An update on regional analgesia for rib fractures

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Purpose of review
To provide an update on new strategies for pain management after rib fractures utilizing regional analgesia.

Recent findings
Pain management for patients with rib fractures can be very challenging. Traditionally, intravenous patient-controlled analgesia (IVPCA) with opioids, epidural, and paravertebral blocks have been used. These techniques, however, may be contraindicated or have limited application in certain patient populations. Recently, ultrasound-guided myofascial plane blocks such as the erector spinae plane (ESP) block and the serratus anterior plane (SAP) block have emerged as alternatives; providing excellent analgesia with minimal side effects. These blocks have the flexibility to be employed in a wide variety of circumstances where epidural and paravertebral approaches may not be feasible such as in anticoagulated patients and in patients with vertebral fractures where positioning options are limited. Myofascial blocks are less invasive and allow for broader and earlier application (e.g. in the emergency department). Further research on myofascial plane blocks is a priority.

Summary
Until recently, epidural, paravertebral, and intercostal blocks have been advocated as primary management techniques for pain associated with rib fractures. Newer myofascial plane blocks may play a key role in the future as part of alternative pain management strategies.

Keywords
epidural, erector spinae plane block, paravertebral, rib fractures, serratus anterior plane block

INTRODUCTION
Rib fractures occur most commonly because of blunt thoracic trauma and occur in up to 12% of all trauma patients [1,2]. Rib fractures themselves pose a significant healthcare burden with its associated morbidity, long-term disability, and mortality [3,4]. Pulmonary morbidity is increased in these patients as a result of diminished gas exchange from fracture-induced pulmonary injury and from inadequate analgesia compromising both ventilation and pulmonary mechanics [1]. Various factors affect outcome and mortality after rib fractures. These include the number of ribs fractured, preexisting comorbidities, advanced age, and level of associated pain. Of these, pain is a significant modifiable factor [5–10]. Adequate analgesia is paramount in enhancing pulmonary hygiene aimed at preventing atelectasis and pneumonia. Systemic analgesia is usually sufficient in younger patients with fewer undisplaced fractures without a flail segment. Regional techniques are particularly useful in elderly patients (>65 years of age), patients with multiple rib fractures (MRFs), and in patients with severe pain or compromised pulmonary function [11]. Conventional regional techniques used to manage rib fractures include epidural analgesia, paravertebral block (PVB), intercostal, and intrapleural block [1]. Some of these techniques, particularly epidural analgesia and PVB, may not be feasible in the presence of anticoagulation, multisystem trauma, or in patients unable to be optimally positioned. Recently, several ultrasound-guided (USG) myofacial plane blocks (both single injection and continuous catheter techniques) have been described. The serratus anterior plane (SAP) block and the erector spinae plane (ESP) block offer the advantages of being less invasive...
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KEY POINTS

- The most widely used regional techniques for providing analgesia to patients with rib fractures are paravertebral block (PVB) and thoracic epidural.
- Both techniques provide superior analgesia with fewer side effects than systemic opioids.
- Preference for one technique over the other largely depends on the availability of resources and expertise.
- Newer myofascial plane blocks such as the erector spinae plane block and the serratus anterior plane block offer effective alternatives when paravertebral or epidural techniques are contraindicated or not feasible (as in the case of coagulation abnormalities, inability to properly position a patient, and in patients with fractures at multiple sites).

The use of thoracic epidural analgesia (TEA), perhaps the gold standard for providing analgesia for rib fractures, is supported by a number of studies [5,6,18,19]. A recent study analyzed data from the National Trauma Data Bank in the United States for 194,766 patients presenting with rib fractures. Of those, 1073 had epidural analgesia and 1110 had PVBs, the remainder had neither [20]. Propensity score-matching analysis revealed no difference between epidural analgesia and PVB in either ICU or hospital length of stay (LOS), duration of mechanical ventilation, or development of pneumonia. This suggests that both techniques (epidural analgesia and PVB) provided comparable results. Patients who received either of these techniques had prolonged LOS and frequent ICU admissions compared with the group that did not receive any regional technique. Interestingly, an increase in the mortality was noted for the group that did not receive any regional technique, and the authors attributed this to selecting a healthier cohort in administering regional anesthesia. Additionally, studies from both Level 1 and Level 2 trauma centres have demonstrated that management of rib fracture pain with epidural analgesia improves mortality [6,21]. Its efficacy in reducing pulmonary complications [22,23], intensive care [22,24] and hospital LOS [22,24,25], and mortality [23,24] have been questioned by a few retrospective studies, meta-analyses, and systematic reviews [22,24,25]. It is worth mentioning that the trials included in the meta-analyses were highly heterogenous, constituted of both thoracic and lumbar epidurals, and using a variety of combinations of local anaesthetics and opioids [26]. In addition, it was acknowledged that the results were most likely influenced by the complexity of trauma patients [11]. A more recent study using rigorous exact matching demonstrated that epidural analgesia could actually be harmful in terms of worsening pulmonary complications and increasing hospital LOS [27]. In another study in elderly patients, epidural analgesia was associated with increased complications and hospital LOS regardless of cardiopulmonary comorbidities; even in patients with less severe injuries [28]. The EAST (Eastern Association for the Surgery of Trauma) guidelines have conditionally recommended the use of epidural analgesia in traumatic rib fractures even in view of the low quality of supporting evidence [29].

Epidural analgesia requires both technical competence and situational awareness to avoid and manage complications. With side effects including hypotension, urinary retention, unintentional motor blockade, along with limitations imposed by anticoagulation, and the fact that epidural techniques are frequently challenging to perform, epidural analgesia may not be the first choice in unilateral rib fracture management.

PARAVERTEBRAL BLOCK

PVB has been shown to be as effective as epidural analgesia in managing multiple rib fractures (MRFs) [30,31]. A recent randomized trial has shown that PVB is superior to intravenous patient-controlled analgesia (IVPCA) in providing better analgesia and improving pulmonary function with MRFs [32].

Unilateral sensory, motor, and sympathetic block can be achieved when local anaesthetic is injected into the paravertebral space. As this space communicates with the intercostal space laterally and the epidural space medially, a 5-6 dermatome sensory block is possible with a single injection of 20 ml of local anaesthetic [11]. Whilst a single catheter (for continuous analgesia) suffices for up to six adjacent rib fractures, a second catheter should be employed when there are either more than six fractures or for bilateral fractures when epidural analgesia is contraindicated [1]. Compared with epidural analgesia, PVB is relatively easy to perform, produces less sympathetic blockade, does not cause urinary retention, and allows for an unimpeded neurological assessment [1,11,33]. PVB catheters...
can also be used in the presence of moderate anti-coagulation, including LMWH [11,33]. They can also be placed in unconscious patients as there is little concern of spinal cord trauma with needle insertion [1,26]. Although PVB can be performed using landmarks and peripheral nerve stimulation, ultrasound guidance has been shown to improve the analgesic efficacy [34]. A unique feature of PVB is its ability to enhance mobility in the ambulatory setting. Newer infusion devices have made it possible to discharge patients home with catheters and infusions for up to a week [35]. Inadvertent neuraxial injection, pneumothorax, and local anaesthetic toxicity (with multiple/bilateral catheters) can occur with this technique.

**INTERCOSTAL NERVE BLOCK**

Intercostal nerve block (ICB) is an effective technique but requires injections at the level of the fracture as well as one level above and below. ICB can be performed either using landmarks or peripheral nerve stimulation as well as with ultrasound guidance. Catheter techniques have also been described when performed lateral to the paraspinal muscles. There is some evidence that ICBs may improve respiratory function [11,36]. Despite its simplicity, ICB has not been popular particularly in patients with multiple rib fractures as it requires several, repeated injections potentiating the risk of pneumothorax and local anaesthetic toxicity. Analgesia is limited in duration and there may be significant discomfort from multiple injections.

**INTERPLEURAL BLOCK**

Interpleural block involves infusion of local anaesthetic into the pleural space. It is an unreliable and unpopular approach that offers no clear benefit. Its analgesic efficacy is inferior to epidural analgesia [37,38].

**SERRATUS ANTERIOR PLANE BLOCK**

Ultrasound-guided SAP block is a recently described myofascial plane technique used in the management of MRFs as an alternative to PVB and epidural analgesia. It provides analgesia to the hemithorax by blocking the lateral branches of the intercostal nerves T2–T9 [1,39]. Evidence of efficacy in managing pain associated with rib fractures is limited to case reports [12–14,15,40]. This block was first described in 2013 by Blanco et al. [39] to provide chest wall analgesia after breast surgery. It has been successfully employed in the setting of dementia in MRFs (as an alternative to intravenous PCA) and impaired coagulation (as an alternative to epidural analgesia) [12]. The serratus anterior muscle originates from the anterior surface of the first eight ribs and inserts on the medial border of scapula. Potential myofascial planes exist both superficial and deep to this muscle. The latissimus dorsi muscle is located superficial to the serratus anterior muscle; ribs and thoracic intercostal nerves lie deep to it with the nerves piercing the serratus anterior muscle [1]. Injecting local anaesthetic into the myofascial plane surrounding the serratus anterior muscle produces blockade of the thoracic intercostal nerves resulting in anesthesia to anterolateral hemithorax. Local anaesthetic can be injected either superficial or deep to the serratus anterior muscle, however, greater duration has been noted after a superficial injection [39] (Figs. 1 and 2).
The SAP block evolved from pectoralis nerve blocks (Pecs I and Pecs II), and is in the same family as other myofascial blocks (transversus abdominis plane, rectus sheath, and ESP blocks). Targeted myofascial plane injections have the ability to produce extensive areas of chest wall analgesia. Some of the benefits of SAP catheter techniques include: their simplicity, their ability to be performed in the supine position and in anticoagulated patients, and their ability to facilitate mobility. They can also be used in the presence of multisystem trauma and in patients with head injuries where epidural analgesia and PVB are contraindicated [1]. Similar to the ESP block, the SAP block has gained popularity in emergency departments where more invasive and time-consuming blocks such as epidural analgesia and PVB are not practical [15]. Neurovascular damage, pneumothorax, and local anaesthetic toxicity are some of the major complications with this block. SAP is not equivalent to PVB as it fails to provide complete anesthesia of the hemithorax. SAP block is effective only for rib fractures of the anterior two-thirds of the chest wall. If ribs are fractured in the posterior one-third of the chest, other modalities such as PVB or ESP plane block should be considered [41]. A recent randomized trial has demonstrated that SAP block is comparable with TEA for postoperative analgesia after thoracotomy [42].

Although originally described being performed in the supine position with both arms abducted (for mid-axillary line placement), a sitting position (for posterior axillary line placement) has also been reported [13]. The fifth rib is identified in the mid-axillary line using a high-frequency linear ultrasound probe 6–13 MHz. The latissimus dorsi and serratus anterior muscles are identified over the fifth rib. Using an in-plane approach, local anaesthetic is injected either superficial or deep to the serratus anterior muscle. Correct needle position is confirmed by visualizing the spread of local anaesthetic either between the latissimus dorsi and the serratus anterior or deep to the serratus anterior. Catheter placement can also be confirmed by visualizing local anaesthetic spread (Figs. 1 and 2). A variety of local anaesthetic solutions have been used ranging from 40 ml of 0.25% ropivacaine [12] or levobupivacaine, 30 ml of 0.5% ropivacaine, and 20 ml of 0.125% bupivacaine [13]. At the authors’ institution, a 10–15 ml bolus of 0.2% ropivacaine is usually administered. This is followed by an intermittent bolus of 10–15 ml of 0.2% ropivacaine every 3 h (with an infusion pump), combined with a patient-controlled option to inject 5 ml of 0.2% ropivacaine at hourly intervals. Dosing strategies are listed in Table 1. The patient’s weight should always be taken into account and a maximum weight-based dose is calculated to avoid unintentional local anaesthetic overdose. This is because local anaesthetic absorption with this technique is similar to that seen with IB where the highest serum concentrations of local anaesthetic can occur. Future studies are required to determine optimal local anaesthetic dosing and pharmacokinetics, site of catheter placement, site of injection (superficial/deep), efficacy relative to other blocks, and safety.

**ERECTOR SPINAE PLANE BLOCK**

ESP block is a novel myofascial plane block recently introduced into clinical practice. It has been successfully utilized in the management of pain after both rib fractures and surgery of the abdomen and thorax, and in the management of chronic thoracic pain [16,17,43–45]. In contrast to the SAP block, the ESP block has the ability to provide analgesia to both the anterior and posterior hemithorax, making it particularly useful in the management of pain after extensive thoracic surgery or trauma (anterior, lateral, and posterior chest wall). Innervation of the ribs and adjoining tissue is primarily through

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Erector spinae plane block</th>
<th>Serratus anterior plane block</th>
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<tbody>
<tr>
<td><strong>Nerves/dermatomes blocked (presumed mechanism)</strong></td>
<td>Dorsal ramus</td>
<td>Lateral branches of the intercostal nerve</td>
</tr>
<tr>
<td></td>
<td>Ventral ramus</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intercostal nerves</td>
<td></td>
</tr>
<tr>
<td><strong>Area of coverage</strong></td>
<td>Anterior, lateral and posterior chest wall</td>
<td>Only anterior 2/3 of chest wall</td>
</tr>
<tr>
<td><strong>Positioning for the block</strong></td>
<td>Sitting/lateral/prone</td>
<td>Supine and sitting</td>
</tr>
<tr>
<td><strong>Pneumothorax risk</strong></td>
<td>Negligent</td>
<td>Present</td>
</tr>
<tr>
<td><strong>Neurovascular injury</strong></td>
<td>Negligent</td>
<td>Negligent</td>
</tr>
<tr>
<td><strong>Feasible with coagulopathy and anticoagulants use</strong></td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Dose (long-acting amide, LA)</strong></td>
<td>Bolus: 20–40 ml of 0.2–0.5% [15,16]</td>
<td>Bolus: 20–40 ml of 0.2–0.5% [12,15]</td>
</tr>
<tr>
<td></td>
<td>Infusion: 0.2%, 5–10 ml/h</td>
<td>Infusion: 0.2%, 5–10 ml/h</td>
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thoracic spinal nerves. After emerging from the spinal cord and traversing through the intervertebral foramina, the thoracic spinal nerves split into ventral and dorsal rami. The ventral rami continue as intercostal nerves innervating the lateral and anterior chest wall, whereas the dorsal rami innervate the posterior chest wall after exiting the paravertebral space [46].

The ESP block is directed at the erector spinae myofascial plane, which is located on the posterior chest wall between the anterior surface of the erector spinae muscle and oriented cephalocaudally to the posterior surface of the spinal transverse process [17]. Local anaesthetic injected in this plane can block the dorsal rami as they traverse the erector spinae plane, producing anesthesia to the posterior hemithorax. Local anaesthetic also spreads anteriorly and cephalocaudally in the erector spinae plane. Ventral rami and intercostal nerves are blocked by anterior spread, providing analgesia to ribs and periosteum as well as large cutaneous areas of the lateral and anterior chest wall (by blockade of lateral and anterior branches of the intercostal nerves) [43]. Cephalocaudal spread provides anesthesia to at least three segments above and four segments below the injection site; a single injection can result in extensive thoracic anesthesia [17,43].

An ESP block is performed in either the sitting or lateral position. The transverse process coinciding with the centre of the pain source is identified using a high-frequency linear array ultrasound probe. If a specific location is not identifiable, the transverse process of either T5 or T7 should be aimed for. The tip of the targeted transverse process is identified in a transverse orientation. The probe is then rotated to a longitudinal orientation to produce a para-sagittal view while keeping the tip of the transverse process in the centre of the image. Skin, subcutaneous tissue, trapezius, and erector spinae (ES) muscles are identified. When targeting the T7 transverse process, the absence of rhomboid muscle provides additional confirmation as its lower border ends at T5–T6. The block needle is inserted in-plane to the ultrasound beam in a craniocaudal direction until contact is made with the transverse process. Correct location of the needle tip in the ESP is confirmed by injecting 0.5–1 ml of isotonic saline and visualizing, with ultrasound, the fluid lifting the ES muscle off the transverse process without distending the muscle (Figs. 3 and 4). The myofascial plane accepts a catheter well. We routinely inject a bolus of 20–25 ml of 0.2% ropivacaine with epinephrine (1:200,000), followed by a 20–25 ml (0.2% ropivacaine) intermittent bolus every 3 h. This is combined with a patient-controlled option to inject 5 ml of 0.2% ropivacaine at hourly intervals. Dosing strategies are listed in Table 1.

ESP block is a simpler, safer, and less invasive alternative to epidural analgesia or PVB that provides extensive truncal analgesia. As there are no vital structures in the immediate vicinity of needle insertion, there is a smaller risk of pneumothorax or neurovascular injury. Using appropriate local anaesthetic solutions, the risk of local anaesthetic toxicity can be minimized. One of the advantages of an ESP

FIGURE 3. Ultrasound image of erector spinae plane block where transverse process is seen and the correct location of the needle tip is confirmed by injecting 0.5–1 ml of normal saline 0.9% and observing linear fluid spread lifting the erector spinae muscle off the tip of the transverse process.

FIGURE 4. In-plane approach to erector spinae plane block in sitting position.
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block is that it can be utilized in the presence of either coagulopathy or anticoagulation. The only limitations to the procedure are related to positioning of the patient and, infrequently, variability in local anaesthetic spread [17].

CONCLUSION

Adequate pain control utilizing regional anesthesia is an essential component in the management of rib fractures. Before the introduction of myofascial blocks, options were limited to more invasive techniques such as epidural analgesia, PVB, and intercostal blocks. The simplicity, safety, and flexibility of SAP and ESP blocks make them attractive alternatives in emergency departments and in the setting of acute trauma. This permits early, aggressive pain control without the need for large doses of opioids. More studies are needed to establish the role of myofascial blocks in pain management after rib fracture. A single technique applicable to every clinical scenario involving rib fractures cannot be proposed. Risks and benefits of each invasive or noninvasive technique should be individually assessed in each setting. Nonetheless, in our opinion, PVB and ESP block are suitable techniques in the majority of situations.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:

• of special interest
• of outstanding interest

21. This study is a review of the National Trauma Data Bank from the United States looking into nearly 200,000 patients with rib fractures, 1073 patients having epidural and 1110 having paravertebral block. A propensity matching revealed that both strategies were acceptable in terms of intensive care and hospital stay, duration of mechanical ventilation, and developing pneumonia.
34. This randomized study on 90 patients with unilateral multiple rib fractures showed that thoracic paravertebral block was superior to intravenous patient-controlled analgesia in terms of better analgesia and preserving pulmonary function.


