

# A contemporary view on plate fixation in thoracic wall trauma

Adrian Tulin\*, Iulian Slavu\*\*, Vlad Braga\*\*, Bogdan Socea\*\*\*, Lucian Alecu\*

\*General Surgery Clinic, "Prof. Dr. Agrippa Ionescu" Clinical Emergency Hospital, Bucharest, Romania

\*\*General Surgery Clinic, Clinical Emergency Hospital, Bucharest, Romania

\*\*\*"Sf. Pantelimon" Clinical Emergency Hospital, Bucharest, Romania

Correspondence to: Slavu Iulian

General Surgery Clinic, Clinical Emergency Hospital, Bucharest,  
8 Calea Floreasca Street, code 014461, Bucharest, Romania  
Mobile phone: +40752 596 675, E-mail: iulian.slavu@yahoo.com

## Abstract

Flail chest in a trauma patient presents itself with a number of problems. The mainstay treatment in the past was analgesia with non-operative observation but due to the increased rate of complications, new treatment modalities have been researched. Chest wall plate fixation has emerged as the go-to solution for these patients but consensus lacks regarding when it should be applied, to what category of trauma patients, which technique and which surgical specialty should be the promoter of this technique. All these problems have arisen due to the lack of large prospective studies. A number of these studies are ongoing with results to be published in the near future. Until then, preliminary data have demonstrated the superiority of plate fixation in flail chest in comparison with the non-operative management.

Keywords: rib fracture, trauma, flail chest, surgical treatment

## Introduction – general aspects regarding the notion of a flail chest

The rib cage fully fulfills the protective role of viscera in trauma by the fact that nearly 39% of the patients with thoracic contusions also have costal fractures [1].

It has been shown that the main mechanisms by which the fractures of the ribs occur during a trauma are the bending and shearing forces that give rise to the most frequent type of fractures with an oblique and short path [2]. The association of a single costal fracture in a traumatized patient has an unexpectedly important impact on mortality, which is placed at values of 4 times greater than

in a patient without costal fractures. Mortality experienced another significant increase when 4 or more concomitant costal fractures were observed [3].

It is true that the majority (58%) of these fractures involve a single rib that does not require any special treatment [4]. In general, if an impact has had enough energy to cause a costal fracture, generally there are other associated injuries such as lung contusions, heart contusions, hemopneumothorax. Patients with a flail chest, associate an important morbidity, and mortality, which is usually secondary to respiratory distress.

A flail chest can be considered engaged when the diagnosis is confirmed radiologically

but there are no paradoxical movements and can be considered non-engaged when the chest wall associates paradoxical movements. In most cases of thoracic trauma, pulmonary contusion usually leads to respiratory distress but pain also contributes to the already present respiratory disorders generating atelectasis. In these patients, pain control should not be neglected because it significantly affects the biomechanics of respiration.

Mortality in patients with post-traumatic flail chest is as high as 33%. These patients require special attention [5]. Although various methods of surgical treatment of flail chest exist and have been practiced in the past, clear indications that can be supported by arguments through large prospective high-quality studies are lacking.

A flail chest leads to instability of a segment of the chest wall. It is defined as the fracture of three or more consecutive ribs in two or more places (anterior, lateral, or posterior ribs, sternum), which give rise to a segment of the chest wall that moves independently during the respiratory act [6].

Also, a flail chest can arise from the existence of more than three consecutive bilateral rib fractures that also associate a sternum fracture as they also give rise to an independent chest wall segment [7].

Mainly, the diagnosis of the flail chest is made clinically; when it is not engaged, one can identify the paradoxical movements of the affected chest segment. In the rest of the situations, radiological investigations represent the go-to evaluations. Chest radiographs are easy and quick to perform, have low costs but due to organ overlap, the multitude of aspects that a fracture line has the incidence of diagnostic error is as high as 10% of the cases [8].

Also, it should not be ignored the fact that these patients are polytraumatized and frequently have lesions of other organs such as cardiac contusions, pulmonary contusions or diaphragm ruptures that cannot be identified

by radiology. In these situations and especially when one considers a surgical intervention in the case of a patient with a flail chest, a CT- investigation should be performed, which allows the clinician to evaluate the full extent of the traumatic lesion. Spiral-CT is ideal [9].

This article aims to offer a modern view of the indications and limits of plate fixation in thoracic wall trauma.

## Flail chest treatment

Although the flail was recognized as a separate surgical entity in a trauma patient, initially the treatment was performed by a non-operative approach that used a system of pulleys and external traction of the chest wall, which limited the paradoxical movements but forced the patient to remain in a fixed position for long periods, thus giving birth to other complications [10].

Due to the multitude of problems created by these severe traumas, there has been an increased interest in solving this traumatic complication. Initially, the surgeons' enthusiasm was increased for external fixation of the affected chest segment. But as technology evolved, newer and improved mechanical ventilation devices were developed, so ventilation with positive pressure established itself as the standard treatment [11].

The use of positive ventilatory pressure as a single non-operative treatment has shown limitations mostly related to the long periods of intubation. Also, the dynamics of the breathing meant that in some cases with severe coastal injuries, the newly formed callus gave birth to a deformed rib or ribs which produced chronic respiratory biomechanical disorders. Also, chronic pain and the aesthetical aspect played an important role in the research of the new and better treatment modalities [12]. Long periods of intubation affect the respiratory tract but are also the source of important and hard to treat pulmonary infections [13]. Multiple clinical studies have shown that these patients have

a significantly increased risk of developing pulmonary atelectasis and deformities of the bony structure of the rib cage [14].

All of these changes translate into chronic pain and breathing disorders that limit the ability to sustain physical exertion and decrease the quality of life of the patient.

As the physiology and biomechanics of respiration were understood, the way in which the healing of the pulmonary parenchyma evolves after chest/ lung contusions is achieved, has caused the interest for external fixation devices to increase. As it often happens in medicine as in daily life, history repeats itself, so, since the 1990s, the role of external fixation devices coupled with positive pressure ventilation has been intensely studied and multiple studies have been published [15].

The preliminary results were encouraging, but nowadays there no widespread application of this type of treatment [16]. There are a number of factors that have led to this moment: the lack of prospective comprehensive studies and the lack of standardization of the optimal method of treatment depending on the type of injury. Also, there is no consensus on what specialty should be responsible for this treatment. Thoracic surgery can be considered a border surgery to which the thoracic surgeon is well acquainted with the local anatomy and structure of the rib cage, so it is logical that he should assume this role. However, the general surgeon frequently enters the thorax for a variety of reasons that can be considered as an option [16]. Also, the trauma surgeon or the orthopedic surgeon who are better acquainted with the technical fixation equipment can perform this intervention. Regardless of the specialist, the physician must have knowledge of the local anatomy, the technical equipment used and the steps of the procedure through which the treatment is achieved.

In conclusion, there is no clear indication for a single specialty to perform this procedure but it is imperative that the person practicing it can resolve any possible complications

that may occur. This procedure should not be performed by inexperienced surgeons in first-level hospitals.

Regarding the operative moment, it is recommended that the procedure is practiced in the first three days after the accident; an extension of the operative moment over two weeks involves an increase in the risks of surgery such as the development of ARDS or lung infections [17].

## Type of plates and plate fixation

The fixation of the rib fractures with metallic plates is recommended in the case of the patients diagnosed with a flail chest. A high priority should be given to the patient who also requires mechanical ventilation with positive pressure. The use of other criteria as indicators of surgery such as pain indices is not recommended due to the subjectivity of this score and the fact that it cannot always be obtained, as the majority of these patients require sedation and mechanical ventilation [18]. One of the first comparative studies on the effectiveness of surgical flail chest fixation to internal fixation belonged to Tanaka [19]. The team compared two groups of patients with traumatic flail chests and the results were clear in favor of surgical fixation. Tanaka identified a reduction in the incidence of pneumonia from 90% in the group with mechanically ventilated patients to 21% in the group with patients with surgery. A relatively recent study belongs to Prof. Marasco S., conducted in Melbourne, which also investigated comparatively two groups of patients treated either by positive pressure mechanical ventilation or positive pressure mechanical ventilation and surgery, which also confirmed a faster social reintegration of the patients with surgery and an overall reduction in pneumonia rates from 74% to 48% [20].

Although varied, modern plates used in securing the fractured ribs, all contain a semi-rigid fastening mechanism made of self-

tapping plates and auto-locking screws. Screws are essential due to the high dynamics of the ribs during movement. It is also important that the thickness of the plates is as small as possible to give a better aesthetic appearance.

Regarding the procedure itself - multiple types of plates have been developed, each with its own indications, advantages, and limits. Still, two types are mainly used: claw-type titanium plates, which are anchored around the fractured rib and plates with auto-locking screws.

Also, there is an investigation on plates made of a resorbable material, the authors of this method mentioning among the advantages that due to the fact that they are made of a material more resistant than the bone the classic metal plates produce a delay of the healing process by delaying the appearance of the bone callus. A less rigid plate allows the bone as it heals to take over some of the tensile forces, which in turn speed up the healing process and bone resistance. Another advantage is that they do not require an extraction [21].

However, there is a set of rules that must be followed until the plate is fixed, rules that are general and must be respected in every procedure. Preoperatively, the exact location of the fracture will be identified and a line will be drawn that will represent the future incision which should be on the middle of the rib. After the incision, a number of elements need to be identified that require protection, especially the vascular and nerves bundles, which are located on the inferior rib margin, the intercostal muscles. Attention should be given to the coastal periosteum, which needs to be protected during dissection. Muscle resection should be kept to a minimum. The surface of the periosteum that requires exposure is approximately 5 cm long, 2.5 cm on each side of the fracture to allow a correct and efficient application of the plates. All fractured ribs do not require mechanical fixation, the first and second rib do not play an essential role in the

ventilation mechanics, also their dissection is quite delicate due to the vascular structures at this level so routine repair is not recommended. Also, the last floating ribs in case of fracture do not require surgical treatment.

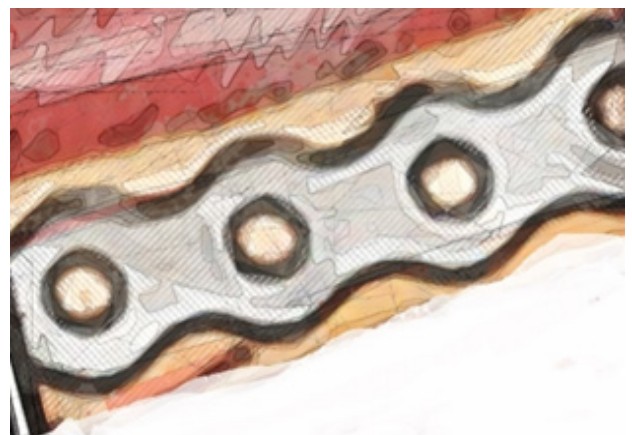
The advantage of the claw-type plates is that they are made of titanium, which translates into fewer artifacts at MRI and CT (Fig. 1).



*Fig. 1 Claw-type plates*

The alloy from which they are produced makes them biocompatible so no surgical reintervention for extraction is required. The fastening mode is also practical and quick by anchoring around the rib and can enclose multiple fracture segments.

If plates with auto-locking are used, bi-cortical screws are required that completely cross the thickness of the rib or more modern unicortical have also demonstrated well tolerance (Fig. 2).



*Fig. 2 Aspect of the plate and screw fixed on the rib*

Some authors recommend that the surgery should be associated with VAT (video

inspection of the thoracic cavity) that allows the exploration of the chest cavity without a large incision, thus allowing the identification of possible bleeding sites or additional lesions omitted during the operative investigations. VAT has already been shown to be useful in diagnosing and staging of lung cancer and in staging of esophageal lesions.

Regarding the costs of this technique, Swart et al evaluated it in comparison with mechanical ventilation. Among the variables introduced in the analysis, the following should be mentioned: the average length of hospitalization, the average length of stay in the intensive care unit, the rate of development of pneumonia, as well as the necessity of a tracheostomy. The conclusion was that the surgical fixation of rib fractures represents a cost-effective method of treatment compared to the simple mechanical ventilation (22).

In conclusion, the treatment of a trauma patient with a flail chest is complex and requires a multidisciplinary approach. Fast diagnosis and primary treatment such as analgesia and positive pressure ventilation are of utmost importance for survival. Surgical fixation of the flail chest has taken the leading role as it decreases the rate of pulmonary infections, lowers the duration of ICU admission, decreases the overall hospital time, and costs when compared to internal fixation. Surgical fixation also affects the long-term prognosis of these patients as it decreases post-traumatic pain and chest deformities. Although multiple solutions are offered in terms of the devices, critical surgical steps should be followed. Time will tell which the optimal technique is.

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### Conflict of Interest statements

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