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*Research Article*

# Surgical Rib Fracture Fixation with Metal Titanium Plates May Improve Patient Outcomes

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### *Abstract*

***Background:*** *Rib fractures are the most common traumatic injuries of patients with thoracic trauma. In this regard, flail chest is associated with poor outcomes due to a higher incidence of pulmonary complications. The introduction of rib-specific plate options has caused increased interest in surgical fixation. We present the experience of the use of MatrixRIB titanium ribs plates for 7 years, by the same surgical team, at different centers in Uruguay.*

***Methods:*** *We carried out a retrospective observational study in selected patients treated with surgical stabilization of rib fractures, in different institutions, between 2011 and 2018. We accessed and retrospectively reviewed the treatment of 22 patients in total. Data collected included age, sex, mechanism of injury, number of fractures, length of stay in Intensive Care Unit and hospital, complications, associated lesions, and surgery procedure specifications. The statistical software used was IBM® SPSS® Statistics V25.*

***Results:*** *22 patients were analyzed. Lung contusion was present in 8 patients (36%), and all of them required Intensive Unit Care admission, flail chest was present in 11 patients (50%), and the remaining 3 patients had more than 3 rib fractures. 18 patients had hemothorax as an associated chest trauma lesion (81.8 %), 1 had empyema (4,5 %), 14 had pneumothorax (63.6%), and 17 patients (77%) required a pre-operatory chest drain placement. Our series had 12.9 days mean duration of mechanical ventilation.*

*The reparation ratio (rib repaired/rib fractured) was 0:51, with 199 rib fractures and 101 fractures repaired. The most commonly used approach was classical posterolateral incision. The mean time to surgery was 8.27 days (minimum 1 day and maximum of 45 days). The mean time of the surgical procedure was 137 minutes (ranging from 90 to 180 min, SD 32 min). We found an 8.7% mortality rate after surgical stabilization (1 patient).*

*The mean length of stay at the hospital in patients with surgical treatment was 23 days, and the time between trauma and surgery 8.2.*

***Conclusions:*** *Rib fractures are a common cause of morbidity and mortality in chest trauma. Correct evaluation and timely fixation can lead to improvement in patient outcomes and reduce hospital stay.*

***Key words:***

*Chest trauma, Rib fracture, Flail chest, Surgical stabilization.*

## Introduction

Rib fractures are the most common traumatic injuries found in 20% of patients with thoracic trauma (85% in blunt trauma). These are responsible for the loss of several working days, and could continue to affect patients several months after the trauma[1]. In this regard, flail chest is associated with a poor outcome due to a higher incidence of pulmonary complications.

For the last half-century, the treatment of these injuries, starting with chest-wall traction and external stabilization methods, up to the internal pneumatic splint using positive mechanical ventilation, was the standard of care in several centers throughout the world[2]. This remained the case until the introduction of rib-specific plate options, which caused increased interest in surgical fixation, despite its high cost, chiefly in undeveloped countries.

Underestimated most of the time, rib fractures are extremely common following blunt thoracic trauma. Even isolated rib fractures are erroneously considered as a minor disorder. Some authors define two parameters influencing mortality and morbidity: more than 4 rib fractures, and patients aged over 45 years[3]. When both factors are combined, there is a significant increase in mortality and in complications such as pneumonia. The effects of multiple rib fractures are related to pain and instability of the chest wall, both leading to poor ventilation and inefficient cough with mucous retention, which could be followed by infection and pulmonary distress. Stability of the chest wall reduces pain and improves respiratory dynamics, which allow efficient cough and correct clearance of secretions, thereby leading to decline in mortality and morbidity. Along with treatment for chest wall stabilization, the duration of Intensive Care Unit (ICU) and hospital stay also need to be shortened[1,4], in order to enhance the patient's quality of life post trauma and enable a faster return to daily activities[5].

In this regard, one of the most important studies was conducted by Pieracci et al., which included a prospective, 2-year clinical evaluation comparing surgery versus conservative treatment. They examined patients having flail chest, rib fractures with bi-cortical displacement, hemothorax, and severe respiratory failure. The authors concluded that surgical fixation improved acute outcomes, when compared to medical management[6].

Titanium is one of the most bio-compatible, corrosion-resistant and robust materials, which can be used in humans. Titanium implants are expected to facilitate healing and restore the mechanical characteristics of the ribs, minimizing migration, fissures, or material release. Currently, different types of rib implants are available. In Uruguay, we have plates and screws like the Matrix RIB ™ (DePuy Synthes ™) system, which provide excellent stabilization. These plates can be curved to allow a precise contour and cut to fit the required length. The plate design allows for uniform stress distribution, immobilizes the fracture site, and can be used on multiple fragmented bones.

We present the experience of the use of Matrix RIB plates for 7 years, by the same surgical team, at different centers in Uruguay.

**Study Design**

Our group started performing surgical stabilization of rib fractures (SSRF) in 2011, in selected patients, who met at least one of the following criteria: inadequate pain management, chest wall instability causing respiratory failure,

rib fractures resulting in chest wall deformity, impaired pulmonary function due to multiple rib fractures, non-union or mal-union of rib fractures, mandatory thoracotomy due to other reasons, and impalement of ribs into pulmonary parenchyma, other solid organs (e.g., hepatic or splenic parenchyma), or diaphragm.

The exclusion criteria for performing SSRF included: respiratory failure due to causes other than pain, severe pulmonary contusion, major concomitant injury in other body regions (chiefly brain contusion), patients who would not tolerate or benefit from surgery due to compromise of their physiological state, and single rib fractures.

The number and location of rib fractures were extracted from three-dimensional computed tomography reconstructions. These pre-operative CT reconstructions were deemed essential to plan the surgical approach (Figure 1).

We are a single group, which performs this procedure in different institutions, using the same rib stabilization criteria, via a thoracotomy incision positioned over the most severely displaced fractures, trying to repair all fractures that can be accessed through this approach, either a vertical or posterolateral incision.

Between 2011 and 2018, our group performed 45 rib-fracture stabilization surgeries on trauma patients. We accessed and retrospectively reviewed the treatment of 22 patients with SSRF; some patients could not be reviewed as the institution refused to share the patient information.

Data collected included age, sex, mechanism of injury, number of fractures, length of stay in ICU and hospital, complications, associated lesions, and

surgery procedure specifications.

The categorical variables were expressed as absolute value and percentage; while the continuous variables were reflected as mean and standard deviations (SD). The statistical software used was IBM® SPSS® Statistics V25.

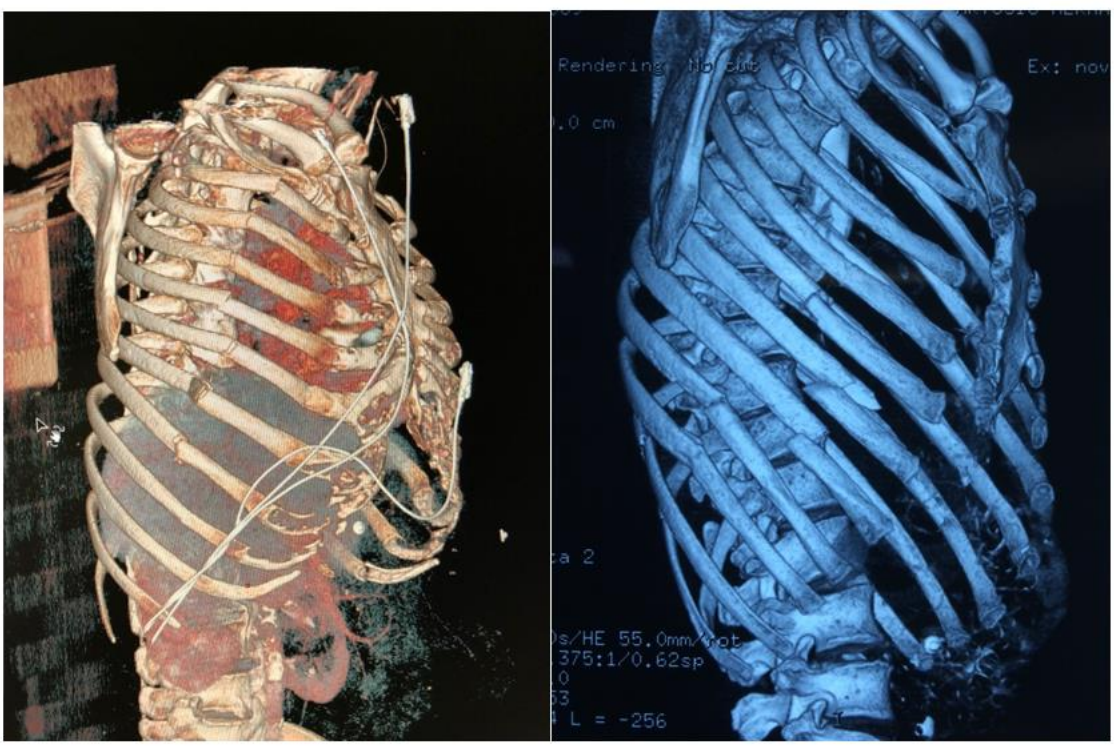

**Fig 1.** 3D CT to evaluate rib fractures number and localization

## Results

22 patients were analyzed, with a mean age of 54 years (ranging between 25 to 86 years old); 16 were male patients. Rib fractures were due to multiple causes that included motorbike crash (7), car crash (7), fall from height (6), and others (2) (Table 1). Eleven patients required ICU admission, with a mean length of stay of 15 and 7 days (ranging from 4 to 40 days), of which 10 required mechanical ventilation due to respiratory failure, and others due to inadequate pain management (Table 2)

Lung contusion was present in 8 patients (36%), and all of them required ICU admission (Table 3).

Flail chest was present in 11 patients (50%) who required chest stabilization, and the remaining 11 patients had more than 3 rib fractures (in total mean rib fractures stood at 5,7, with SD 2 ,2).

Associated lesions included 2 diaphragmatic injuries (9%), 1 sternal fracture (4, 5%), 1 myocardial injury (4, 5%), 2 vertebral lesions (9.1%), 2 on liver (9,1%), 4 on spleen (18, 2%), 7 associated upper-limb fractures (31, 8%), 4 lower-limb fractures (18, 2%) (Table 3).

With regard to associated chest trauma lesions, 18 patients had hemothorax (81.8%), 1 had empyema (4, 5%), 14 had pneumothorax (63.6%), and 17 patients (77%) required a pre-operatory chest drain placement (Table 3).

The reparation ratio (rib repaired/rib fractured) was 0:51, with 199 rib fractures and 101 fractures repaired. The mean time to surgery was 8.27 days (minimum 1 day and maximum of 45 days) (Table 4).

Considering that the mean time of the surgical procedure was 137 minutes (ranging from 90 to 180 min, SD 32 min), we used 60 ribs plates and 30 intramedullary splints, in order to repair 101 fractures. The most commonly used approach was classical posterolateral incision (20 patients) (Figure 2).

We found an 8.7% mortality rate after surgical stabilization, one related to cardiogenic shock and the other one due pulmonary infection. Duration of mechanical ventilation (DMV) mean time were 12.9 days (between 4 and 26 days). The mean length of stay at the hospital was 23 days.

Pneumonia was the most frequent complication (13.6%) in ventilated patients, all of them with pulmonary contusion. No wound infections or hardware disruption were found.

**Fig 2.** Incision Approach

**Fig 3.** Rib repaired with plates or intramedullary splints

Demographic distribution

| | | n | % |
|---|---|---|---|
| Sex | Male | 16 | 72,7 |
| | Female | 6 | 27,3 |

| | Min | Max | Med |
|---|---|---|---|
| Ages | 25 | 86 | 54 |

| Type Accident | Absolute | % |
|---|---|---|
| MotorBike | 7 | 32% |
| Car | 7 | 32% |
| Fall off | 6 | 27% |
| Others | 2 | 9% |
| Mortality | 2 | 9% |

**Table 1**. Demographic distribution of rib fractures

| Days to | Min | Max | Mean | SD |
|---|---|---|---|---|
| days to surgery | 1 | 45 | 8,2 | 9,4 |
| hospitalized days | 4 | 61 | 23 | 14 |
| Mech vent days | 4 | 26 | 12,9 | 6,2 |
| ICU stay | 4 | 40 | 15,7 | 9,7 |

**Table 2.** Mean time to surgery and hospital stay

| Associated injuries | n | % |
|---|---|---|
| Hemothorax | 18 | 82% |
| Neumothorax | 14 | 64% |
| Flail chest | 11 | 50% |
| Lung Contution | 8 | 36% |
| Upper Limbs fractures | 7 | 32% |
| Spleen | 4 | 18% |
| Lower Limbs fractures | 4 | 18% |
| Diapragm | 2 | 9% |
| Spine fracture | 2 | 9% |

| | | |
|---|---|---|
| Liver | 2 | 9% |
| Pelvis fracture | 2 | 9% |
| Sternum fracture | 1 | 5% |
| Myocardial Contusion | 1 | 5% |
| Emphyema | 1 | 5% |

| Associated procedures | n | % |
|---|---|---|
| Previous Chest drain | 17 | 77% |
| Laparotomy | 2 | 9% |
| Upper or Lower limbs surgery | 3 | 14% |

**Table 3.** Associated injuries and treatments

| Type fracture | Min | Max | Mean | SD |
|---|---|---|---|---|
| simple fractures | 0 | 10 | 2,7 | 2,7 |
| double fractures | 0 | 18 | 6 | 5,2 |
| used plates | 1 | 6 | 2,8 | |
| used intremedullary | 0 | 6 | 1,45 | |
| ribs repaired | 2 | 10 | 4,73 | 2,1 |
| | | | | |
| | Minutes | Minutes | Minutes | Minutes |
| surgical time | 90 | 180 | 137 | 32 |

**Table 4**. Rib fractures types and repair method

## Discussion

Before the advent of the 21st century, non-operative treatment for severe thoracic trauma with associated rib fractures was the standard of care. This conservative treatment included aggressive respiratory therapy, prolonged mechanical ventilation, multiple analgesia procedures for pain management, and physical therapy, thereby increasing the duration of and costs related to ICU stay.

At this point, this “conservative” treatment could lead to non-union fractures, chest wall deformity, reduction in lung volume, chronic pain, or respiratory impairment, all of which could appear soon after trauma.

By the beginning of the century, multiple new rib-fixation devices were developed, reducing cost and increasing availability worldwide.

There is a lot of evidence, which supports that SSRF has had a significant impact on patient outcomes in thoracic trauma. SSRF reduces pain, inflammation, bleeding, and synarthrosis. On the other hand, SSRF allows correct drainage of pleural space, repairs lung injuries, and enables insertion of an analgesic catheter under direct vision.

The primary outcome is related to mortality and mainly addresses early mortality, within 28 days. The secondary outcomes are described as follows: duration of invasive mechanical ventilation, ICU LOS, hospital LOS, pneumonia, wound and hardware complications, need for tracheostomy, post-operative pain and long-term effects such as chronic pain, chest wall deformity, quality of life (QoL) and the return to employment. Cost analyses have also been carried out.

Ribs from the 3$^{rd}$ to the 10$^{th}$ are usually repaired surgically, and there is no consensus regarding stabilizing fractures without displacement. Also, due to favorable access, ventral and lateral fractures are preferred, with only one fixation per rib to convert a flail segment into a simple fracture[7]. However, Marasco et al. reported that displacement of posterior segments could be observed over time. We tried to repair all the fractures that could be accessed, even the second and the lower ribs, but we did not try to stabilize posterior rib fractures.

One of the most important aspects of the outcome is related to mortality. At this point, there is almost a complete consensus that the surgical approach significantly reduces mortality rates.

Olland et al. reported that 132 patients were treated with surgical fixation, which included both flail and no flail chest cases, as in our study. They reported an overall mortality rate of 3.8%, related to associated trauma (abdominal or cranial trauma)[3]. The reduction in mortality rates from 30% to 8% is more evident, which is attributed to operative stabilization of rib fractures versus non-operative treatment, in some reports[8].

In this study, we found an 8.7% mortality rate after surgical stabilization, one related to cardiogenic shock in an 85-year-old patient and the other due to pulmonary infection. Both occurred at the initial stages, following which we improved our surgical indications. This high rate could be attributable even to a small number of patients.

There is a significant reduction in the duration of mechanical ventilation (DMV) in patients surgically treated compared to non-surgical management. Olland et al. reported a mean of 8.3 days of mechanical ventilation, and that a high percentage of patients were weaned from ventilators in the first 24 hours. Tanaka et al.

conducted a randomized controlled trial of surgical stabilization versus internal pneumatic stabilization, demonstrating a significantly shorter duration of mechanical ventilation in the surgery group (10.8 vs 18.3 days)[9]. Our series had 12.9 days mean DMV (minimum 4 days, maximum 26 days), which was non-related to pulmonary contusion or other sites of trauma. In our country, we don't have a protocol for performing tracheostomies, hence it is not a regular practice, and this could be a reason for prolonged DMV.

Length of stay at the hospital (LOS) is an important factor in reduction of costs. Most metanalysis and reviews demonstrated a significantly shorter hospital LOS in cases of surgery, when compared to non-operative management on flail chest, but showed no difference in case of simple rib fractures10. In our series, the mean LOS in patients with surgical treatment was 23 days. But in patients with flail chest, the mean LOS was 27.6 days, compared to 17.2 days for patients with simple rib fractures, thereby leading to a significant increase in ICU stay.

The optimal time for surgery is not well-established; some surgeons proposing delayed repair argue for a maximal period of medical therapy before surgery. Others propose an early repair, based on clinical and imaginological findings, as patient data can be used to predict medical treatment failure and decrease adverse outcomes. We agree with an early repair, within 48 hours after trauma. However, this is not always possible, due to additional trauma lesions, operating room availability, institutional policy, and patient preference. Early surgery is associated with shorter operative time, less blood loss, and improved pulmonary outcomes11. We are trying to improve the mean time of 8.2 days between trauma and surgery, as it is the only parameter that determines a reduction in hospital LOS ($p<0.001$).

With regard to pneumonia, in our series, 13.6% (n=3) ventilated patients developed this complication. All of them had a pulmonary contusion and this could be the reason for the high rate, compared to Althausen et al. who reported that only 4.5% of patients treated with SSRF developed pneumonia, compared to 25% who were managed non-operatively[8]. Ollad et al. reported an incidence as high as 30%, related to extubating delay, which was an independent risk factor for prolonged mechanical supports[3].

Only a few studies have showed the results of wound infection. Granetzny et al. reported wound infection in10% of patients who underwent surgical stabilization[12]. In our series, we did not have cases of wound infection or hardware disruption.

In conclusion, rib fractures are a common cause of morbidity and mortality in chest trauma. Correct evaluation and timely fixation can lead to improvement in patient outcomes and reduce hospital stay. Our study has several limitations due to its retrospective nature and the small number of patients. Hence, the current evidence shows surgical stabilization to be safe and effective improving postoperative pain and patient recovery. However, most studies provided a low level of evidence so prospective controlled trials are necessary to confirm these encouraging results.

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