

# Thoracoscopic-assisted rib plating (TARP): initial single-center case series, including TARP in the super elderly, technical lessons learned, and proposed expanded indications

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## ABSTRACT

**Objectives** The application of surgical stabilization of rib fractures (SSRF) remains inconsistent due to evolving indications and perceived associated morbidity. By implementing thoracoscopic-assisted rib plating (TARP), a minimally invasive SSRF approach, we expanded our SSRF application to patients who otherwise might not be offered fixation. This report presents our initial experience, including fixation in super elderly (aged  $\geq 85$  years), and technical lessons learned.

**Methods** This was a retrospective cohort study at a level 1 trauma center of admitted patients who underwent TARP between August 2019 and October 2020. Patient demographics, injury characteristics, surgical indications and outcomes are represented as mean $\pm$ SD, median or percentage.

**Results** A total of 2134 patients with rib fractures were admitted. In this group, 39 SSRF procedures were performed, of which 54% (n=21) were TARP. Average age was  $68.5\pm 16$  years. Patients had a median of 5 fractured ribs, with an average of 1 rib that was bicortically displaced, and 19% presented with 'clicking' on inspiration. Patient outcomes were a mean hospital length of stay (LOS) of  $11\pm 3.7$  days, mean postoperative LOS of 8 days, and mean intensive care unit LOS of  $6.6\pm 2.9$  days. Five patients were  $\geq 85$  years old with a mean age of  $90.8\pm 4.7$  years. They presented with an average of 4 rib fractures, of which an average of 2.4 ribs were plated. The procedure was well tolerated in this age group with a hospital LOS of  $9.4\pm 2$  days, and all five patients were discharged to a rehab facility with no in-hospital mortalities.

**Conclusion** Our experience incorporating TARP at our institution demonstrated feasibility of the technique and application across a broad range of patients. This approach and its application warrants further evaluation and potentially expands the application of SSRF.

## INTRODUCTION

With approximately 248 000 emergency department visits and 46 000 inpatient admissions annually in the USA,<sup>1,2</sup> rib fractures are common injuries accounting for significant morbidity and mortality. Sequelae of rib fractures occur frequently and may be divided into the categories of pulmonary complications, such as atelectasis, respiratory insufficiency,

pneumonia, and respiratory failure; or pleural space complications including pneumothorax (PTX), subcutaneous emphysema, hemothorax (HTX), and empyema. These complications lead to significantly increased morbidity and mortality, intensive care unit (ICU) admission, need for mechanical ventilation, and hospital length of stay.<sup>3,4</sup> These complications are likely potentiated in the elderly population, as demonstrated by increased mortality and an increased risk of pneumonia when compared with younger patients.<sup>5</sup> Management of patients with rib fractures has and continues to be largely supportive. Basic management is well outlined in the literature including the Eastern Association for the Surgery of Trauma and Western Trauma Association consensus guidelines. Multimodal pain management including epidural and regional anesthetic, aggressive respiratory therapy, HTX and PTX decompression with tube thoracostomy, video-assisted thoracoscopic surgery (VATS) evacuation of retained HTX are standard measures used to support patients.<sup>1,6,7</sup> Over the past 15 years, the management of rib fractures has increasingly evolved to include surgical stabilization of rib fractures (SSRF). This has been shown to have the potential to reduce pain, morbidity, and mortality, even in octogenarians.<sup>8</sup> However, the application of SSRF remains inconsistent due to evolving indications and the perceived morbidity associated with typical open operative approaches.

Rib plating has historically required an extra-thoracic (open) approach with extensive soft tissue disruption to expose the exterior rib surface for plate placement. In the geriatric population, this has resulted in reduced use of SSRF due to the perceived associated morbidity. Thoracoscopic-assisted rib plating (TARP), a minimally invasive SSRF approach, avoids the soft tissue disruption mandated by the traditional approach and could overcome these barriers.

We introduced TARP at our center in 2019 with the primary goal to expand SSRF application to patients who otherwise might not be offered fixation given the perceived morbidity of an open approach. Here, we present our initial experience with TARP, including fixation in the super elderly (aged  $\geq 85$  years) and report technical lessons learned and proposed expanded indications for SSRF afforded by the intrathoracic approach.

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## METHODS

A retrospective review of patients who underwent TARP at our level 1 trauma center between August 2019 and October 2020 was conducted. All surgeries in this series were performed with the RibFix Advantage Intrathoracic Fixation System (Zimmer BioMet, Jacksonville, Florida, USA). A single surgeon (FS) was present and involved in all 21 cases for procedural standardization, with a total of 3 surgeons participating.

Data surrounding each patient's hospital course was extracted from operating room records, radiographic images, medical chart, and our institution's internal trauma registry.

Demographic and injury variables included: age (years), gender, mechanism of injury, injury severity score (ISS), transfer from an outside hospital, presence of subcutaneous emphysema, PTX, and HTX present on admission. Rib fracture severity was captured using the number of rib fractures, number of ribs bicortically displaced, presence of flail chest, subjective rib clicking, and surgical indication. Outcomes included chest tube number, duration and output, ICU admissions, ICU LOS, hospital LOS (HLOS), in-hospital mortality, and hospital discharge disposition. Additional data stratification was performed on patients over 85 years of age. Data are presented as average mean±SD, median, or percentage.

## RESULTS

At our institution, out of 3659 admitted trauma patients, 2134 (58%) presented with at least one rib fracture between August 2019 and October 2020. Of those with rib fractures, 1037 (49%) were geriatric patients (78.6 years±8.9) and 1097 (51%) were younger than age 65 years (47.4 years±12.7). A total of 39 SSRF procedures were performed, of which 21 were TARP (54%).

### Patient demographics and injury characteristics

Average age (years) of patients was 68.5±16 (range 34–98) with 66% being male (table 1). Mechanisms of injuries were: fall (n=17), all-terrain vehicle (ATV) accident (n=2), motorcycle crash (n=1), and assault (n=1) with an average ISS of 14±6, and an average chest abbreviated injury score score of 3.14±0.35. Patients presented with a median of 5 fractured ribs, with an average of 1 rib that was bicortically displaced, and

19% presented with clicking on inspiration. Fifty-two per cent of patients presented with subcutaneous emphysema, 57% of patients had PTX, and 67% of patients had HTX (table 1).

### Surgical indications

Surgery was offered to patients with Pieracci/Dobin (P/D) indications. P/D indications include (1) radiographic or clinical flail chest, (2) three or more bicortically displaced fractures, (3) >30% volume loss of a hemithorax, and (4) failure of optimal medical management. Failure of optimal medical management included 4–6 hours or longer with two or more of the following: (1) numeric pain score >5, (2) incentive spirometry <50% predicted, (3) poor cough, and (4) respiratory rate >20.<sup>9</sup> SSRF was also performed if rib fractures penetrating parietal pleura was noted during VATS performed for HTX evacuation, continued air leak, further displacement of rib fractures, and failure to wean from respiratory support. Surgical decision was often made within the first 24 hours of hospitalization, but the timing of surgery was dependent on operating room and surgeon availability with a goal of fixation within 48–72 hours of admission.

Sixteen patients (76%) met P/D indications for surgery while five patients did not and presented with the following indications for SSRF: retained HTX with unstable rib fractures, continued air leak, and further displacement of rib fractures (table 2).

### Operative technique standardization

Review of operative reports demonstrated that standardization of technique occurred during these 21 operative cases, resulting in a consistent surgical approach. The patient was placed in a lateral decubitus position. Following initiation of single lung ventilation, the first thoracoscopic port site was created, most often at the fifth intercostal space at the anterior axillary line, and CO<sub>2</sub> insufflation commenced to assist in complete lung collapse. Fracture sites were identified through a combination of palpation of areas of instability and visualization of pleura injury.

Based on fracture location, a second thoracic port site (2–3 cm) was placed under direct visualization, inferior to the level of the rib fractures at the midaxillary line, most often at the eighth or ninth intercostal space. This small incision allowed for insertion of the RibFix Advantage plate. Finally, a skin incision was made over the involved ribs and small skin flaps created to reveal the underlying musculature. Port and incision placement is demonstrated in figure 1. In our experience, it was difficult to precisely locate the exact fracture site by palpation and observation alone unless the parietal pleura was disrupted.

Once the fracture sites were confirmed, the overlying muscle was spread to permit 1 cm of access to the rib on either side of the fracture. Under thoracoscopic visualization, holes were drilled through the bone at these two sites in a freehand fashion (without the set's clamp-drill guide). An 8 Fr red rubber catheter, with the ends cut at a 45-degree angle, were passed through each hole and out the chest through the caudal thoracic incision. Guidewires attached to the RibFix Advantage plate were then passed into the catheters and out through the drilled holes. The plate was introduced into the chest using the caudal thoracic incision under thoracoscopic visualization, taking attention not to cross wires or snag on anatomical structures.

Reduction of the fracture occurred as the plate was pulled into place. Pulling the wires apart slightly allowed the rib fracture site to distract and reduce as the plate was brought against the rib. The plate was secured with a washer and cap-screw on each of the two posts. After verifying secure fixation and rib stability,

**Table 1** Patient demographics and injury characteristics

Demographics and injury characteristics	All patients n=21
Age, average±SD, median, range	68.5±16, 67, 34–98
Gender—male, n (%)	14 (66)
Mechanism of injury, n (%)	
Assault	1 (5)
ATV accident	2 (10)
Fall	17 (81)
Motorcycle crash	1 (5)
Subcutaneous emphysema, yes, n (%)	11 (52)
HTX, yes, n (%)	14 (67)
PTX, yes, n (%)	12 (57)
ISS average±mean	14±6
MAX chest AIS score, mean±SD, median, range	3.14±0.35, 3, 3–4
# of rib fractures, mean±SD, median, range	5.2±1.8, 5, 2–9
# of ribs bicortically displaced, mean±SD, median, range	1.3±1, 1, 0–4
Rib clicking present, n (%)	4 (19)
Chest tube before surgery, n (%)	8 (38)

AIS, abbreviated injury score; HTX, hemothorax; ISS, injury severity score; PTX, pneumothorax.

**Table 2** Surgical indications

Presence Pieracci/Dobin indications for surgery	Number of patients (%)
Bicortical displaced fracture	2 (12.5)
Bicortical displaced fracture and respiratory decline	1 (6)
Bicortical and monocortical displaced fracture	3 (19)
Flail chest	3 (19)
Failure of pain control	2 (12.5)
Failure of pain control and respiratory decline	2 (12.5)
Respiratory decline despite epidural	1 (6)
Respiratory decline	2 (12.5)

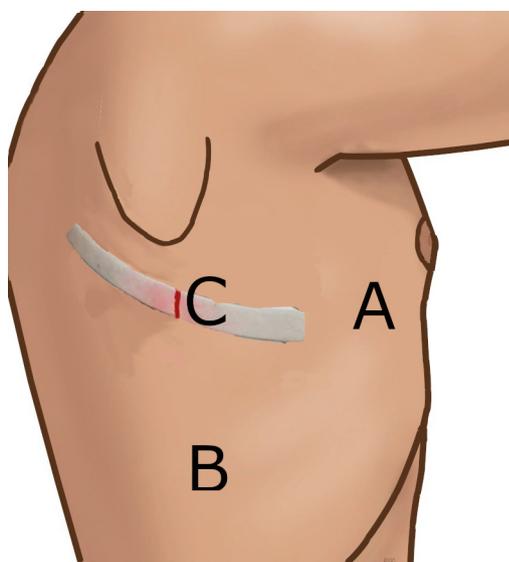
the posts are trimmed flush with the postcutter (diagonal cutting pliers). These steps are repeated for each fracture site. The minimal number of ribs to achieve chest wall stabilization were plated. The thoracic cavity was irrigated, an apical chest tube placed through the caudal thoracic incision, and the lung re-inflated under thoracoscopic visualization.

### Patient outcomes

Timing of surgery was dependent on operating room and surgeon availability. Mean time from presentation to surgery was 3 days (range 0–7). The mean number of ribs fixated per patient was 2.2 (range 1–5) with a mean operative time of 221.7 min (range 98–397) (table 3).

Patient outcomes were a mean HLOS of  $11 \pm 3.7$  days (range 6–24), mean postoperative LOS of 8 days (range 4–21), and mean ICU LOS of  $6.6 \pm 2.9$  days (range 4–16). Discharge disposition included 43% (n=9) to home, 33% (n=7) to skilled nursing facility, 15% (n=3) to rehab, and 5% (n=1) left against medical advice. One patient died after electing for comfort measures due to underlying metastatic lung cancer.

Five patients in our series were super elderly (aged  $\geq 85$  years) who had a mean age of  $90.8 \pm 4.7$  years (range 86–98). This group presented with an average of four rib fractures (table 4). Eighty per cent of this population met P/D indication for surgery. An average of 2.4 ribs were plated (range 2–4). The procedure was well tolerated with an HLOS of  $9.4 \pm 2$  days (range 6–12),



**Figure 1** Port and incision placement. (A) First port site at ~fifth intercostal space, anterior axillary line. (B) Second port site at eighth or ninth intercostal space, midaxillary line. (C) Skin incision over fractured ribs to be addressed.

**Table 3** Outcomes

Surgical and patient outcomes	All patients n=21
Mean time from hospital presentation to surgery $\pm$ SD, median, range (days)	$3 \pm 1.9$ , 2, 0–7
Mean operative time $\pm$ SD, median, range (min)	$221.7 \pm 77.8$ , 199, 98–397
Epidural yes, n (%)	17 (81)
# of ribs plated, average $\pm$ mean, median, range	$2.2 \pm 1.1$ , 2, 0–5
# of patients who underwent concurrent hemothorax evacuation, n (%)	14 (67)
# of chest tubes after surgery average $\pm$ mean, median	$1.35 \pm 0.5$ , 1
Duration in days for chest tube postsurgery average $\pm$ mean, median	$4.5 \pm 2.2$ , 4
Total # admitted to ICU, n (%)	14 (67)
Total ICU days average $\pm$ mean, median, range	$6.6 \pm 2.9$ , 4–16
Total # intubated at the time of rib fixation, n (%)	1 (5)
Ventilator days average $\pm$ mean, median, range	$3.7 \pm 1.5$ , 3.5
Total hospital days average $\pm$ mean, median, range	$11 \pm 3.7$ , 11, 6–24

ICU, intensive care unit.

**Table 4** Super elderly SSRF cohort

$\geq 85$ years of age	N=5
Age, average $\pm$ SD, median, range	$90.8 \pm 4.7$ , 90, 86–98
Gender—female, n (%)	4 (80)
ISS average $\pm$ mean	$11 \pm 3$
Mechanism of injury fall, n (%)	5 (100)
Subcutaneous emphysema, yes, n (%)	1 (20)
HTX (quantify), n (%)	
Trace	1 (20)
Small	1 (20)
Moderate	2 (40)
Large	1 (20)
PTX (quantify), n (%)	
None	2 (40)
Trace	1 (20)
Moderate	1 (20)
Large	1 (20)
Chest tube before surgery, n (%)	2 (40)
# of rib fractures, average $\pm$ mean, median, range	$4 \pm 1.1$ , 4, 2–5
# of ribs bicortically displaced, average $\pm$ mean, median, range	$1 \pm 1.1$ , 1, 0–3
Rib clicking present, n (%)	3 (60)
Met Pieracci/Dobin indication, n (%)	4 (80)
Epidural yes, n (%)	4 (80)
# of ribs plated, average $\pm$ mean, median, range	$2.4 \pm 0.8$ , 2, 2–4
Number of chest tubes after surgery average $\pm$ mean, median, range	$1.4 \pm 0.5$ , 1
Duration in days for chest tube postsurgery average $\pm$ mean, median	$3.4 \pm 1.7$ , 3
Total # admitted to ICU, n (%)	4 (80)
Total ICU days average $\pm$ mean	$5.8 \pm 1.5$ , 5.5, 4–8
Total hospital days average $\pm$ mean, median, range	$9.4 \pm 2$ , 10, 6–12
Mortality, n (%)	0 (0)
Discharged to skilled nursing facility, n (%)	5 (100)

HTX, hemothorax; ICU, intensive care unit; ISS, injury severity score; PTX, pneumothorax; SSRF, surgical stabilization of rib fracture.

and all five patients were discharged to a rehab facility with no in-hospital mortalities.

## DISCUSSION

TARP was selected for use in patients for whom age, multiple comorbidities or functional status rendered them suboptimal candidates for traditional SSRF. Typically, patients offered TARP have fewer fractures and fewer flail chests than those undergoing extrathoracic SSRF. Patients undergoing VATS for retained HTX with concomitant worrisome fracture morphology were offered TARP since the preparation for the two procedure is very similar and the SSRF added little time or morbidity to the procedure.

Outcomes for the procedure were favorable, with only one death in the series in a patient who elected for comfort care due to a cancer diagnosis. Postoperative hospital stay was also in-line with our extrathoracic SSRF patients with a mean stay of eight postoperative days. Furthermore, there were no surgical site infections or empyema in the series and no plates required removal or were dislodged with a minimal follow-up of 18 months.

Just as SSRF indications have expanded nationally, we have also expanded our indications to include patients with fewer fractures and non-flail patterns of injury. At our institution, we have found that patients with multiple rib fractures or specific fracture morphology benefit from SSRF.

Since our initial series, we have made two modifications to our original surgical approach. In addition to palpation of chest wall instability and direct visualization of intrathoracic pleura injury, we now use ultrasound to help identify fracture sites. The RibFix Advantage System has also updated the postcutter to be slimmer. These two changes have allowed us to forgo skin flaps and move toward minimal skin incisions. Additionally, patients with rib fractures are now given a Chest Trauma Score<sup>10</sup> and Pain, Inspiratory capacity, Cough Score<sup>4</sup> is tracked during hospitalization. We used these scores, along with clinician discretion, accounting for concomitant injury and comorbidities, to guide admission level of care as well as application and escalation of multimodal pain control, including regional analgesia as indicated.

## CONCLUSION

TARP is a newer method to stabilize fractured ribs. We report our first series of patients treated by this novel technique. This method allows the use of a smaller, muscle splitting incision with the potential of less surgically related postoperative pain. We primarily use TARP in situations where patient age and comorbidities preclude the use of open SSRF, or the patient requires a VATS for retained HTX/persistent PTX and has significant pleural disruption seen during VATS. This is a somewhat different population than our extrathoracic SSRF patients. We believe this minimally invasive approach allows us to offer the

benefits of SSRF to a group of patients that has traditionally been excluded from SSRF. In addition, TARP has allowed us to offer SSRF in our super elderly (aged  $\geq 85$  years) patients with rib fractures due to its minimally invasive approach.

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