

FLAIL CHEST: A LITERATURE REVIEW

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ABSTRACT

This study aims to make a review about flail chest management so this can be a simple and useful reference for surgeons to make a decision regarding flail chest management decisions. The research method used in this research is the descriptive qualitative method. The type of data used in this study is qualitative data, which is categorized into two types, namely primary data and secondary data. The data were obtained through library research techniques (library studies) which refers to sources available both online and offline such as scientific journals, books and news sourced from trusted sources. From the results of research and discussion concluded that early surgical stabilization of rib fracture has better outcome in the cases of ribs fracture which are severe enough.

KEYWORDS

Flail chest , rib fracture , thoracic trauma , chest wall fixation



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INTRODUCTION

Injury of the thorax is the third most common injury in trauma cases after head and extremity injury. Thoracic trauma occurs in A broad spectrum of severity, ranging from single isolated rib fracture to a flail chest (Peek et al., 2020). Fractures of the rib occur up to 10% of all trauma admission (Dehghan et al., 2018). Rib fractures are present in approximately 25% of patients with blunt chest trauma. Most the patients with rib fractures can heal without major complication. However, flail chest, one of the traumatic condition of thorax, is defined as fracture of 3 or more consecutive ribs in which are broken in at least 2 places is one of the more severe instances of these these injuries with a major cause of mechanically unstable chest wall (Liu et al., 2019). Meanwhile Flail chest is a clinical diagnosis as clinicians observe paradoxical movement of the chest wall (Dantis et al., 2021). In combination with lung contusion caused by trauma, flail chest can cause serious

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disturbance of respiratory function. Up to 30% patients with flail chest and lung contusion reported acute respiratory insufficiency (Apostolakis et al., 2021).

Traditionally, management of flail chests is supportive care consisting of pain control and ventilatory support as needed. However, supportive care in the management of flail chest requires prolonged intubation or even tracheostomy, with the accompanying medical complications and additional resource utilization associated with intensive care and prolonged mechanical ventilation. In addition, these supportive care interventions are associated with high levels of long-term morbidity (Swart et al., 2017). Recently, surgical approach for flail chest by fixing the ribs is more frequently applied. Metal plates, intramedullary devices and encircling wires are implanted to increase chest wall stability thus correcting chest wall deformity and supporting healing process (Wijffels et al., 2020). The researcher would to make a review about flail chest management so this can be a simple and useful reference for surgeon to make a decision for flail chest management decision.

RESEARCH METHOD

The research method used in this research is descriptive qualitative method. The type of data used in this study is qualitative data, which is categorized into two types, namely primary data and secondary data. The data were obtained through library research techniques which refers to sources available both online and offline such as scientific journals, books, and news sourced from trusted sources. These sources are collected based on discussion and linked from one information to another. Data collection techniques used in this study were observation, interviews and research. This data is analyzed and then conclusions were drawn.

RESULT AND DISCUSSION

Anatomy of the ribs

The rib cage is formed by the sternum, costal cartilage, rib, and body of vertebrae. Rib cage is useful for protecting organs resided in thoracic cavity, assisting respiration and providing support for upper extremity. There are twelve pairs of ribs articulated posteriorly with two thoracic vertebrae by the costovertebral joint with exception to first rib. First rib articulates with the first thoracic vertebra only. According to their attachment to the sternum, there are true, false, and floating ribs. The true ribs, first seven ribs, are the ribs that directly articulate with the sternum with their costal cartilages (Figure 1). The false ribs, indirectly articulate with the sternum, has their costal cartilages connected with the seventh costal cartilage by the costochondral joint. However, the floating ribs which are the two most distal ribs are the ribs that do not articulate with the sternum at all. The true ribs articulate with the sternum by the sternocostal joints. The first rib is an exception to that rule which is called synarthrosis (Safarini & Bordoni, 2019).

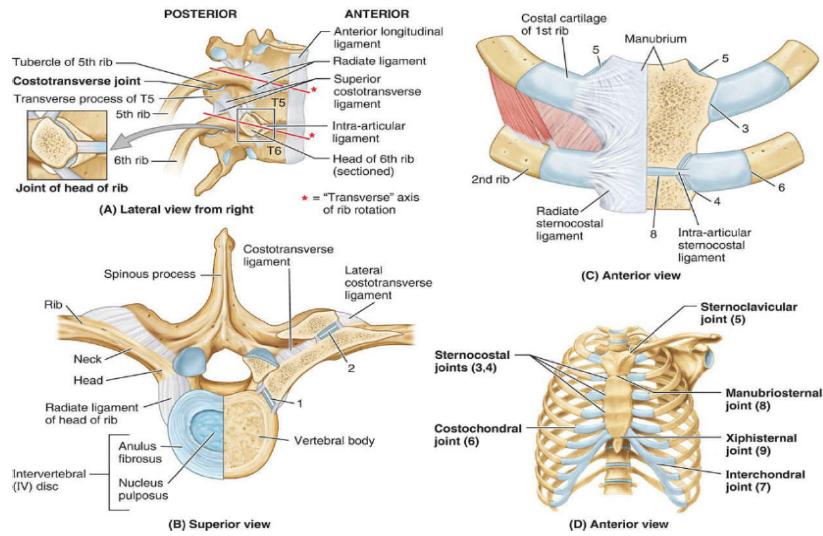


Figure 1 Anatomy of the thoracic wall (11)

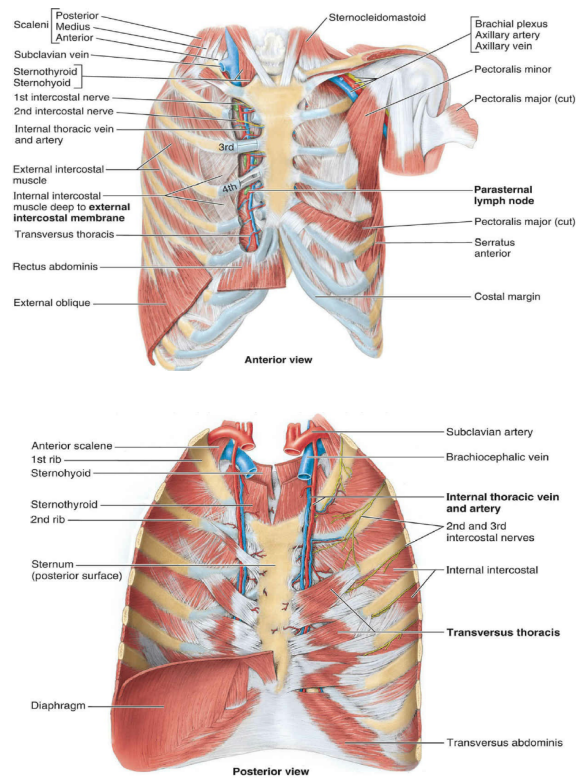


Figure 2 Anatomy of muscle related to respiration(11)

By the help of innervation of phrenic nerve, contraction of diaphragm may lead to normal resting inspiration. Diaphragm is a dome-shaped muscle that separates the thoracic cavity containing the heart and lungs from the abdominal cavity (figure 2) Expansion of thoracic cavity may result from diaphragm contraction by increasing volume of thoracic cavity which causes decrease of intrathoracic pressure. Not only diaphragm, contraction of external and internal intercostal muscle will raise rib cage upward and outward which leads to thoracic volume expansion (figure 2). This causes free air will flow into the lung due to pressure difference (Feher, 2017).

Rib Fracture

Incidence of rib fracture caused by trauma ranged from 7-40%. The most common cause of rib fracture is motor vehicle accident. There may be difference chest trauma consequences between adult and children due to children's rib flexibility (Sirmali et al., 2003). Rib fracture happens as the consequences of blunt trauma which has significant enough force directed at the rib causes a break (Kuo & Kim, 2019). Complications of rib fracture are hemothorax, pneumothorax and lung contusions. The most common symptoms following ribs fracture are significant pain which hinders respiratory effort and leads to complication like pneumonia, pleural effusion and acute respiratory distress. The clinical outcome may related heavily to fracture location, number and pattern (Maduka et al., 2019).

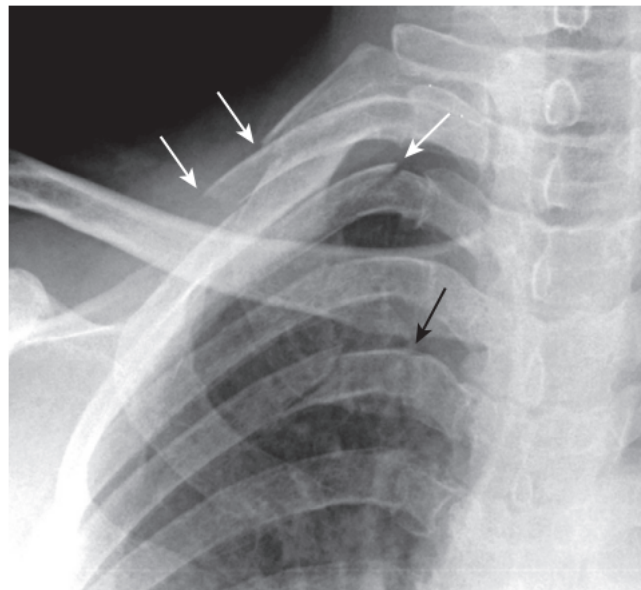


Figure 3 Rib fracture on Plain chest X ray.(16)

Ribs 1 through 3 are the hardest to break and signify a significant degree of trauma if fractured. Ribs 4 through 10 are typically the most vulnerable while ribs 11 through 12 are more mobile and therefore more difficult to break. In the elderly, falls are a common etiology of rib fractures and are associated with higher mortality and morbidity than younger patients (Kuo & Kim, 2019). The number of displaced rib fractures could be a strong predictor for developing pulmonary complications. When fewer than three rib fractures is found without rib displacement and initial lung or other organ injuries, outpatient management can be done safely (Chien et al., 2017). Treatment for most patients with rib

fractures is supportive care, consisting of aggressive pain control and pulmonary rehabilitation.(18) Based on (Fokin et al., 2020), there are indications for surgical stabilization for ribs fracture:

- Flail chest
- Multiple rib fractures with bicortical displacement.
- Fractured ribs acting as penetrating objects.
- Displaced rib fractures combined with sternal fractures and/or ipsilateral displaced midshaft clavicle fractures.
- Uncontrolled pain with failure of nonoperative treatment.
- Chest-wall deformity, especially with reduction of thoracic volume.
- Acute respiratory distress syndrome in patients with thoracic-cage instability.
- Displaced rib fractures found during thoracotomy for other reasons.
- Chronic pain in cases of symptomatic rib nonunion.

Flail Chest

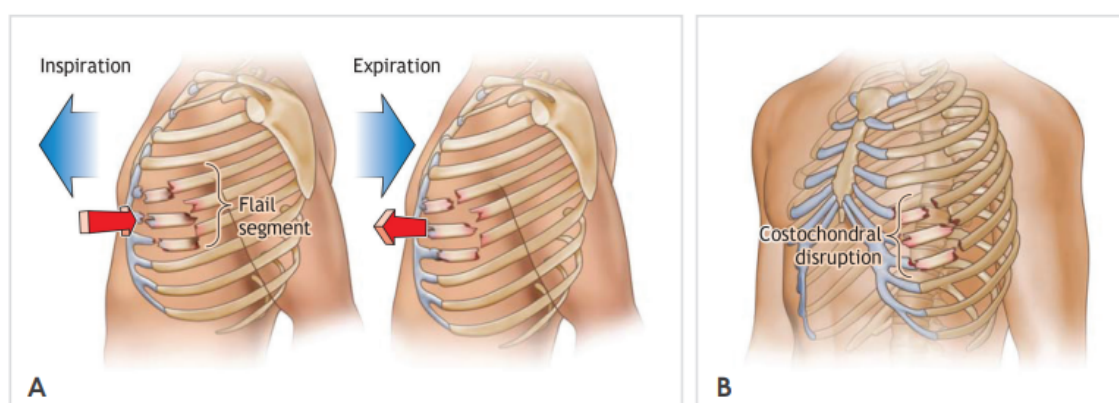


Figure 4 Paradoxical movement of flail chest

Flail chest, a highly morbid condition with reported mortality ranging from 10 to 20%, is defined as fractures in two or more places in three or more consecutive ribs. This injury pattern is caused by high-energy mechanism trauma (Benjamin et al., 2018) This life-threatening condition is seen when there is a loss of bone continuity of the flail segment from the rigid thoracic wall around it, due to comminuted costal fractures (at least two adjacent bifocal rib fractures) or dislocations as a result of trauma (Apampa et al., 2021) As the result of 3 or more segmented fracture, segment of the chest wall may move independently of the rest of the chest wall create paradoxical movement which can be observed clinically as we may call it a flail chest.(3,5) A flail chest can create a significant disturbance to respiratory physiology whose function is important in patients who are older or who have chronic lung disease.(3) Multiple rib fractures may allow a sizable segment of the anterior and/or lateral thoracic wall to move freely (figure 4). The loose segment of the wall moves paradoxically (inward on inspiration and outward on expiration). Flail chest is an extremely painful injury and impairs ventilation, thereby affecting oxygenation of the blood (Moore & Dalley, 2018)

Diagnosis and Management of Flail Chest

The first step in trauma assessment includes obtaining initial information of the patient, preparation of the team and equipment prior to patient's arrival. Upon arrival of the patient, primary survey which assesses airway, breathing, circulation, disability and exposure (ABCDE) should be done immediately and abnormality which is found in primary survey may be managed properly as soon as possible (Kostiuk & Burns, 2020) Once the patient has been stabilized, secondary assessment is performed (Kostiuk & Burns, 2020) For flail chest, Observation of abnormal respiratory motion and palpation of crepitus from rib or cartilage fractures can aid the diagnosis. A chest x-ray may suggest multiple rib fractures but may not show costochondral separation. Chest x-ray may be useful for assessing internal thoracic organ damage.(20) Chest trauma scoring system (Table 1) is developed to predict longer hospital stay (score >4) or increased risk for mortality, admission to ICU and intubation/mechanical ventilation (score >7) (Yeh & Lee, 2016) The traditional management of flail chest is conservative which uses ICU facilitated analgesia if needed (table 1) with rescue mechanical ventilation for chest wall integrity (internal splinting). However, surgical management with rib plate fixation begins to become another management option (Naidoo et al., 2017)

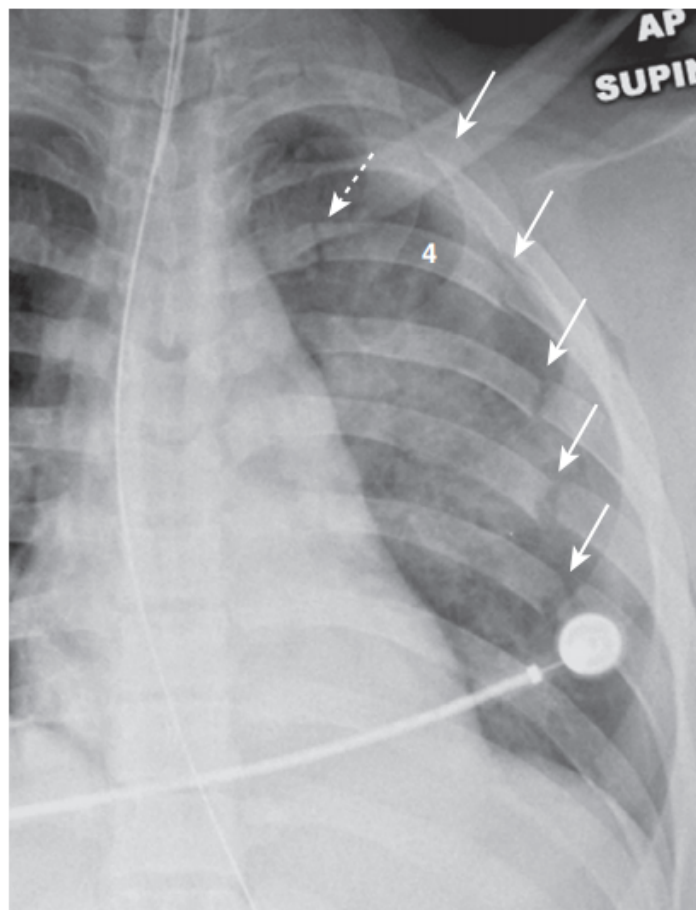


Figure 5 Flail chest on plain chest X-ray (Herring, 2007)

Table 1 Chest Wall Trauma Scoring System (Yeh & Lee, 2016)

Age (years)	
< 45	1 point
45-65	2 points
>65	3 points
Number of Rib fractures	
<3	1 point
3-5	2 points
>5	3 points
Pulmonary Contusion	
None	0 point
Mild	1 point
Severe	2 points
Bilateral	3 points
Bilateral Rib Fracture	
No	0 point
Yes	2 points
Total Score	

Flail chest is often associated with an underlying pulmonary contusion and should be supported with pain relief, stabilization of the chest wall, or even mechanical ventilation (Townsend et al., 2016). Ensuring adequate oxygenation, administering fluids judiciously, and providing analgesia to improve ventilation are important principles management in flail chest. Initial treatment of flail chest and pulmonary contusion includes administration of humidified oxygen, adequate ventilation, and cautious fluid resuscitation. In the absence of systemic hypotension, the administration of crystalloid intravenous solutions should be carefully controlled to prevent volume overload, which can further compromise the patient's respiratory status. Patients with significant hypoxia (i.e., PaO₂ < 60 mm Hg [8.6 kPa] or SaO₂ < 90%) on room air may require intubation and ventilation within the first hour after injury. (20) Choice of analgesic agent are intravenous narcotics or local anesthetic administration which avoids the potential respiratory depression common with systemic narcotics. Options for administering local anesthetics include intermittent intercostal nerve block and transcutaneous intrapleural, extrapleural, or epidural anesthesia. However, prevention of hypoxia is needed to be achieved for trauma patients, and a short period of intubation and ventilation may be necessary until clinicians have diagnosed the entire injury pattern. Careful assessment of the patient's respiratory rate, arterial oxygen saturation, and work of breathing will indicate appropriate timing for intubation and ventilation.

There are no clear guidelines which delineates indications for osteosynthesis in order to restore chest wall stability. It is justified for flail chest which causes severe deformity, and exceptionally for intractable pain (Townsend et al., 2016) In meta-analysis study, rib fixation for patient with flail chest had found to decrease mortality, shorten days on mechanical ventilation, hospital and intensive care length of stay, decrease incidence of pneumonia and need for tracheostomy (Kasotakis et al., 2017) Surgical stabilization of rib fractures has shown success in managing flail chest (Yahn et al., 2021)

Key steps for surgical stabilization of rib fractures include CT imaging (Figure 6) to choose the exact ribs for fixation, selection of optimal incision based on the fracture location, and selection of appropriate technique relevant to the type of fracture (Fokin et al., 2020).

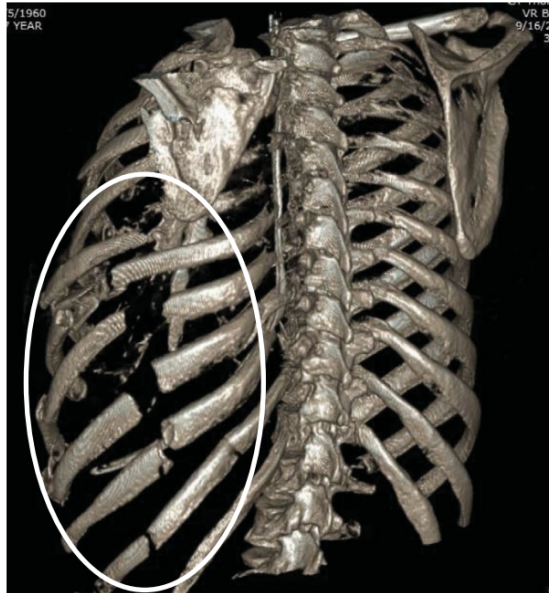


Figure 6 Flail chest on 3D CT scan reconstruction(29)

Surgical Fixation Approach



Figure 7 Key equipment in rib plating system(29)

Before doing operation, we should understand instruments used in ribs stabilization. Chest instrument set, rib fixation system, shaped ribs plate, power screw driver, screw and plate, rib reduction clamps, rib plate clamps, plate cutter and right-angle screwdriver should be prepared before procedure.(29) The patient then is positioned depends on ribs targeted for procedure. There are supine, lateral decubitus and prone position which are widely used

regarding this operation.(29) (For brief illustration of the ribs fixation, see figure 8 – figure 11).

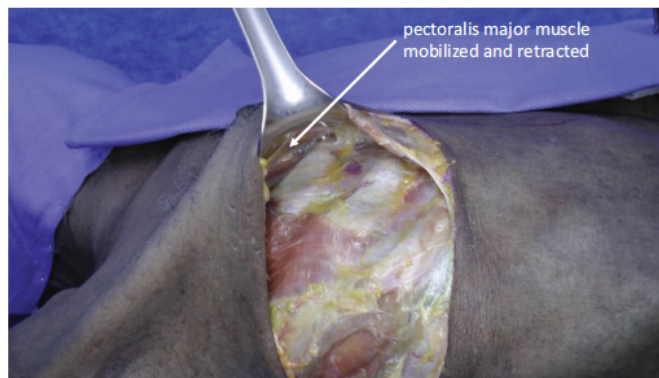


Figure 8 Incision similar to anterolateral thoracotomy is being used in supine positioning (Left); The pectoralis major muscle is mobilized posteriorly off the anterior chest wall to expose the underlying ribs (Right).(29)

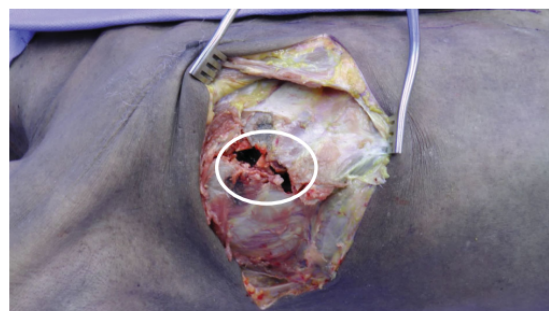
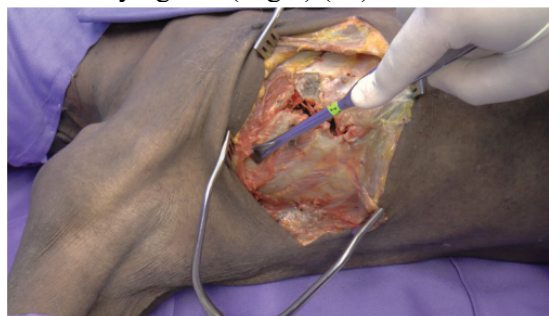


Figure 9 After mobilization of the pectoralis major muscle, the serratus anterior fibers must be cleared from the underlying ribs to be plated (Left); Anterolateral approach. Fractures of the fifth and sixth ribs (circle) are seen following mobilization of the pectoralis major muscle (Right).(29)

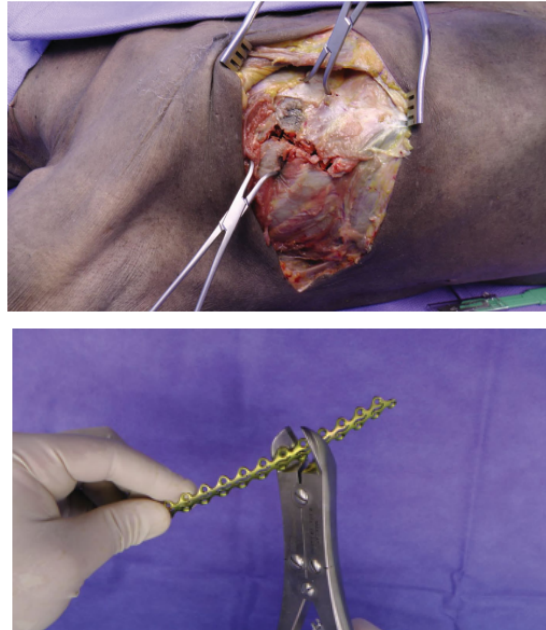


Figure 10 Reduction clamps are utilized to mobilize the ribs and achieve fracture alignment. Anterior fracture view (Left); Plates are cut to the appropriate size to fit the wound using heavy shears (Right)

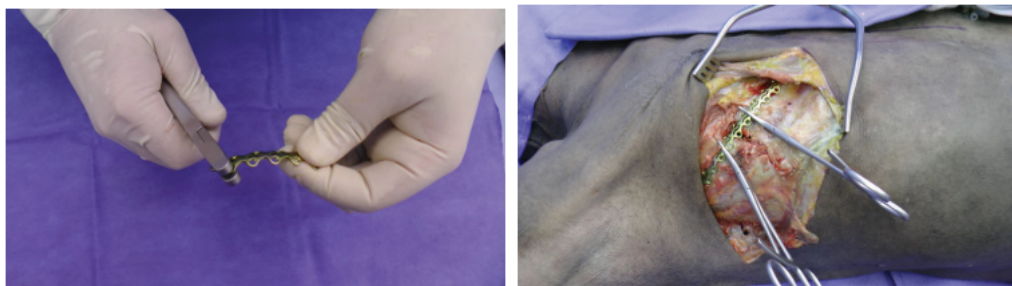


Figure 11 Plates are to be bent to fit the curvature of the rib being plated (Left); Plate clamps secure plates to rib and maintain fracture reduction (Right). (29)

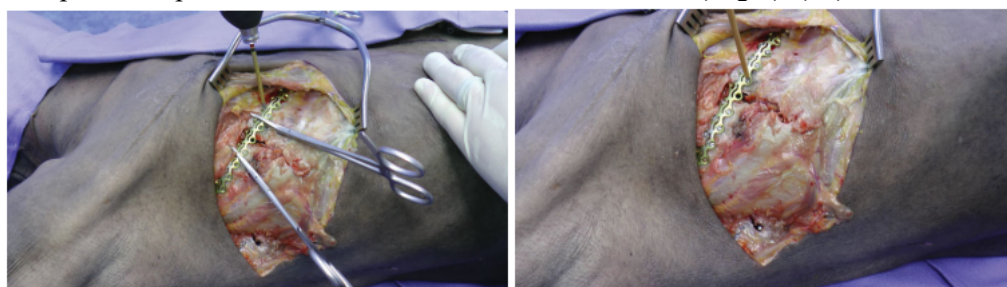


Figure 12 A power screw driver is used to place self-drilling locking unicortical screws (Left); Each screw is hand tightened to ensure locking into place (Right). (29)



Figure 13 Completed rib fixation of anterior sixth and seventh rib fractures. (29)

There are implant-related complications found after ribs fixation around 10%, wound infection 2.2% and fracture-related infection around 1.2% of the patient.(1) Silvana et al., 2022 found that rib fixation procedure when was done in non-flail, non-ventilator dependent ribs fracture had no improvement in pain and even had no different quality of life in 3 or 6 months compared to non-operative management (Marasco et al., 2022). This shows rib fixation procedure should only be done when indicated or when ribs fracture was severe enough (like flail chest). The timing of the rib fixation is also important. This was proven by Prins et al., 2021 who found optimal time to perform surgical stabilization of rib fractures was less than 48-72 hours in which period was associated with improved in-hospital outcomes (Prins et al., 2021).

CONCLUSION

From the results of research and discussion concluded that early surgical stabilization of rib fracture has better outcome in the cases of ribs fracture which are severe enough.

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