like the approach to the upper extremity, there are many methods by which analgesia can be provided to the lower extremity. Blocks can range from the lumbar plexus through the femoral and sciatic nerves to the popliteal fossa and ankle. Figure 4.3 shows the cross-sectional anatomy of the femoral nerve and its surroundings, both in gross specimen and in ultrasound. Ultrasound is the most common technique for accessing nerves of the lower extremity, which ensures the greatest chance of success while minimizing complications. The most likely complication for lower extremity blocks is inadvertent vascular injection [25], although the lumbar plexus block's location does place surrounding abdominal structures at higher risk [29].

Conclusion

Regional anesthesia is a valuable analgesic technique for pediatric patients in the PICU. While the majority of patients who will benefit from nerve block are postsurgical, there are certainly opportunities for nonsurgical intensive care patients to benefit from these techniques, and these techniques are arguably underutilized in many PICUs. Close cooperation between intensive care, anesthesia, and pain service professionals will result in many benefits for PICU patients.

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