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Feasibility of Chest Wall Reconstruction Following Major Chest Wall Trauma: A Single Center Experience

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ABSTRACT

Background: Chest wall trauma with multiple rib fractures or flail segments is associated with substantial morbidity. Surgical stabilization of rib fractures (SSRF) has emerged as an effective strategy to improve respiratory mechanics, reduce pain, and shorten Intensive Care (ICU) and hospital stay.

Objective: To evaluate the feasibility, safety, and short-term outcomes of chest wall reconstruction following major chest wall trauma.

Patients and Methods: This retrospective study included 15 consecutive patients with major chest wall trauma managed at Menoufia University Hospital from January 2022 to December 2024. Eligible patients were 16–90 years old with ≥4 rib fractures, flail segments, or markedly depressed chest wall. Preoperative assessment included clinical and radiological evaluation. Surgical reconstruction used contoured titanium plates and locking screws, with selective rib or sternal fixation based on fracture pattern. Postoperative care included multimodal analgesia, respiratory support, chest physiotherapy, and early mobilization. Outcomes assessed were operative time, number of ribs fixed, ICU and hospital length of stay, complications, mortality, and six-month functional recovery.

Results: All patients were males (19–49 years). Road traffic accidents accounted for 53.3% of cases. Patients sustained a mean of 7.3 fractured ribs, with an average of 3.2 ribs fixed. Mean operative time was 105.6 minutes. ICU and hospital stay averaged 3.3 and 10.5 days, respectively. Minor complications occurred in 2 patients (13.3%), with no hardware failure or mortality. Follow-up showed satisfactory pain control and functional improvement.

Conclusion: Chest wall reconstruction is feasible and safe, achieving stable fixation, low morbidity, and favorable short-term recovery in appropriately selected trauma patients.

Keywords: Chest wall , Rib fractures, Surgical stabilization, Flail chest.

INTRODUCTION

Major chest wall trauma associated with flail chest arising during conflicts of World Wars I and II was recognized to carry an attendant mortality of 50%–90% [1–3]. In the postwar era, blunt trauma causing a major chest wall injury was also related to an approximate 25% mortality, a statistic that has remained unaltered over decades [4,5]. Pathophysiological mechanisms responsible for the morbidity and mortality include severe pain, 'wet lungs' now recognized as contused lung, hypovolemic shock, contused myocardium and respiratory failure [2,6–8]. Mortality has been shown to be related directly to increasing number of ribs fractured, increasing from 6% to >34% [8,9].

Effective treatment has been recognized to require a multidisciplinary strategy; analgesia, immobilization of flail chest wall segments, hemodynamic resuscitation and ventilatory support [4,6,9–11]. Immobilization of injured chest wall segments, targeted to minimize paradoxical movement of segments during respiration, was considered of paramount importance in the strategy to prevent ineffective ventilation and secondary respiratory failure [4,8,11–15]. After early attempts that used methods of soft tissue immobilization, preliminary endeavor to achieve internal fixation of sternal and rib fractures appeared to successfully reduce mortality [3,11,12]. Yet the introduction of artificial ventilation in 1960s assumed a status that appears to supersede surgical treatment. A cultural view has since developed that considers there is little benefit gained by surgical treatment of these injuries [9,13].

The aim of this study was to determine the effect of chest wall reconstruction on morbidity and mortality associated with chest wall trauma.

PATIENTS AND METHODS

This retrospective study was conducted in the Cardiothoracic Surgery Department at Menoufia University Hospital between January 2022 and December 2024. The purpose of the study was to evaluate the feasibility and short-term outcomes of chest wall reconstruction following major chest wall trauma. Ethical approval was obtained from the Local Ethics Committee of the Faculty of Medicine, Menoufia University. Informed written consent was obtained from all participants prior to inclusion. Fifteen consecutive patients presenting with major chest wall trauma involving multiple rib fractures were enrolled in the study. All patients were managed by the on-call cardiothoracic surgery team, and the treatment strategy was determined by the attending surgeon according to the type and extent of injury.

Injured patients who were between 16 and 90 years of age with at least four fractured ribs, presenting

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with a flail segment or markedly depressed chest wall (stoved-in chest), or those in severe pain impairing ventilation, were included. Patients were excluded if their death occurred within the first 24 hours of trauma, if they were over age 90 or younger than age 16, or if they were readmitted for treatment following earlier hospital discharge.

All the patients underwent an extensive preoperative workup including detailed clinical examination and radiological evaluation. Chest X-rays and CT scans of the chest and whole body were conducted to outline the number and pattern of rib fractures and also to look for other associated injuries. Meticulous attention was paid to the examination of the cartilaginous part of the chest wall and sternum because these cannot be visualized on imaging. Any head, abdominal, or limb injury was also noted to give an idea about the extent of trauma.

The majority of patients underwent surgery under general anesthesia via single-lumen endotracheal intubation, while double-lumen intubation was applied for the cases needing intrathoracic repair. A muscle-sparing approach was used to expose the fractured ribs with minimal muscle damage. Also, the department's protocol was to avoid fixing ribs 1, 11, and 12. Fractures were anatomically reduced and stabilized using pre-contoured titanium plates fixed with locking screws. In cases with sternal fracture, additional sternal plates were added to achieve complete stabilization. The number of plates and ribs fixed varied according to the extent and configuration of the fractures.

The postoperative management was designed to ensure proper pain control, respiratory support, and early mobilization. For analgesia, a multi-modal regime was employed, comprising opioid medications along with regional anesthesia, such as thoracic epidural or serratus anterior nerve block techniques. Chest physiotherapy was given daily to all patients, starting from the ICU period and continuing throughout the ward stay. The patients were encouraged to practice early ambulation and breathing exercises to ensure good lung expansion and prevent pulmonary complications. The subjects needing mechanical ventilation either in the preoperative period or postoperatively were followed up in the ICU. ICU stay, total hospital stay, and days on ventilatory support were noted. Postoperative complications were documented.

All patients were followed up for six months postoperatively in the outpatient clinic. Follow-up included serial chest radiographs to assess bone healing, plate stability, and any implant-related complications. Assessment of pain intensity was done using the Visual Analogue Scale (VAS) and Numerical Verbal Pain Intensity Scale (0-10) one week and three months postoperatively. The clinical improvement, return to normal activities, and resolution of respiratory symptoms were also assessed.

Collected data included demographic data, mechanism of injury, associated injuries, number and side of fractured ribs, operative time, number of fixed ribs, days from trauma to surgery, ICU and hospital length of stay, postoperative complications, and mortality. Descriptive statistics were used to summarize the results, including mean and standard deviation for continuous variables and frequency with percentage for categorical variables. The primary outcomes of this study are the feasibility of chest wall reconstruction, postoperative morbidity, and mortality related to the procedure.

Figures 1 and 2 show pre- and postoperative X-rays.

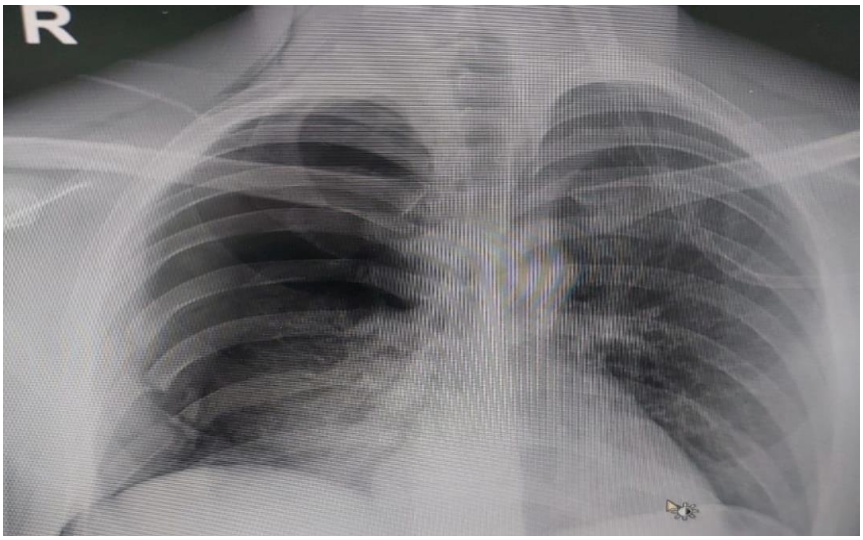

Fig. **1.** The preoperative X-ray shows multiple displaced right-sided rib fractures with chest wall deformity and reduced right lung aeration, suggesting associated contusion or collapse. No major mediastinal shift or large pleural effusion is evident. Overall, findings indicate significant right-sided thoracic trauma warranting stabilization.

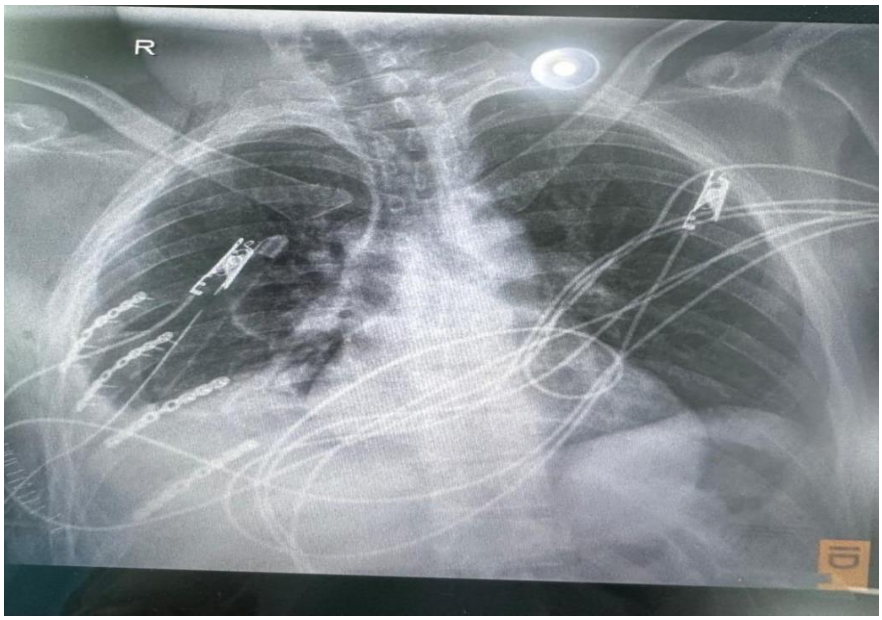

Fig. 2. The postoperative chest X-ray shows multiple fixation plates and screws along the right side of the chest wall, consistent with surgical stabilization of rib fractures. The hardware appears well aligned with no visible displacement or hardware complications. Lung expansion on the right side has improved compared to preoperative appearance, although residual parenchymal haziness is present, likely representing contusion or postoperative changes. No obvious pneumothorax or large pleural effusion is seen.

Ethical Consideration:

The study protocol received approval from the Ethical Committee of the Faculty of Medicine, Menoufia University (IRB: 11/2025 CARS3). A written informed consent was obtained from all patients prior to enrollment. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) software version 26.0 (IBM Corp., Armonk, NY, USA). Quantitative variables were expressed as mean ± standard deviation (SD) and range, while qualitative variables were presented as frequency and percentage. The paired Student's t-test was used to compare preoperative and postoperative continuous variables such as echocardiographic measurements (ESD, EDD, EF). Categorical data were compared using the Chi-square test or Fisher's exact test when appropriate.

A p-value < 0.05 was considered statistically significant.

RESULTS

Table 1 summarizes the baseline characteristics of the 15 patients who underwent surgical stabilization of rib fractures following major chest wall trauma. All were males, with ages ranging between 19 and 49 years. The mechanism of injury included predominantly road traffic accidents, followed by falls from height and crush injuries. Associated injuries such as sternal, clavicular, and scapular trauma were identified in several, reflecting the severity of the trauma mechanism. Most of the rib fractures were right-sided (66.7%), with fewer left-sided and bilateral cases. The number of fractured ribs ranged from 4 to 10, again reflecting the extent of the thoracic trauma. Only three patients required preoperative ventilation. ICU stay ranged from 2 days up to 6 days, and postoperative hospital stay varied between 7 and 15 days, indicating moderate short-term resource utilization**.**

Table 1. Patient characteristics (n = 15)

Patient No.	Age (y)	Sex	Abdomen injury	Head injury	Mechanism of trauma	Associated injuries	Side of fracture	Total number of fractured ribs	Pre-op ventilation	ICU stay (days)	Post-op hospital stay (days)
1	27	M	No	No	Traffic accident	Sternum	Right	7	No	3	10
2	24	M	Yes	Yes	Fall from height	Clavicle	Right	8	Yes	2	15
3	19	M	No	Yes	Traffic accident	None	Left	7	No	2	7
4	21	M	No	No	Traffic accident	None	Right	8	Yes	5	15
5	49	M	No	Yes	Traffic accident	Sternum	Right	6	No	2	8
6	40	M	Yes	No	Fall from height	None	Right	8	No	3	7
7	22	M	No	No	Crash injury	Clavicle & sternum	Right	10	No	2	8
8	38	M	Yes	No	Fall from height	None	Left	8	No	3	9
9	45	M	No	No	Motorcycle accident	None	Right	4	No	4	14
10	19	M	Yes	Yes	Traffic accident	Scapula & clavicle	Right	5	No	4	12
11	22	M	No	No	Fall from height	None	Bilateral	6	No	3	14
12	28	M	Yes	Yes	Fall from height	None	Right	7	No	2	8
13	39	M	Yes	No	Traffic accident	None	Left	10	No	2	7
14	40	M	No	No	Traffic accident	None	Right	6	No	3	8
15	25	M	No	Yes	Traffic accident	Sternum	Left	8	No	3	10

y: years, M: male, Pre-op: preoperative, ICU: intensive care unit, Postop: postoperative.

Table 2 shows the intraoperative parameters, demonstrating consistent use of contoured titanium plates and locking screws for fixation. Single-lumen anesthesia was used in nearly all cases except one requiring double-lumen ventilation due to the complexity of exposure. Most fractures were unilateral, with one bilateral fixation case involving four plates. The majority of patients required fixation of 3–4 ribs, and the operating duration ranged from 70 to 180 minutes, reflecting case complexity. Days from trauma to surgery ranged from 2 to 6 days, indicating early to semi-early surgical intervention. Additional fixation of the sternum was required in two cases, demonstrating flexibility of the fixation strategy based on associated injuries.

Table 2. Intraoperative data

Patient No.	Operating time (min)	Anesthetic technique	Side of fixation	Fixed plates used (no.)	Estimated no. of fixed ribs	Days from trauma to surgery
1	95	Single-lumen	Right	3 plates (titanium)	3	3
2	105	Single-lumen	Right	4 plates	4	2
3	80	Single-lumen	Left	3 plates	3	2
4	120	Single-lumen	Right	4 plates	4	5
5	110	Single-lumen	Right	3 plates + 1 sternal plate	3 (ribs) + sternum	2
6	85	Single-lumen	Right	3 plates	3	3
7	140	Single-lumen	Right	4 plates + 1 sternal plate	4 (ribs) + sternum	3
8	100	Single-lumen	Left	3 plates	3	4
9	75	Single-lumen	Right	2 plates	2	5
10	180	Double-lumen	Right	3 plates	3	3
11	130	Single-lumen	Bilateral	4 plates (2 per side)	4	4
12	70	Single-lumen	Right	3 plates	3	2
13	95	Single-lumen	Left	4 plates	4	2
14	88	Single-lumen	Right	3 plates	3	3
15	105	Single-lumen	Right	3 plates	3	6

min: minutes, no.: number.

Table 3 illustrates favorable postoperative outcomes across the study. Lengths of stay in the ICU ranged from 2 to 6 days, while length of total hospital stay ranged from 7 to 15 days, consistent with the time of recovery following surgical stabilization. Only two patients required postoperative mechanical ventilation for one day each; thus, the cumulative ventilatory support was low. Complications were infrequent and only minor in nature: transient atelectasis in one patient and prolonged postoperative pain in another, both easily manageable with conservative measures. There were no major complications and no mortality in this series, further demonstrating the safety of the surgical approach. These results are consistent with rib fixation being feasible with low morbidity and excellent early recovery profiles.

Table 3. Postoperative data and outcomes (completed)

Patient No.	ICU LOS (days)	Total hospital LOS (days)	Post-op MV (days)	Total days MV (pre + post)	Post-op complications	Mortality
1	3	10	0	0	None	No
2	2	15	1	1	Mild atelectasis	No
3	2	7	0	0	None	No
4	5	15	2	2	None	No
5	2	8	0	0	None	No
6	3	7	0	0	None	No
7	2	8	0	0	None	No
8	3	9	0	0	None	No
9	4	14	0	0	None	No
10	4	12	0	0	None	No
11	3	14	0	0	None	No
12	2	8	0	0	None	No
13	2	7	0	0	None	No
14	3	8	0	0	None	No
15	6	15	1	1	prolonged pain	NO

ICU: intensive care unit, LOS: length of stay, Post-op: postoperative, MV: mechanical ventilation.

Table 4 summarizes the demographic and injury-related operative and postoperative variables for the cohort. All subjects were young to middle-aged males, and over half had injuries due to road traffic accidents. Right-sided fractures predominated, while the average burden of trauma was 7 ribs fractured. Operative metrics revealed that surgical performance had a mean operative time of approximately 106 minutes, an average of three ribs fixed per patient, and early surgical intervention (mean 3 days post-trauma). Postoperative outcomes revealed relatively short ICU and hospital stay with minor complications documented. No mortality was noted, further attesting to the efficacy and safety of the surgical stabilization protocol.

Table 4. Summary of key outcomes (n = 15)

Category	Variable	Value
Demographic Data	Age (years)	19–49 (31.6 ± 9.6)
	Sex (male)	15 (100%)
Mechanism of Injury	Road Traffic Accident	8 (53.3%)
	Fall from Height	5 (33.3%)
	Crush Injury	2 (13.3%)
Fracture Characteristics	Right-sided	10 (66.7%)
	Left-sided	3 (20.0%)
	Bilateral	2 (13.3%)
	No. of fractured ribs	4–10 (7.3 ± 1.7)
Operative Data	Preoperative ventilation	3 (20.0%)
	Operating time (min)	70–180 (105.6 ± 27.5)
	No. of fixed ribs	2–4 (3.2 ± 0.6)
	Days from trauma to surgery	2–6 (3.0 ± 1.0)
Postoperative Outcomes	ICU stay (days)	2–6 (3.3 ± 1.2)
	Hospital stay (days)	7–15 (10.5 ± 2.9)
	Postoperative complications	2 (13.3%) minor / 0 major
	Mortality	0 (0%)

n: number, No.: number, min: minutes, ICU: intensive care unit, data are presents as rang (Mean ± standard deviation) or as number (percent).

DISCUSSION

Surgical stabilization of rib fractures has developed into an increasingly effective intervention in the management of multiple or unstable rib fractures, with advantages over conservative treatment in terms of reduction of pain, respiratory complications, ventilatory requirements, and stay in the ICU, especially in high-energy trauma and flail chest cases [16]. While practices vary in regard to patient selection and timing of surgery in different centers, the current evidence, especially those in favor of early fixation within 72 hours, shows better outcomes with low rates of hardware complications [17]. Recent reviews and position statements highlight standardized indications and refinements in fixation techniques that collectively reinforce SSRF as a safe and beneficial approach to improvement in chest wall stability and recovery [18].

The demographic and injury-related characteristics of our cohort conform very closely to patterns from the contemporary literature on SSRF. In agreement with **Fugazzola *et al.*, Uchida *et al.***, and many large reviews[19,20], the overwhelming majority of our population consisted of young to middle-aged males, which reflects the global epidemiology of thoracic trauma, where males are disproportionately affected and high-energy mechanisms, especially RTAs, are dominant. More than half of our injuries were due to RTAs, a finding similarly reported in **Dai *et al.*** [21] and the **Sermonesi *et al.*,** [22] both of which identified RTAs as the leading cause of severe rib fractures.

Regarding the injury pattern, our cohort was dominated by right-sided fractures, with an average of 7 fractured ribs, which is in line with systematic reviews by **Peek *et al.*** [23] and **Beks *et al.*** [24] and which also identified multiple (≥5) rib fractures as the usual threshold beyond which operative stabilization is considered. Our results regarding an average of three fixed ribs per case are in line with the technique-oriented analyses of **Kim** [25] and **Abd-Elnaim *et al.*** [26], in which the selective stabilization of the most displaced or unstable ribs was commonly performed rather than fixation of all fractures. Operative variables in our series also compare well with the published data. Our mean operative time of ~106 minutes falls within the ranges described in both multicenter and narrative reviews: [24], typical durations range from 90 to 150 minutes depending on fracture complexity and approach. Most importantly, early SSRF (mean 3 days post-injury) was performed on our patients; this practice is strongly supported in the literature. Both narrative reviews and the guidelines from Chest wall injury society call for early intervention within 72 hours because it enhances ventilation, decreases pain, and expedites recovery [22] .

Outcomes in our series following surgery were promising and mirrored previous reports demonstrating the advantages of SSRF. Similar to the long-term series reported by **Uchida *et al.*** [20] and **Beks *et al.*** [24], our patients demonstrated short ICU and hospital lengths of

stay, reflecting the physiologic benefits of early chest wall stabilization. Complications in our series were minor in nature, with no evidence of hardware failure, similar to the low rates of complication reported in Korean and U.S. case series The lack of mortality in our study also follows previously published SSRF series [25,27] , which have consistently demonstrated low mortality rates when surgery is performed in appropriately selected trauma patients.

Taken together, our findings add to the growing body of literature that SSRF is effective and safe in adequately selected patients with multiple or unstable rib fractures. The demographic profile, mechanism of injury, operative timing, procedural metrics, and postoperative recovery in our cohort also mirror that of the previous studies quite closely, further indicating not only the safety but also the efficacy of the surgical protocol used in our study.

CONCLUSION

Chest wall reconstruction for major chest wall trauma appears to be a feasible and safe surgical intervention. In this series of 15 patients with multiple rib fractures, selective fixation with contoured titanium plates and locking screws effectively stabilized the chest wall and led to a low postoperative morbidity with minimal ventilatory support and no mortality. Early surgical intervention within three days of trauma has contributed to favorable outcomes, including reduced ICU and hospital stay .

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