Regional anaesthesia for trauma: an update

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Key points
The value of regional anaesthesia for managing trauma victims in challenging environments has been demonstrated in recent military conflicts and natural disasters.
Appropriate use of regional interventions can complement ATLS® management priorities.
Peripheral nerve block is generally safer and more practical than neuraxial techniques in trauma patients.
Potential caveats to regional block in trauma patients require detailed risk-vs-benefit appraisal of injuries and their likely sequelae.
The challenge of translating benefit from regional interventions to earlier in the patient care pathway requires appropriate infrastructure and training.

The term trauma has Greek origins, meaning ‘wound’. Trauma represents a major global health burden, with significant morbidity, mortality, and socioeconomic impact. Injuries vary in aetiology, distribution, severity, and prognosis. Worldwide, millions are injured, disabled, or killed each year. Falls, burns, violence, and road traffic accidents are among the most significant causes stated by the World Health Organization.

Acute phase resuscitation has improved dramatically after introduction of Advanced Trauma Life Support (ATLS®) algorithms. The result is a reduction in mortality rates, but comparatively more patients progressing to long-term disability.

Regional nerve block is contentious in the context of trauma. Historical reports apportion blame to regional interventions as contributing to poor outcomes in particular patients, such as those at risk of compartment syndrome.

Traditional aversion is now being questioned. A growing evidence base from military and civilian sources is supportive of a greater role for regional anaesthesia (RA) in the management of trauma casualties. Optimized pain control may improve outcome in such patients.

This article aims to clarify the current evidence, address common controversies, and provide a summary of the advancing role of RA in the trauma setting.

The changing approach to trauma pain management

Trauma victims are vulnerable. Injury initiates significant endocrine, metabolic, and inflammatory responses, extending from the time of injury through to rehabilitation. Physiological derangement after injury may be exacerbated by systemic analgesics. Deleterious effects of opioid administration include clouding of consciousness, respiratory depression, nausea, ileus, sleep disruption, tolerance, dependence, and immunosuppression.

As a strategy to facilitate painless elective surgery, RA is well validated and continues to refine. Advantages are often not translated to the trauma population. Short- and long-term benefits are often overlooked for fear of uncommon complications, and less effective opioid-based regimens predominate. Barriers to progress have included:

- The potential for multiple absolute or relative contraindications to regional block (e.g. distorted anatomy, coagulopathy, compartment syndrome).
- Competition with resuscitation objectives has resulted in analgesia given lower priority status in acute management.
- Lack of appropriate equipment and training, especially in emergency department and pre-hospital care.
- Improvements in the safety profile of general anaesthesia.
- Case reports asserting links between adverse outcomes and regional interventions have led to surgical resistance.

The validity of arguments against the use of RA in trauma is being challenged. Drivers for change include:

- Increased reliability and safety of neural block, facilitated through improvements in training and technology (e.g. ultrasound, needle/catheter design) obviating the need for nerve stimulator techniques.
- Greater recognition of pain as a disease process, leading to detrimental functional and psychological outcome if poorly managed.
- Shortcomings and side-effects from administration of systemic analgesics.
- Growing evidence from military and civilian sources detailing encouraging results from regional interventions.
- Publication of guidelines addressing how relative contraindications may be negotiated on balance of risk.

Rationale for RA use in trauma

Regional block offers many attributes of an ideal analgesic. Unique advantages include superior...
analgesia, attenuation of stress response, increased alertness, patient cooperation and avoidance of systemic side-effects, facilitating ease of transport, and chronic pain protection. Avoidance of general anaesthesia may avert iatrogenic risks of airway instrumentation and positive pressure ventilation, such as difficult or failed intubation, aggravation of cervical spine injury, and pneumothorax enlargement.

The anaesthetist may encounter the trauma patient at any point during the continuum of care, from the pre-hospital environment, emergency department, operating theatres, and critical care unit through to the pain service. Each stage affords an opportunity for the patient to benefit from RA.

Military experience

The appeal of RA in managing combat injuries was first described during the Vietnam War. Recent conflicts have revived interest through accumulation of favourable evidence. RA interventions now make an important contribution to the management of modern battlefield casualties. Typical casualties are young males sustaining high-energy injuries. Collaboration between anaesthetists, surgeons, and emergency physicians has expanded the role of RA in a population considered high risk for compartment syndrome.

In a prospective study detailing casualties evacuated to the Walter Reed Army Medical Centre (WRAMC) between 2003 and 2004, 287 patients (of whom 35% were amputees) underwent operative care for extremity injuries utilizing RA including single shot, continuous peripheral nerve block (CPNB), and continuous epidural infusions. More than 900 operations were performed before arrival at WRAMC, with 634 further operations after arrival. Overall, 646 RA procedures were performed, including 361 perineural catheters. The mean catheter infusion duration was 9 days. Catheter-related complication rate was 11.9%, with problems encountered non-significant in nature, including catheter occlusion/failed placement (2.2%), failure of intended block (2.8%), and multiple attempts required for successful block (0.6%). Catheter infection rate was 1.9%, all of which were superficial infections that resolved after removal. Pain scores were significantly reduced over the 7 days that indwelling CPNBs were used. The authors conclude that RA facilitated safe perioperative surgical anaesthesia and analgesia.

Case reports outline excellent results from RA interventions throughout multiple stages of care for combat casualties, including faster recovery and increased morale. Superiority of ultrasound guidance over nerve stimulator techniques for nerve localization has been observed in victims with multiple injuries.

Applications in trauma

Thoracoabdominal trauma

Thoracic blocks include:
- epidural,
- paravertebral,
- intercostal,
- intrapleural.

Blunt thoracic injuries such as rib fractures and pulmonary contusion are common, with significant morbidity and mortality. Pain impairs respiratory mechanics, predisposing to atelectasis, secretion retention, and pneumonia. RA modalities include thoracic epidural analgesia (TEA), thoracic paravertebral block (TPVB), intercostal block, and intrapleural catheters.

Thoracotomy is associated with severe acute pain and a chronic pain incidence of ~50%. TEA is considered the gold standard for managing post-thoracotomy pain. In trauma, it is utilized for managing multiple and bilateral fractures, particularly in elderly patients. Rib fractures affect up to 10% of trauma admissions, and are associated with severe pain. TEA demonstrates improved analgesia and respiratory function with reduced nosocomial pneumonia rates when compared with alternative analgesic modalities. However, previously reported reductions in mechanical ventilation duration, hospital stay, and mortality rate are contested. In trauma, multiple exclusion criteria often preclude its use, including spinal cord or bone injury, hypovolaemia, infection risk, thromboprophylaxis, and developing coagulopathy. Consequently, a minority of patients are offered this technique.

TPVB has recently undergone a resurgence of interest. This provides unilateral segmental thoracoabdominal somatic and sympathetic block comparable with TEA, but fewer limitations concerning cardiovascular instability, urinary retention, and anticoagulation. TPVB is described with concomitant spinal trauma, allowing targeted analgesia without compromising neurological assessment.

Intercostal nerve block involves injection of local anaesthetic (LA) near to the posterior segment of thoracic spinal nerves. Advantages are similar to TPVB, although use is limited due to the need for multiple-level and repeated injections involving palpation of painful ribs. Numerous injections carry increased pneumothorax and LA toxicity risk. The bony scapula may impede access to higher (T1–7) intercostal nerves. Radiographic studies of intercostal injections have demonstrated the spread of injectate to adjacent dermatomes, representing spread via the extrapleural or paravertebral spaces.

Intrapleural analgesia requires application of LA between the visceral and parietal pleura, usually via an indwelling catheter. Analgesic effect is variable due to imprecise distribution of LA, which is influenced by factors including catheter site, patient position, and location of injury. Analgesic quality and respiratory parameters from intrapleural catheters is inferior to that provided by TEA and TPVB. Inadvertent pneumothorax rate complicating intrapleural block is ~2%. Haemothorax after trauma may reduce the effect of LA through increased protein binding or impedeance of its spread within the pleural space, while local inflammation may enhance systemic absorption.

Abdominal blocks include:
- epidural,
- subarachnoid,
- paravertebral,
• transversus abdominis plane (TAP)/quadratus lumborum compartment,
• rectus sheath.

TAP and rectus sheath blocks provide sensory, but not visceral, analgesia to the anterior abdominal wall. The anterior divisions of spinal nerves T7–L1 can be blocked along their course between the internal oblique and transversus abdominis muscles (TAP), or as they perforate the rectus abdominis muscle (rectus sheath). Although widely performed in elective and emergency care, data relating to their performance in trauma patients are scarce. Recent data suggest thoracolumbar analgesia from posterior TAP or quadratus lumborum block may be useful for pelvic fractures and iliac crest bone graft harvest. The appeal of these compartmental blocks is their feasibility in patients where neuraxial analgesia is contraindicated (e.g. coagulopathy, sepsis).

**Limb trauma**

Upper limb blocks include:

• brachial plexus (e.g. interscalene, supraclavicular, axillary),
• peripheral nerve (e.g. radial, median),
• i.v. regional anaesthesia (IVRA).

Extremity injuries are particularly suited to regional techniques. Brachial plexus block (BPB) achieves superior analgesia, reduced opioid consumption, and earlier hospital discharge compared with general anaesthesia for ambulant upper limb trauma surgery. Bilateral BPB has been used, although distal approaches and ultrasound guidance are recommended to minimize LA dose and risk of phrenic nerve palsy. Distal radius fractures undergoing closed reductions in the emergency department are amenable to supracondylar radial nerve block to minimize sedation requirements.

Joint dislocations, particularly shoulder, are associated with significant pain. Deep sedation is often required to achieve sufficient analgesia and muscle relaxation to allow reduction. Procedural sedation may necessitate a fasting period, introduce airway risks, and prolong emergency department stay. Interscalene or supraclavicular BPB may be used as an alternative method for shoulder reduction, and confers prolonged post-reduction analgesia (Fig. 1). This technique has demonstrated reduced length of stay and nursing time demand in the emergency department compared with matched sedation groups.

IVRA allows extremity procedures of short duration (e.g. manipulation of closed fractures), and is commonly used for ambulatory patients or those with serious comorbidity. A poor surgical field and short analgesic period (45–60 min, limited by tourniquet pain) make IVRA unsuited to open surgery. The need to move the injured limb during needle insertion and exsanguination, plus LA toxicity risk from cuff failure, are other limitations. A recent study found that tourniquet placement on the forearm results in improved analgesia, reduced supplementary analgesia and sedation requirements, and a greater ability to bypass the recovery room. Although potential benefits include efficacy and cost, forearm tourniquets can impede surgical access, and further study is warranted.

**Fig 1** Ultrasound anatomy of the brachial plexus in the supraclavicular fossa. The transducer is placed at the base of the neck with its short axis pointing towards the shoulder to achieve a true transverse view of the plexus. SA, subclavian artery; upper/middle/lower, trunks of the brachial plexus. LA is deposited posterior to the subclavian artery and deep to the prevertebral fascia of the brachial plexus sheath (pink line). Visualization of the needle tip is essential to prevent inadvertent vascular or pleural puncture. If reading the pdf online, click on the bottom right-hand part of the figure to view the video. The video shows the short-axis ultrasonographic view demonstrating insertion of a supraclavicular perineural catheter using an in-plane approach. The needle is advanced into the prevertebral fascia and placed into the optimum position using hydrodissection, i.e. injecting small volumes of local anaesthetic to create a space into which the needle can be safely advanced.
Lower limb blocks include:
- lumbar epidural,
- subarachnoid block,
- lumbar/sacral plexus block,
- compartment blocks (e.g. fascia iliaca),
- peripheral nerves (e.g. femoral, sciatic, obturator).

Unrelieved pain and adverse side-effects from opioids are well recognized in pre-hospital, emergency medicine, and critical care literature. There has been a consequent trend towards increased training and performance of neural block by emergency physicians to address these issues. Femoral and fascia iliaca compartment blocks for femur fractures are effective, safe, and economic in a usually vulnerable patient group. The importance of non-opioid analgesia in patients with proximal femoral fractures is detailed in guidelines from the Association of Anaesthetists of Great Britain and Ireland. For lower leg injuries, sciatic nerve approaches (e.g. popliteal) facilitate analgesia and surgery, such as amputation. Ankle blocks to terminal branches of the sciatic and femoral nerves allow surgery to the foot without affecting proximal sensorimotor function.

Ultrasound guidance can be challenging in oedematous or bruised tissues. However, the ability to visualize target anatomy while avoiding painful or absent responses to nerve stimulation in injured extremities makes ultrasound the superior method for nerve localization in trauma.

Paediatric femoral fractures are infrequent, but serious injuries requiring effective analgesia to facilitate investigations, transfer to specialist care, and definitive management. Caudal analgesia requires moving the injured child, whereas femoral or fascia iliaca compartment block is preferable, and optimizes analgesic quality and reduces distress for both child and parents. Furthermore, reasons for under-treatment of pain in paediatric subjects are addressed, such as fear of adverse events and communication difficulties.

Controversies

Compartment syndrome

Acute compartment syndrome (ACS) involves a critical pressure increase within a confined fascial compartment, with resultant microvascular ischaemia. ACS is a feared yet uncommon consequence of traumatic injury. Multiple intra-compartmental (e.g. oedema, bleeding) and extra-compartmental causes (e.g. tight casts, patient positioning) are recognized. Definitive treatment is emergency decompression of all affected compartments. ACS is a source of morbidity, mortality, and litigation, particularly when treatment is delayed.

Diagnosis can be notoriously challenging. Paraesthesia, pain distal to the surgical site, and motor weakness may result from compression of nerves crossing the affected compartment. Controversy exists concerning the potential of RA to eliminate pain as the presenting symptom. Regional techniques have been implicated as a cause of delayed diagnosis of ACS in isolated case reports (level 3 evidence), subject to reporting and publication bias. These reports detail other plausible factors in delayed diagnosis, including the absence of compartmental pressure monitoring, misattribution of blame to the wrong nerve distribution, and failure of timely decision-making despite clear clinical signs.

Pain is an unreliable symptom for diagnosing ACS, demonstrating poor sensitivity (19%) and positive predictive value (14%). After injury, conceivably any form of analgesia may contribute to delayed recognition. Patient-controlled analgesia, peripheral nerve, and epidural block have all been implicated in case reports as masking pain as the presenting symptom. A recent systematic review concludes there is no convincing evidence that RA hinders diagnosis; rather it may facilitate detection by heralding breakthrough pain in the presence of satisfactory CPNB. Similar conclusions were reached in a prospective national Paediatric Epidural Audit. From 10 633 epidurals, four incidents of ACS were reported, none of which were masked by epidural analgesia.

Overall, ACS risk does not preclude the practice of RA. Judicious use of RA using low-concentration infusions of long-acting LA coupled with low-dose boluses of short-acting LA (e.g. for operative intervention), in monitored patients, can accomplish joint objectives of effective analgesia and diagnostic capability for ACS. Peripheral blocks provide targeted analgesia, and may permit earlier detection of ACS in territories of unblocked nerves (e.g. femoral vs sciatic nerve discrimination). Discussion between the responsible surgeon and anaesthetist should occur before regional block in ‘high risk’ situations. Strategies based on contemporary evidence are summarized in Table 1.

Pre-existing nerve injury

The ‘double crush syndrome’ proposes that patients with pre-existing nerve lesions are more susceptible to further injury when exposed to a secondary insult. Concomitant nerve injury in trauma

Table 1. Evidence-based approach to RA safety in patients at risk of compartment syndrome

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<th>Institutional factors</th>
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<td>Vigilance</td>
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<tr>
<td>Staff education and training</td>
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<tr>
<td>Attention to other causes of ACS (e.g. casts, positioning)</td>
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<tr>
<td>Serial patient assessment</td>
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<td>Unified approach using locally agreed protocols</td>
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<tr>
<td>‘Time out’ before proceeding with surgery</td>
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<tr>
<td>Patient education</td>
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<td>Commitment to audit</td>
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<th>Regional anaesthesia factors</th>
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<tr>
<td>Avoid dense, long-acting neural blocks</td>
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<td>Preference for peripheral nerve approaches</td>
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<tr>
<td>Short-acting LA boluses for operative procedures</td>
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<tr>
<td>Use of additives (e.g. α-2 agonists, opioids) is not established</td>
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Where continuous catheter techniques are used:
- use low concentrations of long-acting LA
- patient-controlled function can increase pain reporting
- avoid motor block by reducing LA concentration/dose
may follow laceration, compression, axial stretch, and vascular injury. Concern over exacerbating nerve dysfunction has contributed to a reluctance to perform regional block, although the evidence base is equivocal. While risk may be conferred through needle trauma and LA injection, a resulting sympathetic block may also improve neurovascular compromise in an affected extremity.

Individual risk–benefit analysis is essential. Modifications such as using a less potent LA, reducing volume, concentration, or both, and avoiding vasoconstrictors may minimize risk from new or progressive neurological complications. Before block performance, detailed neurological examination and documentation of findings is essential for medico-legal purposes, especially in circumstances of existing neurological deficit. Other causes of secondary nerve injury such as tight casts, patient positioning, and arterial hypotension should be actively sought and treated.

Anticoagulation

Trauma predisposes to both bleeding and thrombosis. Risk depends on the patient, mechanism of injury, medication, and treatment. In the acute phase, hypothermia and haemorrhage may lead to coagulopathy. In the perioperative period, thromboprophylaxis is standard practice. For the anaesthetist, this poses bleeding risk during regional interventions, and later on catheter removal.

Practice of RA in anticoagulated patients should be consistent with established guidelines. Published reports of clinically significant haemorrhagic complications from peripheral or plexus block show all patients with neurovascular deficits recovered completely within 6–12 months.

Neuraxial block poses greater risk than peripheral approaches since bleeding occurs into a non-expandable space. Thromboprophylaxis with low molecular weight heparin may prohibit neuraxial block. Effective coordination of regional interventions and anticoagulant dosing schedules is essential. Superficial approaches to peripheral nerves, and avoidance of vascular structures through ultrasound guidance provides the safer option in anticoagulated patients.

Point-of-care coagulation testing (e.g. thromboelastography, platelet function monitors) provides rapid, objective assessment of haemostatic function. This may be used before interventions where coagulopathy of trauma is suspected. However, reference points for such tests are not covered in current guidelines.

Chronic pain

Unrelieved acute pain is a risk factor for chronic pain development. Progression to chronic pain involves peripheral and central mechanisms of sensitization, with detrimental functional, cognitive, and psychological outcomes. Complex regional pain syndrome, post-amputation pain, and post-traumatic stress disorder are common after trauma and require urgent attention.

Analgesia provision after injury should be early, effective, and sustained to limit the incidence and severity of chronic pain. Early involvement of the pain service is important. Effective acute pain management with regional techniques may prevent development of chronic pain. Administration of systemic pain modulators such as ketamine, tramadol, and gabapentinoids should also be considered.

Perineural catheters

CPNB involves catheter insertion adjacent to a peripheral nerve, allowing extended periods of LA administration (see the online video). In trauma, CPNB facilitates patient transport, surgical anaesthesia, perioperative analgesia, sympathetic block (e.g. limb salvage, tissue flaps), and chronic pain protection.

Perineural catheter techniques require a higher operator skill level than single-shot blocks, but avoid the phenomenon of rebound pain as a single-shot block wears off. CPNB should be used particularly in patients where pain is likely to continue into the postoperative period or where repeated procedures are planned.

Low-concentration ropivacaine (0.1–0.2%) or bupivacaine/levobupivacaine (0.1–0.125%) are commonly used infuses due to a longer duration of action and favourable sensorimotor discrimination. Regimens include continuous basal infusion, bolus dose, or a combination of both. Concentration and rate should be individualized to patient requirements.

Most complications of CPNB are minor and easily managed. These include catheter problems (e.g. displacement/dislodgement/occlusion), secondary block failure, leakage, and infusion pump malfunction. Serious and rare complications include catheter knotting or shearing, LA toxicity, perineural haematoma formation, prolonged Horner’s syndrome, myotoxicity, and neurotoxicity.

Limitations of RA in trauma

Careful risk–benefit analysis must be used when considering RA techniques. Circumstances when RA is not appropriate include:

- Where there is direct competition with ATLS® resuscitation objectives (e.g. threatened airway, treatment of shock).
- Where direct harm may be caused (e.g. neuraxial anaesthesia in the presence of raised intracranial pressure).
- Injuries mandating general anaesthesia for definitive surgical treatment (e.g. neurosurgery).
- Inability to position the patient for procedure (e.g. spinal board immobilization).
- When consent cannot reliably be obtained.
- Safety concerns due to uncooperative patients (e.g. intoxicated, illicit drug use, combative).
- Polytrauma patients. A systemic approach is likely to be more practical than multiple regional procedures and averts LA toxicity risk.
- Standard contraindications (e.g. refusal, allergy to LA).
- Lack of appropriate training, equipment, and care bundles.

The debate on whether peripheral blocks are safer when performed on awake or anaesthetized patients is unresolved. Available evidence is low-level and conflicting, and expert opinion is divergent. The
American Society of Regional Anaesthesia (ASRA) recommends against performing blocks in anaesthetized or heavily sedated patients, unless benefits plainly outweigh risks. The rationale is that sedation removes the ability to report pain as the presenting feature of neuronal injection. However, pain is an unreliable and subjective indicator, and most published reports of neurological injury are not associated with painful injection. Visual feedback of needle–nerve relationship using ultrasound provides a surrogate marker of safety, suggesting that benefits of judicious use of RA in obtunded trauma patients can outweigh risks.

**Future direction**

Trauma represents a considerable, and increasing, demand on healthcare resources. Innovations in military medical care, coupled with reassuring data from civilian sources, are challenging historical attitudes to pain relief in trauma. RA is more versatile and reliable than ever before. With appropriate patient selection and management, such interventions are effective and safe. Although further evidence is required, the role of RA is likely to expand to meet the growing burden of trauma.

**Online video**

The video associated with this article can be viewed from the article in Continuing Education in Anaesthesia, Critical Care & Pain online.

**Declaration of interest**

None declared.

**References**


Please see multiple choice questions 29–32.