

Surgical stabilization of flail chest: the impact on postoperative pulmonary function

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Abstract

Objectives Flail chest results in significant morbidity. Controversies continue regarding the optimal management of flail chest. No clear guidelines exist for surgical stabilization. Our aim was to examine the association of bedside spirometry values with operative stabilization of flail chest. **Methods** IRB approval was obtained to identify patients with flail chest who underwent surgical stabilization between August 2009 and May 2011. At our institution, all rib fracture patients underwent routine measurement of their forced vital capacity (FVC) using bedside spirometry. Formal pulmonary function tests were also obtained post-operatively and at three months in patients undergoing stabilization. Both the Synthes and Acute Innovations plating systems were utilized. Data is presented as median (range) or (percentage).

Results Twenty patients (13 male: 65 %) with median age of 60 years (30–83) had a median of four ribs (2–9) in the flail segment. The median Injury Severity Score was 17 (9–41) and the median Trauma and Injury Severity Score was 0.96 (0.04–0.99). Preoperative pneumonia was identified in four patients (20 %) and intubation was required in seven (35 %). Median time from injury to stabilization was four days (1–33). The median number of plates inserted was five (3–11). Postoperative median FVC (1.8 L, range 1.3–4 L) improved significantly as compared to preoperative median value (1 L, range 0.5–2.1 L) ($p = 0.003$). This

improvement continued during the follow-up period at three months (0.9 L, range 0.1–3.0) ($p = 0.006$). There were three deaths (15 %), none of which were related to the procedure. Subsequent tracheostomy was required in three patients (15 %). The mean hospital stay and ventilator days after stabilization were nine days and three days, respectively. Mean follow-up was 5.6 ± 4.6 months.

Conclusion Operative stabilization of flail chest improved pulmonary function compared with preoperative results. This improvement was sustained at three months follow-up.

Keywords Flail chest · Rib stabilization · Pulmonary function

Introduction

Flail chest results in significant morbidities and repeat hospital admissions [1]. With development of better ventilator strategies for patients with flail chest, the overall outcome of this group of patients had improved; however, a subset is still in need for surgical intervention. Internal pneumatic stabilization using mechanical ventilation was considered as the main treatment for those with respiratory failure especially in the presence of other major thoracic and/or abdominal injuries [2]. Mortality of these patients has been reduced with the advances in ventilator management [3]; however, ventilator-associated pneumonia is a real concern [4]. Controversies still exist in regards to the surgical indications in such severe injuries as well as the timing and indications of surgical interventions. The presence of pulmonary contusions was considered a relative contraindication to surgical fixation [5] due to the need for prolonged ventilation and low benefit from surgical

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stabilization [6]. Our aim was to examine the association of bedside forced vital capacity (FVC) with operative stabilization of flail chest, and to evaluate the effect of surgical stabilization of flail chest on postoperative pulmonary function. We hypothesize that pulmonary functions will improve with operative fixation of flail chest.

Patients and methods

The Institutional Review Board (IRB) approved the current study, and informed consent was obtained to participate in the research. From August 2009 through May 2011, 20 patients underwent operative stabilization of their flail chest and met the criteria for enrollment, which included: traumatic flail chest (≥ 2 contiguous rib levels with at least two fractures). We excluded patients with non-flail rib fractures who underwent surgical fixation. Our indications for surgery included: (1) significant chest wall collapse or deformation with paradoxical respiratory dysfunction and with or without pulmonary contusions, (2) impalement of ribs into pulmonary parenchyma and or other solid organs (e.g., hepatic or splenic parenchyma), or diaphragm necessitating concomitant repair, (3) significant and refractory pain, and (4) anticipated non-union or malunion.

Preoperative management of these patients was according to a well-established protocol at our institution that entailed: adequate pain control, arterial blood gases measurement and routine measurement of their FVC using simple bedside spirometry, on admission and every 6 h thereafter for 24 h and once after any of the following interventions: rib catheter or epidural catheter insertion for pain control, and or initiation of dexmedetomidine infusion.

Chest CT scan with or without 3D reconstruction was performed on admission as part of our trauma protocol as well as postoperatively. Surgical technique utilized single lung ventilation in all patients. Descriptive statistics for categorical variables are reported as frequency and percentage; continuous variables are reported as mean (SD) or median (range) as appropriate. A p value of <0.05 was considered statistically significant.

Results

The median age was 60 years (range 30–83 years). The median Injury Severity Score (ISS) was 17 (9–41), and the median Trauma And Injury Severity Score (TRISS) was 0.96 (0.04–0.99). Preoperative pneumonia was identified in four patients (20 %). Intubation was required preoperatively in seven patients (35 %), and the indications were: respiratory failure in four patients (57 %), combativeness in two (29 %), and need for surgical intervention in one patient

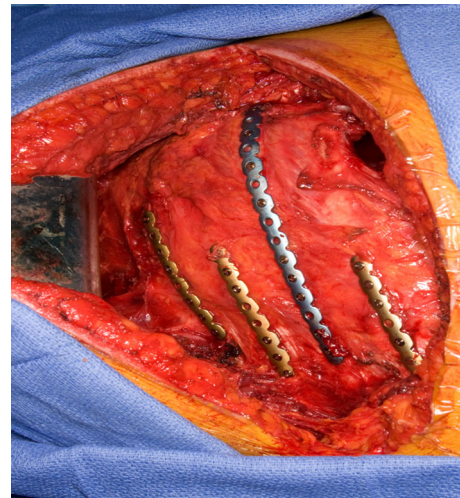


Fig. 1 Intraoperative photo of the Synthes MatrixRib plating system that was used in 13 patients of our series (65 %)

(14 %). Video-assisted thoracoscopy (VATS) was performed in ten patients (50 %). The most common indications for concomitant VATS were: evaluation of associated parenchymal injury, assistance with thorotomy placement, and evacuation of retained hemothorax. Left-sided stabilization was required in 11 patients (55 %). Both the Synthes MatrixRib (Fig. 1) and the Acute Innovations RibLoc (Fig. 2) plating systems were utilized in 13 (65 %), and six (30 %) patients, respectively, while in one patient (5 %), both systems were used. The most common associated procedure was evacuation of ipsilateral hemothorax in 11 patients (55 %). Pulmonary function tests were obtained early postoperatively or prior to dismissal, and at three months. The median number of days from injury to operative stabilization was four days (range 1–33 days). The median number of ribs plated was four ribs (range 2–9 ribs), and the median number of plates inserted was five plates (range 3–11 plates). We identified one (5 %) early mortality; due to massive polytrauma and progressive decline in the neurologic status. Early morbidities occurred in 11 patients (55 %), the most common ones were: atrial fibrillation with rapid ventricular response in three (27 %), and cellulitis and pneumonia in two patients (18 %) each. Tracheostomy was required in two patients (10 %). Mean follow-up was 5.6 ± 4.6 months. Two late mortalities (10 %); non-surgically related, were identified. One patient required re-operation, 12 months later for additional fixation of a single rib fracture. No reoperation for recurrent hemothorax or hardware infection or failure. The mean hospital stay, intensive care unit (ICU) stay, and ventilator days after fixation were nine days, six and three days, respectively. Postoperative median FVC (1.8 L, range 1.3–4 L) improved significantly as compared to preoperative median value (1 L, range 0.5–2.1 L) ($p = 0.003$). This improvement continued during

Fig. 2 **a** Postoperative chest computed tomography (CT) with 3-D reconstruction and **b** intraoperative photo of the Acute Innovations RibLoc plating system that was used in six patients (30 %)

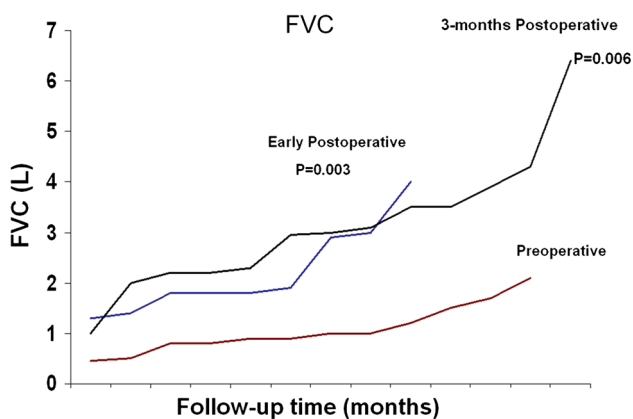
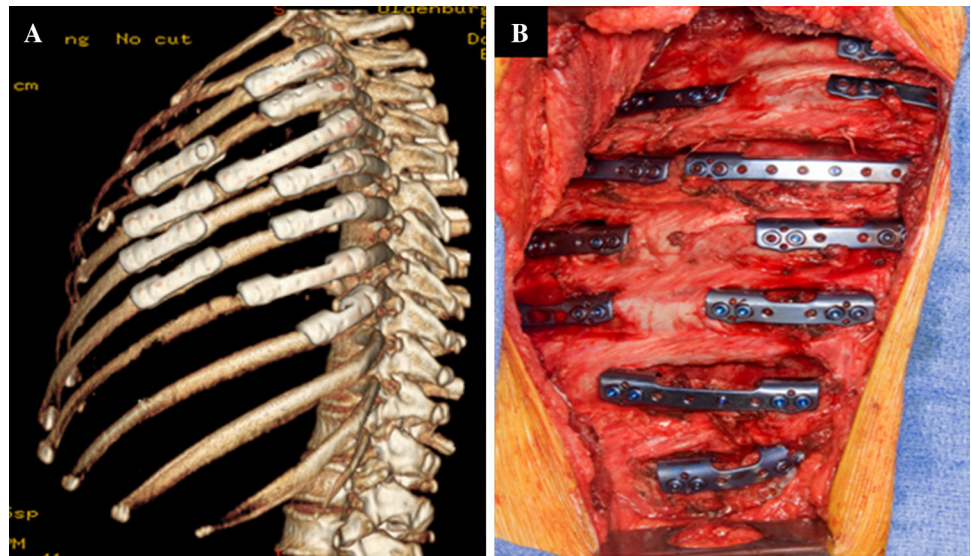


Fig. 3 Forced vital capacity (FVC) improved significantly as compared to the preoperative period ($p = 0.003$), and this improvement continued during the follow-up period at three months ($p = 0.006$)

the follow-up period at three months (0.9 L, range 0.1–3.0) ($p = 0.006$) (Fig. 3).

Discussion

Flail chest results in significant morbidities that are not only limited to the associated multiple rib fractures, but also extend to include the associated lung contusions, and atelectasis which makes it a complex traumatic acute respiratory failure syndrome [7]. Several treatment options exist for flail chest which may include and not limited to adequate pain control, ventilatory management with internal pneumatic stabilization [8], or surgical fixation. Internal pneumatic stabilization technique was associated with lower mortality compared to conventional therapy, and was considered as the treatment of choice by many trauma

centers due to its non-invasive nature but soon was limited by the risks associated with prolonged ventilation particularly ventilator-associated pneumonia, which had its separate impact on mortality in these critically ill group of patients [9].

Non-surgical therapy of flail chest is not always successful and its long-term impact on respiratory mechanics [10] or chest wall deformity for those who recovered from initial injury is unknown [11]. Landercasper et al. [12] reported the long-term disability after flail chest injury in 62 patients with traumatic flail chest. Pulmonary complications developed in 60 % of the patients. During follow-up, 21 patients underwent comprehensive testing that included spirometry, flow volume curves, diffusion testing and dyspnea index calculation. Only one-third of the patients returned to full-time employment. Thoracic cage pain was still present in 49 % of the patients, and 38 % had experienced at least moderate change in their overall level of activity. During the healing phase, fractured ribs can be displaced, which may result in malunion, non-union or significant chest wall deformity [13]. Some studies have even reported chest wall collapse with resultant respiratory failure especially with posterolateral flail injuries [14, 15].

Surgical stabilization of the chest wall has emerged as a method of treatment with its indications continuing to evolve from just those patients with significant paradoxical rib motion and ventilatory dependence to the current practice. Several techniques have been reported for stabilization of flail ribs, which included simple wire suture fixation, rod fixation [16], or more recently special anatomic rib plates and screws [17]. The use of these anatomic rib plates facilitates reduction of the rib fragments quickly, which reduces the complexity of the procedure as well as the operative time, and it provides a useful means of a

multilevel stabilization for the flail ribs [18]. Using this type of plates enables the use of long plates which provides strong, and at the same time, low-profile support and bridging to the flail segment. In our study, we have used two types of rib plates, the Synthes MatrixRib and the Acute Innovations RibLoc plating systems in 13 (65 %), and six (30 %) patients, respectively, while in one patient (5 %), both systems were used. The availability of different designs may help to tailor the technique based on the location and the specific patient's anatomy. We believe that the following patterns of rib fractures are amenable to fixation: rib fractures with respiratory failure requiring mechanical ventilation without severe pulmonary contusion, severe pulmonary contusion limiting liberation from mechanical ventilation, and non-intubated patients with deteriorating pulmonary function, which may point out the importance of some type of monitoring or periodic evaluation of these patients' pulmonary functions.

Recently, several studies demonstrated the clinical benefits of early surgical stabilization of flail chest patients [19], and these benefits are not limited only to the clinical aspect but include lower cost and shorter ICU and hospital stays [20]. The study by Bhatnagar et al. [21] demonstrated that surgical fixation of flail chest is cost-effective due to the reduction in pneumonia rates and ventilator and length of stay days, which resulted in an overall reduction in the cost and improvement in effectiveness. We do believe in early fixation if indicated, and if other associated injuries do not preclude this intervention, and if the patients can tolerate the lateral decubitus position. Few studies showed the impact of surgical fixation on improvement of the respiratory function in these patients, and controversy still exists in regard to the optimal timing of surgical intervention. In the study by Lardinois et al. [22], the authors prospectively evaluated the pulmonary function after surgical stabilization of traumatic flail chest. Surgery was performed in 66 patients and all had anterolateral flail segments that involved more than four ribs. Respiratory failure was present in 28 patients with failure to wean in 21. In their study, stabilization was done using stainless steel 3.5 mm reconstruction plates. The mean ventilator time was 2.1 days, with 47 % of the patients underwent immediate extubation. All the patients returned to work at two months after surgery. In our study, the mean number of days on mechanical ventilation was three days, and the median FVC (1.8 L, range 1.3–4 L) improved significantly as compared to the preoperative period (1 L, range 0.5–2.1 L) ($p = 0.003$), which continued during the follow-up period at three months (0.9 L, range 0.1–3.0) ($p = 0.006$).

The emergence of video-assisted thoracoscopic surgery (VATS) as an adjunctive technique during operative fixation has appeared in a few recent studies. We have use

VATS in ten patients (50 %) of our series. The advantages of using VATS were: concomitant evaluation of associated lung parenchymal injuries, assistance with thoracotomy incision placement during fracture fixation, and the ability of evacuation of associated hemothorax or decortication.

We believe that management of flail chest has to include early surgical fixation side by side with the proper ventilatory adjustment. Adequate pain control is important in these patients as well as chest physiotherapy. In our institution, we have established a flail chest protocol that includes every patient admitted to our trauma unit with traumatic flail chest. This protocol begins when the patient is admitted to our unit. The appropriate level of care is determined based on the associated injuries and the need for proper level of monitoring. Pain control is achieved by a combination of analgesics, with or without regional analgesia catheter delivery devices or epidural catheters. Bedside pulmonary function testing is the key portion in our protocol. This includes FVC and negative inspiratory force (NIF), which are performed on admission and every 6 h thereafter for 24 h and once after any of the following interventions: chest pain or epidural catheters insertion or dexmedetomidine infusion. These parameters are trended and followed to monitor the improvement or deterioration in the patient's condition. Further aggressive treatment is determined based on the results of these tests. The goals of this protocol are: (1) providing a uniform language for communication between every member of the team who takes care of these patients, (2) decrease pulmonary morbidity, decrease ventilator days and ventilator-associated pneumonia by early detection of those who are deteriorating as a result of flail chest and referral to a more aggressive form of treatment, (3) improve post chest wall injury pulmonary function, and (4) improve patient analgesia by way of early stabilization. We feel that this protocol is simple, effective and provides objective evidence that will help in the decision making process. These bedside respiratory tests are simple and can be performed without the need for patient transfer to a more complex suites where formal pulmonary functions are usually performed. Additionally, these tests can be taught to bedside nursing staff and surgical trainees.

Study limitations

This is a retrospective review, and its accuracy depends on availability of information in medical records. The small number of our patient cohort represents another limitation; however, this study points out the importance of a bedside spirometry as a simple and easy test to perform without the need for transfer of these complicated trauma patients into a more complex suite for evaluating their pulmonary

functions. It also changed our practice towards routine performance of these bedside evaluations in all trauma patients admitted to our trauma unit.

Conclusion

Operative stabilization of flail chest can be performed safely with low mortality and minimum morbidities. Bedside spirometry is a simple and objective way to longitudinally follow the patient with flail chest. Operative stabilization of flail chest improved pulmonary function compared with preoperative results. This improvement was sustained at three months follow-up.

Conflict of interest S. M. Said, N. Goussous, M. D. Zielinski, H. J. Schiller and B. D. Kim declare that they have no conflict of interest.

Compliance with Ethics Guidelines The Institutional Review Board (IRB) approved the current study, and informed consent was obtained to participate in the research.

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