Current Strategies in the Management of Rib Fractures: A Comprehensive Review

Mona Abdel Hamid Elharrisi, Sanaa Ahmed Eltohamy, Amr Shaaban Hafez, Ahmed Raafat Mansour,

Department of Anesthesia, Intensive Care and pain management, Faculty of Medicine, Zagazig University

Corresponding author: Ahmed Raafat Mansour

Email: Loyalman54 @gmail.com**, Mobile:** 01097785845

Article History: Received: 11.06.2023 **Revised:** 08.07.2023 **Accepted:** 15.07.2023

Abstract

Chest trauma that is either blunt or penetrating happens frequently. Rib fractures are the most frequent sign of blunt chest trauma, and they frequently happen at the posterior portion of the rib's weakest location. Injuries like pulmonary contusions can arise from the force needed to fracture ribs and subsequent energy transfer those damages underlying tissues. Effective care of rib fractures is critical for minimizing complications and reducing associated mortality. Chest wall pain is directly associated with rib fractures, and it can exacerbate pulmonary problems and impair breathing. Splinting, guarding, low tidal volumes, limited movement, an inability to cough and remove secretions, and an unwillingness to engage in chest physiotherapy are all possible outcomes of this pain. Effective analgesia is therefore essential for enhancing pulmonary mechanics, removing secretions, and enhancing patient mobility. There are various approaches to managing rib fracture pain, including systemic analgesia and regional techniques.

Keywords: rib fracture, flail chest, pain management, regional anesthesia.

DOI: 10.53555/ecb/2023.12.1169

I. Introduction:

Trauma is the primary cause of death in the first forty years of life and a major global cause of illness and mortality. At least 10% of all injured patients have rib fractures, which are extremely prevalent and mostly the result of blunt thoracic trauma (75%), which is primarily caused by traffic accidents. Penetrating injuries account for the remaining 25% of cases. Significant morbidity is linked to rib fractures; patients often need to be admitted to the intensive care unit (ICU); mortality rates can reach 33% as a result of inadequate pulmonary function and mechanical ventilation, which raises the risk of pneumonia, a common cause of death. [1]

II. Anatomical considerations:

There are twelve pairs of ribs, each of which articulates posteriorly with its corresponding thoracic vertebra and transverse processes. Ribs 1-7 are real ribs since they articulate anteriorly with the sternum through costal cartilages. Ribs 8-10 are false ribs because their relationship to the sternum is indirect, but ribs 11 and 12 are floating since they have no anterior connection. The inferior aspect of the rib is grooved to accommodate the neurovascular bundle, which includes the intercostal vein, artery, and nerve. The neurovascular bundle can be found at many locations posteriorly. The bundle is more likely to sit in the groove as it moves laterally and anteriorly. [2]

The most common ribs to fracture are 4-10. The clavicle and shoulder girdle protect the first three ribs, therefore it takes a lot of force to fracture them. The lower floating ribs 11 and 12 are more movable and less prone to fracture. Traumatic fractures typically occur at the place of impact or at the weakest location, which is frequently the posterolateral curve.[3] T1 to T12 thoracic spinal neurons exit the intervertebral foramina and branch into anterior and posterior ramus branches. In the neurovascular space, the anterior ramus branches (intercostal nerves) follow the posterior intercostal vessels slightly beneath each rib.[4]

During their course, collateral, lateral cutaneous, and anterior cutaneous branches branch off. The anterior ramus branches innervate the skin over the ribs and muscles of the thoracic wall. The posterior ramus branches go on to innervate the skin over the posterior thoracic wall and the muscles of the spine .[5]

III. Mechanism of injury:

Direct trauma to the chest wall is the leading cause of rib fractures. This could be related to high-impact trauma, such as those observed in car accidents or falls from heights. A considerable proportion of individuals with serious trauma will sustain a chest wall injury. However, as the old population grows, so do the numbers of elderly people who sustain rib fractures as a result of a simple fall from standing. The rib's posterolateral angle is its weakest structural point. The pattern of injury, however, is frequently influenced by the point of impact and the degree of force applied.

It is important to note that due to the relative elasticity of tissues in young children, a significant force is required to result in rib fracture. This makes this clinical presentation rare in this age group and when it occurs, non-accidental injury must be considered. Less commonly, rib fractures can occur due to repeated coughing (stress fracture) or due to underlying malignancy (pathological fractures). [6]

IV. Flail chest

Radiologically, a flail segment is the presence of three contiguous ribs fractured in two or more places. Clinically, a flail chest is paradoxical chest wall movement in a patient who is breathing spontaneously. This is a more variable phenomenon; it can occur in a patient with one rib fractured in two places, or sometimes not be present even in a patient with a significant radiological flail. Both clinical and radiological definitions of flail chest signify increased severity of injury; the presence of a flail chest injury is associated with a mortality rate of up to 35%.[3]

V. Pathophysiology

Morbidity and mortality associated with rib fractures is caused by three main problems:[7]

1. Hypoventilation due to pain:

Pain associated with rib movement reduces the tidal volume and predisposes to significant atelectasis. This can further lead to retention of pulmonary secretions and pneumonia. [7]

2. Impaired gas exchange in damaged lung underlying the fractures:

An injury severe enough to shatter ribs, particularly if it causes a flail segment, will almost always result in a large contusion of the underlying lung. The lungs become edematous, with variable degrees of bleeding and necrosis. The injured lung is weakly compliant and will not take part in gas exchange, causing intrapulmonary shunting and a drop in arterial partial pressure of oxygen (PaO2). [7]

3. Altered breathing mechanics:

In the presence of a flail segment, the generation of negative intrapleural pressure produces paradoxical movement of the flail, causing it to move inward, while the rest of the ribcage moves outward. This means that the underlying lung does not expand and as a result, the tidal volume decreases; this has been demonstrated clinically, although an increase in the respiratory rate means that arterial partial pressure of carbon dioxide ($PaCO_2$) remains normal. This inefficient breathing results in higher oxygen consumption and has been shown to reduce PaO_2.
7

VI. Complications:

Complications associated with traumatic rib injuries include:

1. Pneumothorax.
2. Hemothorax.
3. Pneumonia.

4. Pulmonary contusion.
5. Injury to major vessels and intra-abdominal organs.

The most important sequela of significant chest wall injury is worsening respiratory failure. The likelihood of patients with multiple rib fractures developing an associated pneumonia is high. This can further exacerbate problems with oxygenation and ventilation associated with the initial chest trauma (atelectasis, contusion). Severe pneumonia leading to respiratory failure is a major cause of death in this patient population. [6]

VII. Factors affecting adverse outcome after rib fractures:

Several factors have consistently been shown to correlate with adverse outcomes and increased likelihood of death after rib fractures. The most significant are:

1- Age over 65 years.

2- Comorbidities, especially respiratory and cardiovascular diseases.

3- More than three broken ribs.

4- Development of pneumonia. [8]

VIII. Management

1. Diagnosis:

A. Clinical: In patients with isolated injuries, localized pain to the chest wall, particularly with deep inspiration and associated tenderness or deformity, would raise suspicion of underlying rib fractures. The absence of breath sounds on the affected side or developing surgical emphysema may indicate the presence of an underlying pneumothorax. A tension pneumothorax could develop as a result of displaced rib fractures; this may need immediate needle decompression to prevent cardiovascular collapse.[6]

B. Radiological:

a. Anteroposterior chest x-ray: Chest x- ray may identify rib fractures, particularly if significantly displaced. However, chest X-ray alone will miss up to 50% of fractures. [2,6]

b. Computed tomography: Computed tomography is the most sensitive

imaging modality that will confirm the number and site of fractures and detect flail segments, underlying intrathoracic injury and pulmonary contusions.[2]

2. Pain management:

Close consideration of the effectiveness, safety, and side effect profile of an analgesic intervention is paramount in the selection of an appropriate management strategy. [9]In patients with fractured ribs, effective analgesia started promptly prevents hypoventilation, enables deep breathing, adequate coughing with clearance of pulmonary secretions, and compliance with chest physiotherapy. Overall, this reduces secondary pulmonary complications, including atelectasis, pneumonia, respiratory failure, and the need for respiratory support. Opioids were previously the mainstay of treatment, but with significant side-effects, including respiratory depression, depressed cough reflex and delirium; multi-modal analgesia is now more commonly used. [7]

A variety of approaches to pain management for fracture ribs exists, which include systemic analgesia and regional analgesic techniques. [9] **A. Systemic analgesia**

a. Simple analgesics

Regular paracetamol and nonsteroidal anti-inflammatories (caution in elderly, due to the risk of renal impairment) should be prescribed unless contraindicated. [6] **b. Opioids**

Patients in the acute environment are likely to require titrated doses of IV morphine or equivalent opioids to manage pain, especially if they have multiple injuries. If the pain is somewhat well-controlled, try prescribing an oral morphine equivalent for breakthrough pain.[6]

In patients with moderate to severe pain, IV patient-controlled analgesia should be considered to allow regular small boluses of opioid to be delivered on demand. The protocol can be altered to allow a larger bolus dose or a background infusion if necessary. Despite their efficacy in terms of pain relief, these medications may not be well tolerated due to common side effects such as nausea and vomiting. In elderly patients, additional side effects, such as drowsiness and confusion, may limit the effectiveness of a patient-controlled analgesia. [6] **c- Non opioid analgesics**

IV ketamine may be a useful adjunct in the initial management of patients with chest wall trauma. Gabapentinoids such as gabapentin or pregabalin can have opioid-sparing effects as part of a long-term analgesic regimen in this patient group.[6]

B. Regional analgesia

Patients unable to deep breathe or cough despite the above measures should be considered for regional anesthetic techniques to optimize their pain control. Regional analgesia offers a plethora of benefits in patients with multiple rib fractures. Pain relief is often satisfactory and immediate, with a minimal side effect profile. [6,9]

The options for regional techniques include:

a. Epidural analgesia.

Thoracic epidural analgesia has long been regarded as the gold standard in the treatment of severe rib fractures. Modern improvements in this procedure include the use of ultrasound guidance to improve practitioners' effectiveness when inserting thoracic epidural catheters. [10] By blocking spinal nerves as they emerge from the spinal cord within the epidural space, nociceptive inputs from intercostal nerves are prevented from transmitting central pain signals. Thoracic epidurals have been suggested to reduce mortality in trauma centers and have benefits on analgesia, postoperative pulmonary ventilation and duration of stay. [11]

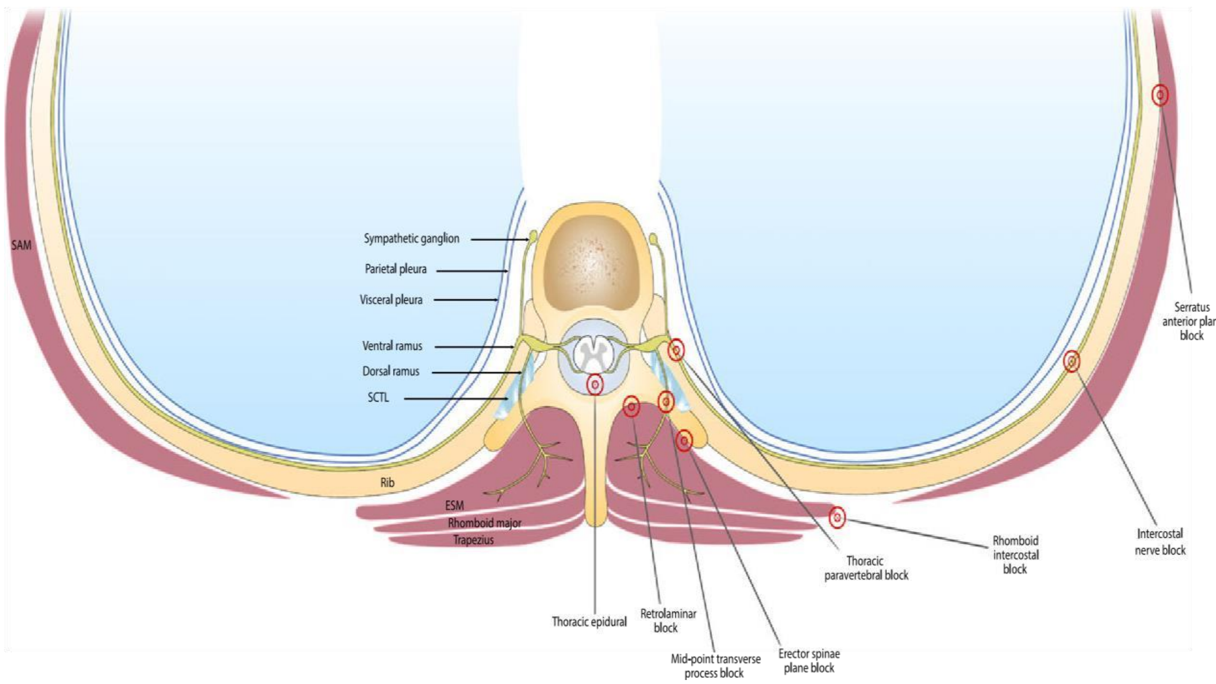

Fig (1): The available regional analgesic techniques for pain control in patients with multiple fractured ribs Axial cross-sectional illustration of a thoracic vertebra demonstrating the key anatomical structures (left) and the site of injection of local anesthesia for blocks (right) used in the management of traumatic rib fractures. ESM, erector spinae muscle; SAM, serratus anterior muscle; SCTL, superior costotransverse ligament. . [11]

However, thoracic epidural analgesia might not have longer term outcome benefits, and meta-analyses have now demonstrated that these effects are not as marked as once thought, questioning the utility of this technique in the setting of traumatic rib fractures.[12] Moreover, thoracic epidural analgesia is contraindicated in patients with hypotension, hypovolemia, coagulopathy, significant spinal or traumatic brain injuries, and systemic infection, all of which are common in the multi-trauma patient.[11]

Placement of thoracic epidural analgesia is particularly associated with hypotension, mainly due to a reduction in systemic vascular resistance from the blockade of sympathetic output. This can result in significant hemodynamic compromise, especially in the under-resuscitated patient. Moreover, the technically demanding nature of this procedure may pose challenges in a patient with multiple injuries and sites of pain. Finally, it is important to consider the risks of dural puncture, motor blockade, pruritus, and urinary retention. [9]

This technique should therefore no longer be considered the gold standard analgesic strategy for rib fractures. Indeed, for isolated rib fractures, especially if unilateral the role of thoracic epidural analgesia is perhaps best reserved for historical texts, rather than contemporary clinical practice. [11]

b. Paravertebral analgesia

The TPVB allows for the delivery of local anesthetic to the ventral and dorsal rami of ventral nerves within the paravertebral space (PVS). Analgesia can be accomplished by intermittent injection, continuous infusion, or frequent dosage using a catheter, which can cause a unilateral multilayer nerve blockage in adjacent dermatomes .[13] Many institutions have adapted TPVB as a means to manage patients with multiple rib fractures because of its relative technical ease, liberal anticoagulation guidelines, lower incidence of sympathectomy, preservation of bladder sensation, and absent risk of spinal cord injury. Furthermore, since there is sparing of lumbar and sacral nerve roots, TPVB can be performed in patients who require neurological assessment for concomitant spinal cord compression. [14]

The TPVB has proven to be as effective as thoracic epidural analgesia for pain management in patients with unilateral rib fractures and may contribute to improved survival. The complication rate is low and has been described as comparable to that of epidural and intercostal nerve blocks. However, there remains the risk of pneumothorax, pleural puncture, inadvertent bilateral blockade, and vascular puncture. With the advent of ultrasound technology and its utility in more precise TPVB placement,
TPVB may have an improved safety profile. [15,16,9,13]

c. Myofascial Plane Blocks

1. Serratus anterior plane block:

The SAP block delivers analgesia to the lateral branches of the intercostal nerves T2-T9 by injecting local anesthetic into the serratus anterior muscle, either superficially or deeply. Notably, SAP block will only cover the anterior two-thirds of the hemothorax, limiting its use to rib fractures in these areas. Several case reports suggest a reduction in opiate consumption and improvement in pain scores after the performance of SAP block in patients with multiple rib fractures. [17,18]

2. **Erector spinae plane block:**

Erector spinae block provides analgesia to the anterior, lateral, and posterior hemithorax through the injection of local anesthetic deep to the erector spinae muscle. Numerous case reports have identified its value in patients with multiple rib fractures. Most recently, Adhikary et al. demonstrated a significant improvement in inspiratory volumes and a reduction in pain scores and opioid requirements.[19,20,21]

3. **Rhomboid intercostal and sub-serratus block :**

The region described is known as the triangle of auscultation that is bounded medially by inferior part of the trapezius, inferiorly by the superior border of latissimus dorsi, and laterally by the medial border of the scapula. In this ultrasoundguided block, the local anesthetic drug is administered between the rhomboid major and the intercostal muscle fascia at the level of T6–T7 and provides analgesia of T3– T8 dermatomes.

Elsharkawy et al. described a modification to the rhomboid intercostal block to expand dermatomal coverage. They describe the RISS (Rhomboid Intercostal and Sub-Serratus) block that is a two-injection block of both the rhomboid intercostal and sub-serratus space. After the first injection, the ultrasound probe advances caudally and laterally distal to the inferior angle of the scapula, the second injection applies between the serratus and intercostal muscle fascia **.**[22,23,24]

d. Intercostal Nerve Block

Intercostal nerve blocks are simple to perform and directly block intercostal nerve-associated nociceptive transmission. They are therefore reliable and reproducible. However, intercostal nerve blocks are associated with a high risk of systemic absorption of local anesthetic, require multiple injections and are limited by the duration of action of local anesthetics. Catheter techniques are used rarely, as these are only of utility in the event of single rib fractures. The site of injection must also be carefully considered, as posterior rib fractures might require a very posterior approach. There are few high-quality data demonstrating clinical efficacy and/or safety of intercostal nerve blocks, and the primary reason for their continued use is the ease of performance, particularly without ultrasound, and presumed safety due to the relatively superficial nature of the target nerves.[11]

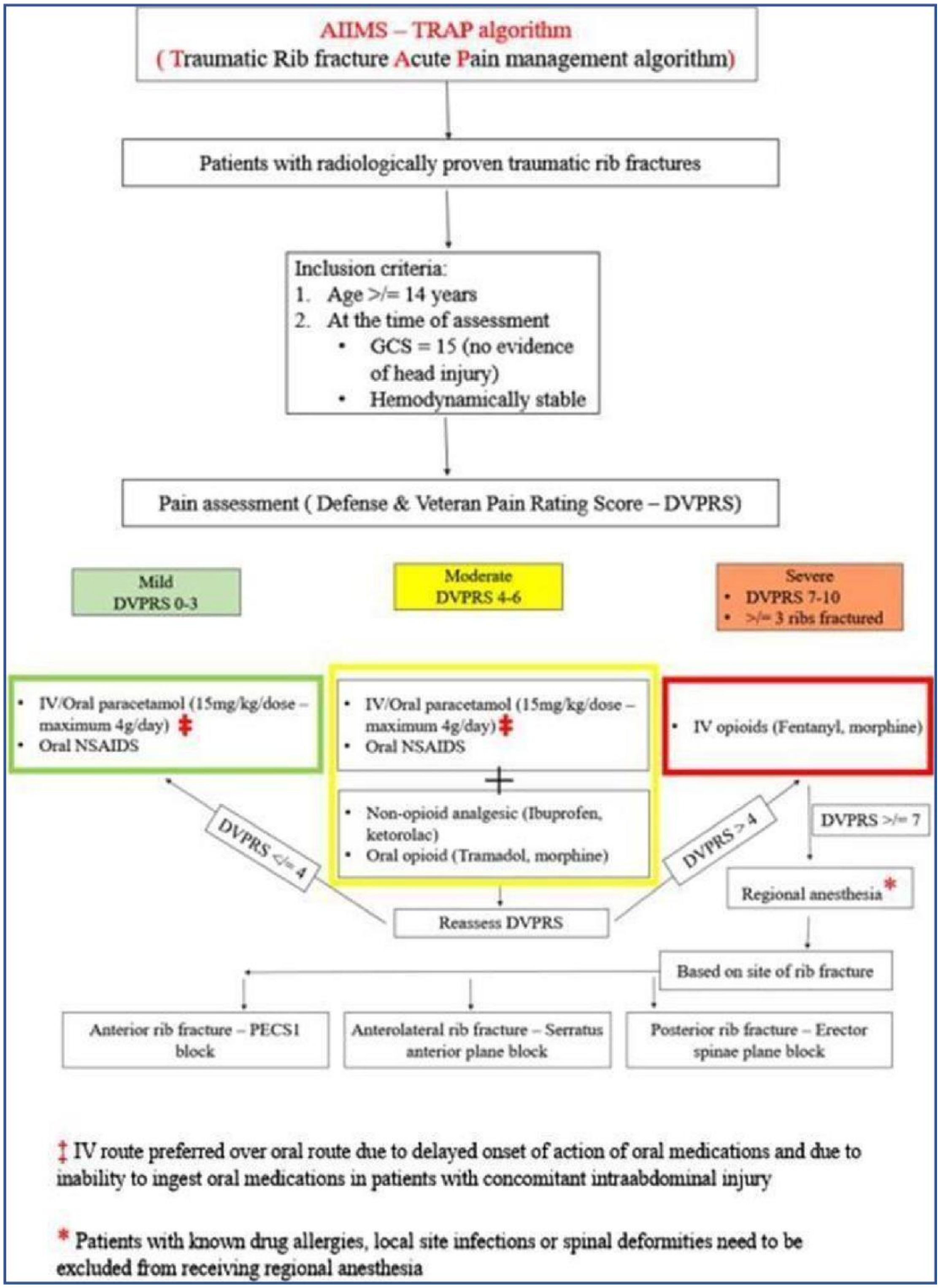

Figure (2): Traumatic Rib Fracture Acute Pain Management" (TRAP) Algorithm.[25]

3. Ventilatory and supportive management:

1- Supplementary oxygen will often be required to treat hypoxia[2.]

2- High-flow nasal cannula or non-invasive ventilation (NIV) can be used in Patients developing more significant hypoxia with or without hypercarbia. These devices, used in conjunction with good-quality (often regional) anesthesia, have been demonstrated to be associated with reduced intubation rates and mortality Certain patients may have contraindications to NIV, such as base of skull fractures, reduced levels of consciousness or pneumothorax before chest drain insertion. Continuous positive airway pressure reduces atelectasis, intrapulmonary shunting, and the paradoxical movement of a flail segment, if present. However, it can be uncomfortable for the patient and may make expectoration more difficult.[2,7]

3- Invasive ventilation will be required if the thoracic injuries are sufficiently severe or the extrathoracic injuries dictate airway or ventilatory control.[2]

4- Chest physiotherapy strategies include Incentive spirometry and pulmonary toilet to clear secretions. The effectiveness of chest physiotherapy, however, is dependent on the patient having adequate analgesia.[6]

5- Chest drain insertion to treat any associated pneumothorax or haemothorax should be considered.[6]

4. Operative fixation:

Management of rib fractures by stabilizing the chest has been around for centuries, but has gone in and out of fashion. However, more recently, rib fracture fixation has made resurgence with evidence suggesting it is beneficial for a certain group of patients. [6]

1. Intubated patients with a flail chest leading to respiratory failure and prolonged ventilation with failed weaning. [26]

2. Non-intubated patients with a flail with deteriorating pulmonary function. The aim is to stabilize the chest to restore pulmonary mechanics and reduce pain. [26]

3. Rib fractures refractory to conventional pain management, rib fracture nonunion, and during a thoracotomy performed primarily for other injuries.[27]

5. Quality of life:

For the patient, the goal is not just to survive, but also to improve their quality of life. In today's society, enhancing one's quality of life is more important than curing a condition.[27] The indicators of the long-term treatment efficacy of rib fractures included chronic pain after injury, vital capacity, return to work rate and return to work time, quality of life, and the appearance of the chest wall, among others.[28]

Conclusion

Rib fractures are a frequent injury that carry a considerable risk of morbidity and death. The prognosis of individuals suffering from rib fractures can be influenced by various factors such as age, coexisting medical conditions, the quantity of cracked ribs, and the occurrence of pneumonia. Physiotherapy, supportive care, and pain control are the mainstays of treatment for rib fractures. Surgery might be required in certain situations to treat rib fractures. Most rib fracture patients will recover completely with quick diagnosis and treatment. On the other hand, some people might develop chronic pain or other long-term issues.

References

1. Pressley, C. M., Fry, W. R., Philp, A. S., Berry, S. D., & Smith, R. S. (2012). Predicting outcome of patients with chest wall injury. Am J Surg, 204(6), 910913.
2. Williams, A., Bigham, C., & Marchbank, A. (2020). Anaesthetic and surgical management of rib fractures. BJA Education, 20(10), 332-340.
3. Dehghan, N., de Mestral, C., McKee, M. D., Schemitsch, E. H., & Nathens, A. (2014). Flail chest injuries: a review of outcomes and treatment practices from the National Trauma Data Bank. J Trauma Acute Care Surg, 76(2), 462468.
4. Headrick, D. H., & Gordh, G. (2009). Anatomy: head, thorax, abdomen, and genitalia. In Encyclopedia of insects (pp. 11-21). Academic Press.
5. Klinkhachorn, P., Klinkhachorn, P., Kamsala, M., Wijesinghe, T., Altemus, J., Davis, A., & Reilly, F. (2008). Sectional and radiological anatomy of the thorax. MedEdPORTAL, 4, 1707.
6. Dogrul, B. N., Kiliccalan, I., Asci, E. S., & Peker, S. C. (2020). Blunt trauma related chest wall and pulmonary injuries: An overview. Chinese journal of traumatology, 23(03), 125-138.
7. May, L., Hillermann, C., & Patil, S. (2016). Rib fracture management. Bja Education, 16(1), 26-32.
8. Battle, C. E., Hutchings, H., & Evans, P. A. (2012). Risk factors that predict mortality in patients with blunt chest wall trauma: a systematic review and meta-analysis. Injury, 43(1), 8-17.

9. Kim, M., & Moore, J. E. (2020). Chest Trauma: Current recommendations for rib fractures, pneumothorax, and other Injuries. CurrAnesthesiol Rep, 10(1), 61-68.
10. Chin, A., Crooke, B., Heywood, L., Brijball, R., Pelecanos, A., & Abeypala, W. (2018). A randomised controlled trial comparing needle movements during combined spinal-epidural anaesthesia with and without ultrasound assistance. Anaesthesia, 73(4), 466-473. Current opinion in Anaesthesiology, 24(5), 508.
11. El-Boghdadly, K., & Wiles, M. D. (2019). Regional anaesthesia for rib fractures: too many choices, too little evidence. Anaesthesia, 74(5), 564-568.
12. Duch, P., & Møller, M. H. (2015). Epidural analgesia in patients with traumatic rib fractures: a systematic review of randomised controlled trials. Acta Anaesthesiol Scand, 59(6), 698-709.
13. Karmakar, M. K. (2011). Ultrasound-guided thoracic paravertebral block. In Atlas of ultrasound-guided procedures in interventional pain management (pp. 133-148). Springer, New York, NY.
14. Ho, A. M., Karmakar, M. K., & Critchley, L. A. (2011). Acute pain management of patients with multiple fractured ribs: a focus on regional techniques. Current opinion in critical care, 17(4), 323-327.
15. Mohta, M., Verma, P., Saxena, A. K., Sethi, A. K., Tyagi, A., & Girotra, G. (2009). Prospective, randomized comparison of continuous thoracic epidural and thoracic paravertebral infusion in patients with unilateral multiple fractured ribs–a pilot study. J Trauma, 66(4), 1096-1101.
16. Malekpour, M., Hashmi, A., Dove, J., Torres, D., & Wild, J. (2017). Analgesic choice in management of rib fractures: Paravertebral Block or Epidural Analgesia?. AnesthAnalg, 124(6), 1906-1911.
17. Rose, P., Ramlogan, R., Sullivan, T., & Lui, A. (2019). Serratus anterior plane blocks provide opioid-sparing analgesia in patients with isolated posterior rib fractures: a case series. Can J Anaesth, 66 (10), 1263-1264.
18. Rose, P., Ramlogan, R., Sullivan, T., & Lui, A. (2019). Serratus anterior plane blocks provide opioid-sparing analgesia in patients with isolated posterior rib fractures: a case series. Can J Anaesth, 66 (10), 1263-1264.
19. Forero, M., Adhikary, S. D., Lopez, H., Tsui, C., & Chin, K. J. (2016). The Erector spinae plane block: A novel analgesic technique in thoracic neuropathic pain. Reg Anesth Pain Med, 41(5), 621-627.
20. Hamilton, D. L., & Manickam, B. (2017). Erector spinae plane block for pain relief in rib fractures. Br J Anaesth, 118(3), 474-475.

21. Wardhan, R. (2013). Assessment and management of rib fracture pain in geriatric population: an ode to old age. CurrOpinAnaesthesiol, 26(5), 626631.
22. Elsharkawy, H., Saifullah, T., Kolli, S., & Drake, R. (2016). Rhomboid intercostal block. Anaesthesia, 71(7), 856-857.
23. Elsharkawy, H., Hamadnalla, H., Altinpulluk, E. Y., & Gabriel, R. A. (2020). Rhomboid intercostal and subserratus plane block-a case series. Korean journal of anesthesiology, 73(6), 550-556.
24. Elsharkawy, H., Maniker, R., Bolash, R., Kalasbail, P., Drake, R. L., & Elkassabany, N. (2018). Rhomboid intercostal and subserratus plane block: a cadaveric and clinical evaluation. Regional Anesthesia & Pain Medicine, 43(7), 745-751.
25. Bhoi, S. K., RL, B., Yadav, S., Halder, D., & Sinha, T. P. (2022). “All India Institute of Medical Sciences Traumatic Rib Fracture Acute Pain Management”(AIIMS TRAP) Algorithm for Pain-Free Experience in Chest Injury Patients. Indian Journal of Surgery, 84(6), 1-3.
26. Hasenboehler, E. A., Bernard, A. C., Bottiggi, A. J., Moghadamian, E. S., Wright, R. D., & Chang, P. K. (2011). Treatment of traumatic flail chest with muscular sparing open reduction and internal fixation: description of a surgical technique. J Trauma, 71(2), 494-501.
27. Nirula, R., Diaz, J. J., Trunkey, D. D., & Mayberry, J. C. (2009). Rib fracture repair: indications, technical issues, and future directions. World J Surg, 33(1), 14-22.
28. Hoepelman, R. J., Beeres, F. J., Heng, M., Knobe, M., Link, B. C., Minervini, F., Babst, R., Houwert, R., & van de Wall, B. J. (2022). Rib fractures in the elderly population: a systematic review. Archives of Orthopaedic and Trauma Surgery,143(2), 1-7.