ARTIGO DE REVISÃO REVIEW ARTICLE

CHEST WALL TRAUMA SURGERY – REVIEW

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Abstract

Rib fractures are frequent in trauma patients, being most of them managed on a non-surgical way. However, in selected cases, it is advocated.

Chest wall stabilization (CWS) only recently has been best characterized.

Available data shows plenty of benefits related to CWS versus non-surgical treatment in selected cases. Even though, it is only performed in a small number of patients according to some national databases.

There are lots of topics to define concerning CWS such as the subgroups that benefit most, the time of surgery, which ribs should be stabilized and which incision should be performed. Most of these subjects need to be tailored for each patient.

So far, no guidelines for CWS are available, although some algorithms have been proposed based on a combination of clinical experience and risk factors.

In high-volume trauma centers it has become a common procedure. The complexity of some cases demands a careful evaluation, especially in the context of multiple injuries, and it should be taken into account in the decision.

INTRODUCTION

Rib fractures are frequent in trauma patients accounting up to 39% of blunt chest trauma and are present in 10% of all trauma admissions.[1]

Sternum fractures are rare, corresponding only to 1% of all fractures and mostly associated with high energy blunt trauma, with an incidence between 3-8%.[1,2] These fractures are also seen in low-energy trauma, especially in older patients since the introduction of seatbelt regulations.[3]

Even so, there are much more trauma patients than those that actually are enrolled for surgery. Most patients are treated non-operatively.

There are no guidelines for CWS but a few interest groups have their own recommendations based on personal experience.

To date, only three randomized clinical trials (RCTs) and three meta-analyses of these and another trial have compared surgical stabilization of rib fractures (SSRF) with best medical management in those patients. Although these trials have favored the SSRF, the number of patients in each trial was low and all limited they focus to flail chest injuries due to its severity, and their conclusions and recommendations were not unanimous.[4,5]

They showed a reduction of the need and duration of mechanical ventilation, decreased incidence of pneumonia, less pain, shortened ICU and hospital length of stay, earlier mobilization, faster return to active life and decreased use of narcotics in this population when early surgical intervention was performed.[4,6]

Flail chest is a clinical diagnosis characterized by paradoxical movement of a portion of the chest wall due to fractures of two or more consecutive ribs in at least two places. It is responsible for high morbidity and mortality, which can reach 9-16%. It is frequently associated with acute respiratory failure related with inefficient ventilator mechanics, underlying pulmonary contusion and subsequent pneumonia.[1] Long term consequences are chronic pain, deformity, disability and loss of quality of life. Although these are well known severe outcomes, treatment options are still poorly defined. Even with data favoring SSRF, only a small number of patients actually had surgery as treatment of choice. Data from Canada's National Trauma Bank showed that between 2007 and 2009, only 0,7% of flail chest injury patients were treated with surgical fixation of the chest wall.[1]

The most recent promising results of SSRF in flail-chest, the higher interest in application of techniques in patients with multiple rib fractures non-flail chest and, of course, the lack of data supporting the benefit of SSRF in those subset of patients, lead the Chest Wall Injury Society to create a multicenter randomized control trial which will try to establish indications for chest wall stabilization in patients with non-flail rib fractures.

WHEN IS THE RIGHT TIME TO OPERATE?

Trauma patient as a complex patient

Many researchers support intervention within a few days of the initial trauma. It is assumed that early intervention can reduce the deleterious effect of inflammation, severe hematoma, clotted hemothorax, empyema, rigidity with deformities of the chest wall, and early callous formation.[5]

But frequently the patient with rib and/or sternum fractures is a multi-traumatized patient. Brain, spine and bowel injury are commonly associated. Chest wall stabilization can and should be delayed until other injuries are treated, and even then its benefits can be seen.[6]

Patients with rib fractures and head/brain trauma are often in coma or sedated with the need for mechanical ventilation. In this kind of patients, the benefit of the SSRF when done precocious can't be seen. But after brain function has recovered and they are weaned from the ventilator, SSRF will help to reduce the need for sedation and analgesia, shorten the time needed for ventilation.[6]

Patients with spinal injury usually need long bed rest. SSRF can help to relieve pain, promote effective cough and so reduce respiratory complications caused by prolonged immobilization.[7]

Pulmonary contusion is present in 30% to 75% in patients with blunt chest trauma.[7] For years, patients with pulmonary contusion and rib fractures where not elected for surgery, in fact, it was thought that surgery was associated with poor outcomes. Pulmonary contusion evolves in 48 to 72 hours. Nowadays many groups consider that those patients benefit from surgery but the time of surgery still isn't well defined. Some considered operation only after the peak of contusion to avoid its effect on lung function and its negative influence in anesthesia.[1] Others, described the operation intervention within 72 hours of injury, and ideally within 24 hours of the injury.[5,8] In fact little data exist about the time of operative fixation in the setting of pulmonary contusion. There is a need to clarify the concept of lung contusion, its severity and its influence on the time of SSRF.

The impact of multiple injuries must be always carefully evaluated and taken into account in decision of CWS.

Potential indications for surgery

Reports reveal that the most concordant indication for CWS is uncontrolled acute pain even when treated with the best possible management, which was in 2012 considered by the Eastern Association for the Surgery of trauma the epidural or paravertebral analgesia.[9] There are an increasing number of studies using pain relief as the main indication for SSRF.

Chronic pain and disability is also a main concern. Chronic non-union is defined as a lack of bone healing nine months after injury. Fractures that have not healed within 3 months have been defined as delayed union. It can occur in 5-10% of the cases and mostly remain symptomatic.[10] Symptoms include persistent pain and a clicking or a motion sensation, and is exacerbated with cough, sneezing and exercise.[5,10]

Table 1 **Potential general criteria for CWS**

3 or more rib fractures with rib displacement of more than 1 rib cortical diameter
Flail chest
Severe non-union, loss of continuity or deformity of the sternum
Uncontrolled acute or chronic pain
Intubation/ mechanical ventilation dependent of CW deformity
Lung impalement
Open chest deformity
Pulmonary herniation
Stabilization on the retreat of thoracotomy
Symptoms associated with non-union

Table 1 resume a few indications for rib and sternum fixation.[7,11]

Considering age, it seems like the older ones are those who most benefit from CWS. When comparing outcomes of surgical and nonsurgical treatment in patients with age over 65 and with more than one rib fracture, those submitted to SSRF had less respiratory complications and mortality.[8]

In fact, some papers associate age of 65 years or older and the number of rib fractures with the outcome. Mortality increases in this population depending of the number of rib fractures.[12] Even if there's this kind of evidence, the selection of patients based on this criteria for CWS isn't easy and different groups use different patient age cut off.

There's no doubt that several variables must be taken into account when choosing patients to CWS. Those mentioned above are some of them.

When should surgery be performed?

The challenge in performing rib fractures stabilization is to define which fractures must be corrected, which will be the best incision(s) to accomplish our purpose with minimal aggressiveness to the patient.

PLANNING CHEST WALL STABILIZATION

Patient evaluation

Patient observation is mandatory, especially in patients with severe trauma and multiple rib fractures located in different places of the thorax. It is crucial to know if there is an important and visible deformity of the thorax, paradoxical movement, rib mobilization with palpation and specific pain location.

Sometimes this observation is not as easy as it seems. Patients can be ventilated and the effect of positive

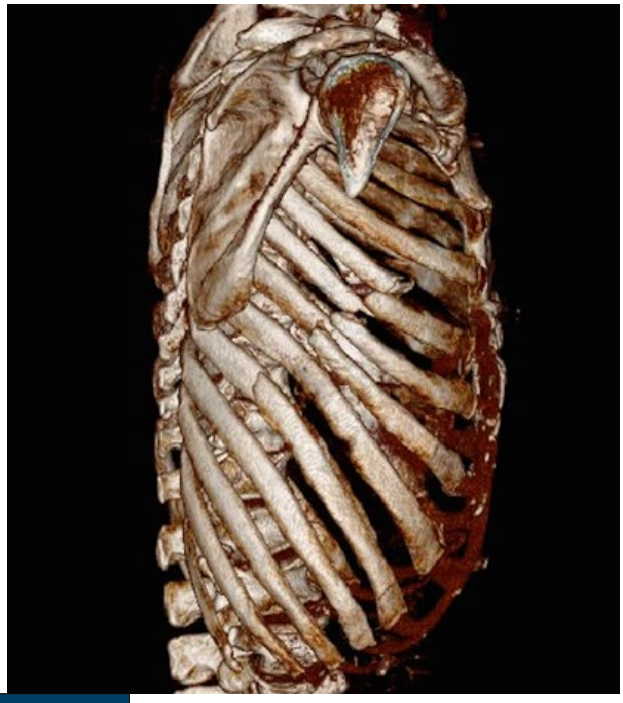

Figure 1 *Three-dimensional reconstruction CT scan of a right lateral rib fractures.*

pressure can mask the rib fractures mobility. Also, in obese patients and those with extended hematomas, palpation may be tricky.

Complementary exams and techniques

Pre-operative thorax CT scanning combined with three-dimensional reconstruction technology helps to visualize fracture location and plan surgical positioning and incision(s) (Fig.1).[13]

Ultrasound examination after anesthesia further provides more accurate information regarding the incision design, assisting in determination of rib fractures on the body surface. It can also detect fine fractures and fracture hematomas.[13]

Video-assisted thoracoscopic surgery (VATS) in conjunction with rib fixation is commonly described. It is a useful method to precisely identify the fracture sites.[13,5] One trick is marking on the surface of the body the fractures placing syringe needles that can be seen inside the thorax (Fig.2).VATS can guide the placement of the incision minimizing is length, muscle division, allowing complete evacuation of hemothorax, facilitate optimal chest tube placement, aid in fracture reduction, and rule out and repair diaphragm or pulmonary laceration.[5]

A totally thoracoscopic approach to rib fixation is possible and has been demonstrated, but its widespread application requires further development in equipment and training.[5,10,14]

Which fractures should be corrected?

A principle must be taken into account, the benefit of CWS should always be higher than the risk or damage that we can cause to the patient in surgery when attempting

Figure 2 *Using VATS for location of rib fractures.*

to correct the fractures. In multiple rib fracture injury it is not necessary fixation for all fracture sites.[10]

We have twelve pairs of ribs and they are not equivalent. They have different length, diameter and angulation, and contribute differently for ventilation.

The selection of fractured ribs to correct depends on: 1) which ribs are fractured; 2) how many ribs are fractured; 3) the localization of the fracture in the different ribs; 4) how may fractures exist in which rib; 5) which kind of fracture exists: aligned, uncoated or comminute; 6) the anatomic relationship around rib fractures; 7) how much the fractured ribs contribute to ventilation; 8) and how much pain and instability do they cause.

Ribs one and two are deep, have less mobility, little contribution to respiratory physiology and are in close relationship with vascular and nervous bundles. Unless those structures are damaged in trauma and surgery is needed, those ribs are usually not considered for stabilization, they're challenging to expose.[5,13]

Ribs from third to tenth have progressively a larger degree of motion, a higher contribute for ventilation and stability of the ribcage. When fractured, they cause more pain and can be responsible for important thorax deformity.[5,13] When fractured, those ribs are more actively treated, especially when the fracture is anterior or lateral.

The floating ribs are not critical to respiration and not easily accessible with standard muscle sparing incisions. Usually are not submitted to surgery unless responsible for liver or spleen damage.[5,13]

Antero-lateral rib fractures are easier to access but posterior fractures are much more difficult to expose because of the scapula and the incision may cause extensive muscular damage. Recent improvements in materials and techniques have helped to make this surgery less invasive. The posterior portion of the rib cage is actually more protected by these structures and so fractures located there are usually more stable and cause less pain. Posterior flail chest is difficult to evaluate, and so in these cases complementary exams can help to decide if it is necessary to SSRF.

On the left side, misaligned fractures from 5 to 9

ribs, with intrapleural tops, can drill the aorta, so SSRF is recommended.[5,13]

There is no apparent advantage to repairing "every other rib" to minimize dissection and tissue damage. Fixation of one rib, many times is sufficient to stabilize fractures in the rib above and below it, reestablishing the thorax configuration and minimizing the rigidity conferred by the materials used.

Surgical approaches

Incision is planned according to the location of rib fractures considered for stabilization. It must allow full exposure, minimal injury and aesthetic appearance. Each case is different and that's why it is difficult to standardize the incisions.[12]

Although, the rib fractures can be divided into anterior (anterior axillary line), lateral (between anterior and posterior axillary lines) and posterior (posterior to the axillary line).[5,13]

Whenever possible we should start with minimal incision and muscle splitting. With a small incision over a fracture site the thoracic wall is exposed. Other fractures can be located by inspection or palpation to guide the extension and direction of the incision.

The rib fractures approach can be summarized as follows:

a) **Anterior chest wall fractures with or without simultaneous sternum fracture:**

With the patient in a supine position, anterior rib fractures can be exposed through a oblique incision along the submammary sulcus an then a subpectoralis major myocutaneous flap is made to expose ribs 4-6 (Fig.3(a) and (b)). Exposureof the third rib can be made through a cutaneous transverse incision above the fracture and then splitting the fibers of pectoralis major and minor (Fig.4).[13]

When there's an anterior flail chest, with rib fractures on both sites of the sternum a clamshell incision can be made and both pectoralis major are dissected

Figure 3(a) *Sub-mammary incision for anterior unilateral fourth to sixth rib fractures stabilization.*

Figure 3(b) *Anterior unilateral rib fractures stabilization with plates and bicortical screws.*

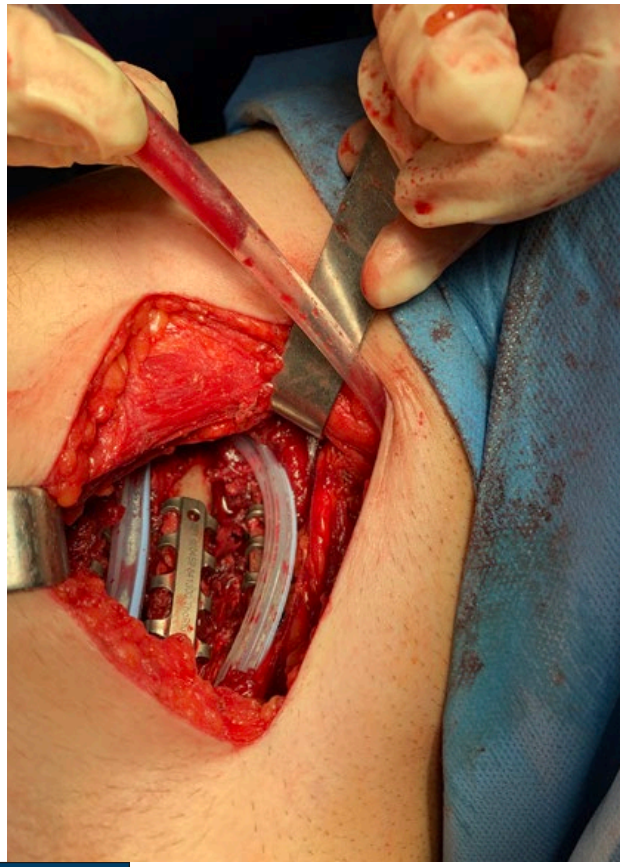

Figure 4 *Antero-lateral third and fourth rib fractures. Latissimus dorsal muscle dissection through its anterior limit and incision along the pectoralis major fibers to expose the fractures. Rib fracture stabilization with clamping plates.*

Figure 5 *Anterior bilateral rib fractures stabilization with plates and bicortical screws through a clamshell incision.*

from their rib and sternum insertions to expose the anterior chest wall (Fig.5).

In both cases, if there's a simultaneous sternum fracture it can be corrected using both incisions, but when there are only unilateral fractures the middle incision must be prolonged upwards along the sternum to better expose the bone fracture. The incision will have an L shape.

In simple sternum fractures the incision is usually a vertical one along the bone, lateral mobilization of the myocutaneous flap just enough to expose the fracture and insert the stabilization material.

b) Lateral chest wall fractures:

The patient must be placed in a lateral decubitus position with the upper arm supported above the head. A vertical incision is made along the anterior edge of the latissimus dorsi muscle. The anterior edge of the muscle is dissected from the most internal muscular layer so it can be retracted backwards. Serratus anterior muscle is then exposed and can be split to access the rib fractures (Fig.6(a) e(b)). Care must be taken to not damage the long thoracic nerve.[13]

Figure 6(a) *Surgical approach for lateral rib fractures..*

Figure 6(b) *Stabilization of lateral rib fractures with plates and bicortical screws.*

c) Posterior or subscapular chest wall fractures:

The proximity to the transverse process, costal angle and subscapular location of these fractures makes them technically the most difficult to repair.

The patient can be placed in prone position and the ipsilateral arm is supported in a lower rack of the operation table. This positioning will move the scapula anteriorly allowing a better expose of the triangle of auscultation and the subtrapezius and latissimus dorsi flap. Sometimes is inevitable to make a partial division of the latissimusdorsi and trapezius muscle at the extremes of exposure in some fracture patterns and the need for scapular retraction to gain exposure to subscapular fractures (Fig.7). Traditionally postero-lateral thoracotomy can be performed.[13]

For multiple fractures scattered in the fracture site, deep muscular tunnels can be made by separating and retracting muscles to expose the fracture site, and 90º angle fixation device or a small incision upon the other extreme can be used for fracture fixation.[13]

Chest trauma can be tricky. Patient can have all kinds of fracture combinations and so many times the CWS must be done using multiple incisions (Fig.8).

Fixation materials

The better method for CWS is still unknown. There are several commercial available systems for rib fixation, each with advantages and deficiencies.[10] The development of these materials and technologies made CWS easier and

Figure 7 *Surgical approach for stabilization of posterior rib fractures.*

with relatively few complications. The most frequently used are based in moldable metal plates with different lengths, applied on the surface of the rib and attached with bicortical screws. Alternatively, there are intra-medular splints, once again attached in one of the extremities by a bicortical screw.

There are U-shaped plates applied to the upper edge of the rib and fixed with screws. Other systems use clamping plates.

The advantage of this kind of systems is that they allow stabilization of rib fractures many of them with minimal invasive approaches, with sparing muscle incisions and minimal to the intercostal nerve.

Figure 8 *Three-dimensional reconstruction CT scan after complex rib fractures stabilization.*

For sternum fixation there are also similar systems, the most commonly adopted use different shapes of plates applied on the sternum surface and attached to it with bicortical screws.

All systems come with user-friendly equipment for quick and safe use.

No data are available concerning long term use of metal plates.

There are, off course, many other systems available but less is known concerning their application, like the absorbable ones.

CONCLUSIONS

There are no guidelines for CWS. Treatment algorithms have been proposed based on a combination of clinical experience and identification of the most relevant risk factors available in the published literature.

SSRF has become a common operation at most high-volume trauma centers. Increased experience with the procedure and development of new materials has spawned a variety of technical modifications to minimize incision length, muscle division, scapular retraction and general tissue trauma.

The impact of multiple injuries must be carefully evaluated and taken into account in decision of CWS.

Current available data shows benefit for a surgical approach of CWS versus non-surgical treatment. A prospective randomized control trial is now being enrolled by the Chest Wall Injury Society. We hope that is will bring us more information on this matter and validate the surgical approach of thoracic trauma patients and improvements in therapeutic strategies.

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