Surgical management of rib fractures in chest wall trauma

Fabrizio Minervini[1], Peter B. Kestenholz[1], Pietro Bertoglio[2], Marco Scarci[3], Gregor J. Kocher[4]

[1]Department of Thoracic Surgery, Kantonsspital Luzern, Lucerne, Switzerland; [2]Division of Thoracic Surgery, IRCCS Sacro Cuore-Don Calabria Hospital and Cancer Care Centre Negrar-Verona, Negrar, Italy; [3]Department of Thoracic Surgery, Ospedale San Gerardo, Monza, Italy; [4]Division of General Thoracic Surgery, Inselspital, Bern University Hospital, University of Bern, Bern, Switzerland

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Correspondence to: Fabrizio Minervini, MD, PhD. Department of Thoracic Surgery, Kantonsspital Luzern, Spitalstrasse, 6000 Lucerne, Switzerland. Email: fabriziominervini@hotmail.com.

Abstract: Chest wall trauma along with resulting pulmonary complications are associated with considerable morbidity and mortality in the context of polytraumatized patients. Non-surgical treatment of rib fractures has represented historically the gold standard for the past few decades but a new trend towards operative management has been encouraged by many surgeons who aimed to reduce morbidity, mortality and hospital length of stay (LOS). Optimal pain control, pulmonary hygiene, chest physiotherapy among with early mobilization have been considered the cornerstone of the management of patient's with chest trauma. Goals of an additional surgical management could be a reduction of morbidity and/or even mortality following chest trauma. To date there is a lack of international recognized guidelines on the surgical management of rib fractures. Indications, patient selection and timing of surgical stabilization of rib fractures (SSRF) remains still debated and the results of international conducted surveys show a large variability in decision-making process. In absence of several randomized controlled trials, actual practice is based on surgeon's experience and retrospective studies or case series. In this article, we focus our attention on the state of the art of surgical management of traumatic rib fractures exploring several aspects, like indications, contraindications and surgical aspects.

Keywords: Rib fractures; surgical rib fixation; thoracic trauma; chest wall injury

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Introduction

Chest injuries have a substantial impact on patient morbidity and mortality following trauma. They represent one of the most common injuries in the context of polytrauma with a reported incidence of around 30% (1). Chest trauma was found to be the cause of death in 25% of polytrauma patients (2). The most common type of chest injury is represented by rib fractures, which are associated with considerable morbidity and mortality due to respiratory complications resulting from pain and an impaired ventilation capacity (3). This occurs especially in case of flail chest, which is defined by multiple fractures of 3 or more adjacent ribs with subsequent paradoxical chest wall movement during respiration.

Even if more than 90% of chest trauma was historically treated conservatively, already in 1926 Jones published a paper reporting the first case of external support for a flail chest using a percutaneous technique for the application of traction by means of bullet forceps (4). Many alternative traction principles along with internal fixation devices or plates have been described since then, but only during the 80 s a renewed interest in rib fixation started when Labitzke, maybe the first surgeon who used titanium plates, published an article in which he described the effort to design and develop a plate with a grasping mechanism known as the Labitzke plate (5). Over the last 20 years, surgical stabilization of rib fractures (SSRF) has become a routinely performed surgery, especially in large trauma centers with a multidisciplinary expertise. Even if the enthusiasm surrounding the surgical management of rib fractures is growing exponentially, engaging more and more surgeons, there are still many concerns regarding the selection of patients and the potential benefits. Large randomized controlled trials are scarce and an additional open question to date is who should ideally be the leading team involved in SSRF.

Currently, thoracic surgeons, orthopedic surgeons, general surgeons and traumatologists are all involved in the surgical management of rib fractures. Actually, rib fixation per se is not much different from the treatment of fractures involving for example the spine or extremities, but in our opinion an exhaustive knowledge of chest wall pathophysiology and biomechanics is mandatory. The treating surgeon should not only be familiar with the exact structure and anatomy of the chest wall as thoracic pathophysiology, but should also be able to treat associated injuries of adjacent organs (e.g., thoracoscopic evacuation of hemothorax, suturing of lung lacerations, repair of diaphragmatic injuries etc.).

Indications

Even if there are to date no internationally recognized guidelines that would help in identifying the patient population who benefits most from SSRF, the variability of injuries should be taken in account. Chest wall trauma can range from simple rib fractures to flail chest with the need for endotracheal intubation and prolonged mechanical ventilation.

Several studies indicate that the patients who are most likely to benefit from SSRF are those with flail chest (6-10). Flail chest injuries carry a high morbidity and mortality, particularly in patients who require prolonged invasive mechanical ventilation in the intensive care unit (ICU). A retrospective study published by Kocher *et al.* evaluated the outcomes and cost-effectiveness of SSRF in patients with flail chest and associated ventilator dependent respiratory insufficiency. The authors reviewed a total of 61 patients who underwent surgery with a locking titanium plate fixation system and found that 62% of patients could be weaned from the ventilator within the first 72 post-operative hours. According their findings, rib fixation was already cost-effective starting from 2 days of ICU treatment that can be saved due to earlier extubation (6). The same length of stay (LOS) reduction was reported by Marasco and colleagues in a prospective randomized trial, in which this group observed that patients in the operative fixation group had a significantly shorter ICU stay (285 hours for the surgical group *vs.* 359 hours for the conservative group; P=0.03) (7). A prospective randomized study published by Tanaka and his group reported that the mean ventilation time in the surgical treatment group (10.8±3.4 days) was shorter than in the conservative treatment group (18.3±7.4 days), and that patients who underwent surgery may be successfully weaned from ventilator 2.5±3.2 days after surgery. In this study, patients in the conservative group had a ventilation time (13.7±4.4 days) significantly longer than patients in the surgical group (10.5±3.7 days) (8).

A meta-analysis published in 2016, including three randomized controlled trials, showed a significant shorter duration of mechanical ventilation (mean difference –6.30 days, 95% CI: –12.16 to –0.43, P=0.04) and ICU LOS (mean difference –6.46 days, 95% CI: 9.73 to –3.19, P=0.0001) in the operative group if compared to a population who underwent conservative treatment for flail chest. The same benefit was observed in the overall LOS in hospital (mean difference –11.39, 95% CI: –12.39 to –10.38, P<0.0001) (9). An even larger meta-analysis conducted by a group from Washington reported many potential benefits in patients who underwent surgical stabilization for flail chest. In particular, they analyzed 9 studies with 538 patients and found that surgical management was associated with 4.5 fewer days of mechanical ventilation, 3.4 fewer days in the ICU, and almost 4 fewer days in the hospital, compared to patients managed non-operatively. Additionally, operative stabilization was associated with a >50% reduction in mortality, incidence of pneumonia, and use of tracheostomy (10).

Pneumonia is a common complication in patients with flail chest. Studies have reported that pulmonary infection is one of the main factors associated with longer time of mechanical ventilation and ICU LOS (11). Xu and colleagues showed that the rate of pulmonary infection was significantly lower in the surgical group compared with the conservative group, maybe because the early ventilator weaning reduces the incidence of ventilator-associated pneumonia and allows early mobilization, a better respiratory therapy along with autonomous cough and expectoration, which could decrease the accumulation of airway secretions (12).

In line with these trials, recently a multicenter cohort study was conducted in the Netherlands but, after propensity score matching, rib fixation for flail chest was not associated with significant differences in LOS, duration of epidural analgesia, morbidity and in hospital mortality. As stated by the authors themselves, the study conclusions must be interpreted with caution, considering important limitations such as the retrospective nature of the study and the relatively small number of included patients (13).

Outside the setting of flail chest, the evidence for surgical rib fixation is slightly less delineated. Uchida and colleagues reported that SSRF could provide benefits not only for flail chest patients but also in the setting of multiple displaced rib fractures.

The patients who underwent surgery were extubated significantly earlier than the patients managed non-operatively [5.5 (1–8) *vs.* 9 (7–12) days; P=0.019], they received less continuous intravenous narcotic analgesia days [4.5 (3–6) *vs.* 12 (9–14) days; P=0.002] with a shorter duration of ICU stay [6.5 (3–9) *vs.* 12 (8–14) days; P=0.008]. The incidence of pneumonia was higher in the non-operative management group (P=0.05) (14). A meta-analysis conducted by Girsowicz *et al.*, despite the fact that several low evidence studies were included, showed that SSRF in the management of isolated multiple non-flail rib fractures could improve outcomes in terms of pain, respiratory function, quality of life and reduced socio-professional disability (15). The latter is a very important issue, since after hospital discharge 40–60% of patients are not able to resume full-time employment due to persistent chest pain (14) especially if complicated with non-union or intercostal nerve entrapment (16). Recently, additional data has been published corroborating the efficacy of SSRF for non-flail chest fracture patterns (17,18). Considering that the available data is mostly preliminary, more large randomized controlled trials are needed, which may finally serve as a solid base for the development of new guidelines.

Contraindications

As previously mentioned, patients with chest wall trauma frequently suffer from associated injuries like traumatic brain injury, pulmonary contusion or contusio cordis. Even if the level of evidence is very low, according to the clinical practice guidelines elaborated by Pieracci and colleagues, the indication and the timing for surgery should be evaluated on a case to case basis preferably in a multidisciplinary setting (19). An open rib fracture is usually considered a contraindication for surgical rib fixation due to the reluctance to insert a foreign body into contaminated operative field. Nevertheless, in our opinion, the timing of the surgery and the character of the wound should be taken into consideration as well during the decision-making process.

Pre-operative planning

Imaging

According to the advanced trauma life support (ATLS) principles, all polytrauma patients should get a chest X-ray (20). However, due to the low sensitivity of chest radiographs, computed tomography (CT) scan plays an essential role in the thoracic trauma setting, not only for diagnostic purposes but also for preoperative planning. Even if there is no sufficient evidence to recommend the routine use of 3D CT reconstructions of the chest (19), in our opinion these are extremely helpful for planning the procedure.

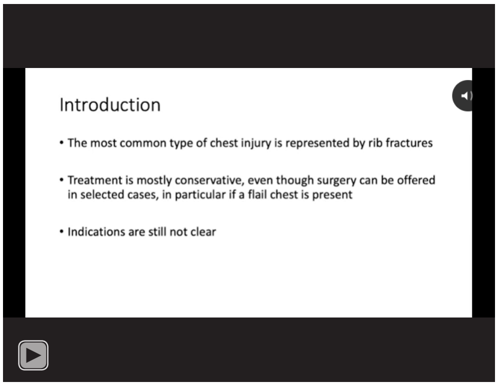
Antibiotic and venous thromboembolism (VTE) prophylaxis

To date, there is no available data focusing on peri-operative antibiotic and VTE prophylaxis for SSRF. Several studies suggesting antibiotic prophylaxis for many procedures may be applied to SSRF and therefore the administration of cefazolin within 30 min before the skin incision (or vancomycin in case of penicillin allergy) is favored (21-24).

The American College of Chest Physicians 9th edition guidelines recommend the use of in-hospital routine VTE prophylaxis with either unfractionated heparin or low-molecular-weight heparin (LMWH) after thoracic surgery. Grade A recommendations from several societies support the use of LMWH to reduce the risk of VTE in trauma patients (25,26). In our opinion, we can extend the above-mentioned recommendations to patients who underwent SSRF.

Technical considerations

SSRF must usually not be carried out in all fracture sites. In the preoperative planning, it should be taken into account not only the benefit from surgical fixation but also the tissue trauma generated from exposing the fracture site. In order to identify the best incision site, minimizing the dissection of the respiratory musculature, some surgeons prefer to perform a video assisted thoracoscopy (VATS), useful



Video 1 Surgical management of rib fractures (33).

moreover to evacuate a possible hematothorax and place a chest tube under direct visualization. The combination of better fracture visualization and minimization of trauma to the thoracic structures has brought with it the futuristic idea to perform a complete intrathoracic SSRF using only a VATS approach (27). However, at present, the lack of proper instruments and studies focused on advantages of the VATS approach over the traditional open techniques does not allow a spread of this innovative method yet.

Even in the setting of multiple rib fractures, current guidelines suggest not to stabilize rib fractures involving ribs 1, 2, 11, 12 (with exceptions of displaced lower ribs that can result in injuries of liver and spleen or lung herniation) (19). Several authors suggest to repair ribs 4 to 10 which provide the greater stability to the chest wall (28-30).

In case of a flail chest the ribs are broken, by definition, in at least two different sites and no consensus exists if it is sufficient to stabilize only one or both fractures per rib in order to restore a good stability of the chest wall. An empiric approach (check instability after SSRF of one fracture site and then decide if it is necessary to gain more stability approaching the other fracture on the same rib as well) is preferred by many surgeons.

Optimal timing of surgical stabilization

Nowadays an emerging crucial factor in improving outcomes after surgical rib fixation seems to be the timing of the procedure. The inflammation and the callus formation could potentially create difficulties in reducing the fracture to a normal alignment, making surgery more challenging. In addition, it has been reported that patients who underwent early SSRF could benefit from it even more. In a multicenter evaluation, Pieracci and colleagues observed that despite repairing the same median number of ribs (4; range, 1–13), the duration of the procedure was 68 minutes longer in patients who underwent late stabilization (between 3 to 10 days from hospital admission) when compared to the early group (<1 day from hospital admission) ($P<0.01$). But it's not just a matter of time, each additional hospital day before SSRF was associated with a 31% increased incidence of pneumonia ($P<0.01$), a 27% increased incidence of prolonged mechanical ventilation ($P<0.01$), and a 26% increased incidence of tracheostomy ($P<0.01$) (31). Similar results have been reported by Iqbal *et al.* in a retrospective study published in 2018. They compared 65 patients who underwent SSRF within 48 hours of the injury, and 37 patients who underwent surgery after 48 hours. In the early surgery group a shorter ICU stay ($P=0.01$), fewer cases of pneumonia ($P=0.001$), reduced duration of mechanical ventilation ($P=0.03$), fewer tracheostomies ($P=0.02$) and shorter LOS ($P=0.008$) were reported (32).

Conclusions

Chest wall trauma can produce not only significant mortality and morbidity, but subsequently also substantial healthcare costs. Even if there is no international consensus about indications, contraindications and timing of surgery, the available literature shows that patient benefits from SSRF, especially if performed in an early phase after the injury, may be substantial. Considering that patients with chest trauma have usually other injuries outside the chest, a multidisciplinary approach in the decision-making process is a key point in order to achieve excellent clinical outcomes (*Video 1*).

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