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Surgical Stabilization of Rib Fractures With a Parallel-Hook Clamp System: A Retrospective Case Series of 18 Patients From a Brazilian Hospital

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Abstract

Introduction: Surgical stabilization of rib fractures (SSRF) is increasingly used for flail chest and severely displaced rib fractures, but data from Latin America on screwless clamp-type implants are scarce. This study describes the clinical profile, in-hospital outcomes, and patient-reported outcomes of patients who underwent SSRF with a parallel-hook clamp system.

Methods: This retrospective case series included patients who underwent SSRF with a parallel-hook clamp system at a hospital in southern Brazil and who attended a follow-up visit and completed a structured interview. Data from medical records and interviews were analyzed descriptively, and missing data were not imputed.

Results: Of 20 eligible patients, 18 were included (mean age 52.8 ± 13.4 years; 13 men, 72.2%). Car or motorcycle collisions caused 10 injuries (55.6%). A median of five ribs were fractured (range 1-7); 12 of 17 patients (70.6%) had multiple non-flail fractures, and three (17.6%) had flail chest. Twelve of 16 patients (75.0%) had a hemothorax or hemopneumothorax before surgery. Surgery was performed more than 72 hours after injury in 11 patients (61.1%). A median of three implants (range 1-5) was used per patient. The median hospital stay was 7.5 days (interquartile range 6.0-11.5), and eight patients (44.4%) required intensive care. Five patients (27.8%) had postoperative complications: pneumonia in three and reintervention associated with hemothorax in two. At follow-up, 10 of 15 patients (66.7%) reported no severe pain after discharge, six of 12 patients with a valid pain score (50.0%) were pain-free, and 10 of 15 (66.7%) were very satisfied with the treatment.

Conclusions: In this small series, SSRF with a parallel-hook clamp system was performed mostly for multiple non-flail fractures and usually more than 72 hours after injury. Hospital stay and complication rates were within the ranges reported for SSRF, and most patients reported little residual pain. Without a control group, these findings cannot establish a benefit over nonoperative management.

Categories: Trauma, General Surgery, Cardiac/Thoracic/Vascular Surgery
Keywords: chest wall injury, flail chest, patient-reported outcomes, rib fixation, rib fractures, surgical stabilization of rib fractures, thoracic trauma

Introduction

Thoracic injury affects about one-third of trauma patients and independently predicts 30-day mortality. Rib fractures are the most frequent thoracic injury and were present in 57% of patients with chest trauma in a Swedish trauma registry [1]. In Brazil, chest trauma predominantly affects young men injured in traffic collisions, and rib fractures were the leading thoracic injury at a regional referral center [2]. Mortality rises with each additional fractured rib [3], and many survivors report prolonged pain and disability. In a prospective cohort, 59% of patients had persistent chest wall pain and 76% had functional or work disability two or more months after injury [4].

Nonoperative management with multimodal analgesia, pulmonary hygiene, pleural drainage when needed, and ventilatory support remains the standard for most patients. In an international prospective cohort of 845 patients with three or more rib fractures treated nonoperatively, pneumonia occurred in 13.3%, and the median hospital stay was seven days [5]. Surgical stabilization of rib fractures (SSRF) aims to restore chest wall stability, reduce pain, and improve respiratory mechanics. In patients with flail chest, a randomized trial showed a shorter intensive care unit (ICU) stay and less noninvasive ventilation after SSRF [6]. In patients with severe non-flail fracture patterns, a multicenter controlled trial found lower pain scores at two weeks, better respiratory-related quality of life, and fewer pleural complications [7]. In contrast, a randomized trial of severe chest wall injury found a longer hospital stay and no quality-of-life benefit up to six months [8].

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Meta-analyses support SSRF mainly for flail chest, with less certain benefit for multiple non-flail fractures [9]. A 2025 meta-analysis of 47 studies found lower mortality with SSRF but no overall reduction in hospital or ICU length of stay [10]. Current guidelines recommend considering SSRF for flail chest, three or more ipsilateral severely displaced fractures, and failure of nonoperative management, ideally within 48-72 hours of injury [11,12]. Most of this evidence comes from North America, Europe, and Asia and is based on plate-and-screw systems. Few reports describe outcomes with screwless clamp-type implants or from Brazilian centers, and patient-reported outcomes after discharge are rarely described.

The objective of this study was to describe the surgical technique, clinical profile, in-hospital outcomes, and patient-reported pain and satisfaction among patients who underwent SSRF with a parallel-hook clamp system at a Brazilian hospital.

Materials And Methods

Study design and setting

This was a retrospective, observational, descriptive case series with a structured follow-up interview conducted at Hospital do Rocio, Campo Largo, Paraná, Brazil. The report follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [13] and, where data were available, the Chest Wall Injury Society (CWIS) recommendations for reporting SSRF studies [14].

Ethics

The study was approved by the Research Ethics Committee of Faculdade Evangélica Mackenzie do Paraná (CEP/FEMPAR; CAAE 90832425.3.0000.0103; approval number 7.784.434, August 21, 2025; amendment number 8.835.882, October 28, 2026). It was conducted in accordance with Resolutions 466/2012 and 510/2016 of the Brazilian National Health Council. All participants provided written informed consent before the interview. Data were coded and analyzed without personal identifiers.

Participants

Patients were identified from a list of all SSRF procedures provided by the hospital medical records department. The search covered procedures performed from 2020 to 2025, as defined in the approved protocol. The parallel-hook clamp system became available at our hospital in February 2023, so no eligible procedures were performed before that date. No other rib fixation system was used at our hospital during the study period. Patients who underwent SSRF with the parallel-hook clamp system between 2020 and 2025, attended a postoperative follow-up visit, and agreed to be interviewed were eligible. Patients with incomplete or illegible medical records, those who did not attend a postoperative follow-up visit, and those who declined to participate were excluded. Medical records were reviewed from September 1 to September 15, 2025, and follow-up interviews were conducted from October 1 to October 16, 2025. The included patients underwent surgery between February 16, 2023, and March 21, 2025.

Surgical technique

All patients underwent SSRF with the MarlexFix system (MB Indústria e Comércio de Produtos para Saúde Ltda., Cunha Porã, Santa Catarina, Brazil). This screwless clamp-type implant consists of a bar with sets of paired parallel hooks at each end, which are closed around the superior and inferior borders of the rib on both sides of the fracture using dedicated forceps supplied with the system. Implants of different lengths are available (Figure *1*).

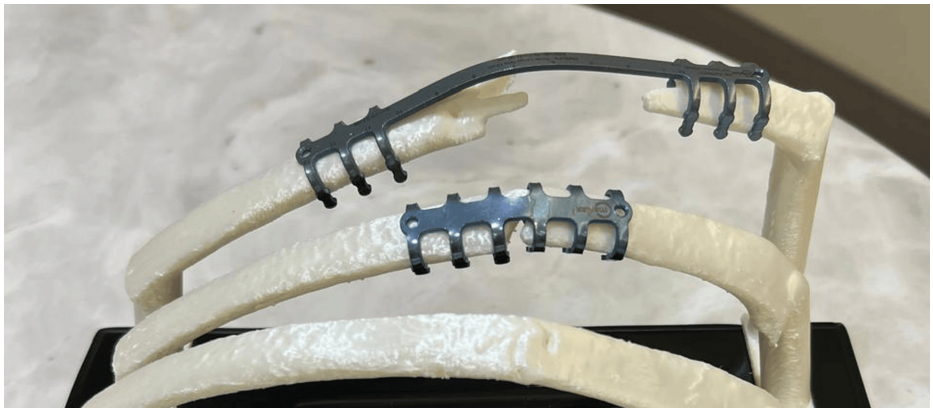


FIGURE 1: Parallel-hook clamp system

Demonstration model with two implants on synthetic ribs. Each implant consists of a bar with pairs of hooks that grasp the superior and inferior borders of the rib on both sides of the fracture. A longer implant (top) bridges a fractured segment, and a shorter implant (middle) spans a single fracture. The model was provided by the manufacturer.

All patients underwent chest computed tomography (CT) before surgery. Patients were placed in the lateral decubitus position on the side opposite the fractures, and the fractures were approached through a posterolateral thoracotomy approximately 10 cm long, positioned according to the fracture location on CT. In patients with more than one fracture in the same rib, the overlying muscles were divided to expose the fractures; in the others, the muscles were retracted and spared. Displaced fractures of ribs 3-10 that were accessible through the incision were fixed, usually with one implant per rib; additional implants were placed on the same rib when instability persisted (Figure *2*).

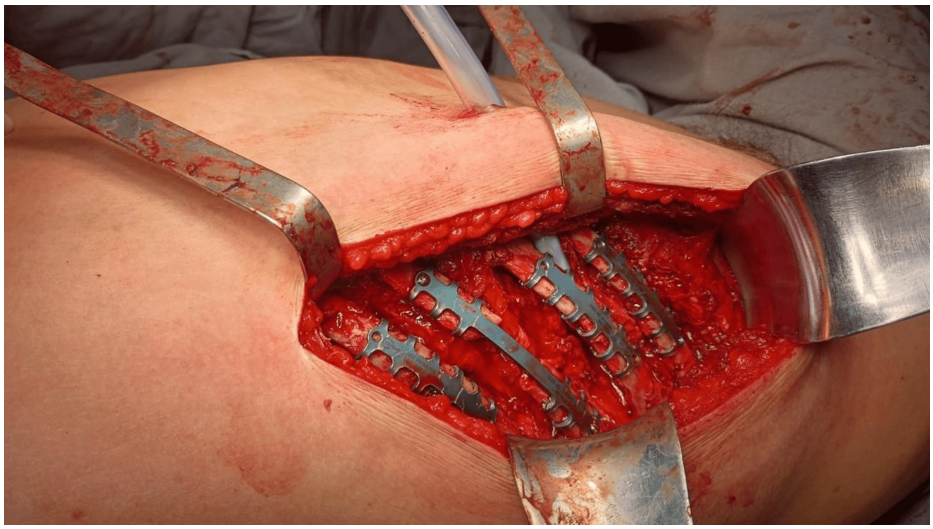


FIGURE 2: Intraoperative view of the parallel-hook clamp system

Left posterolateral thoracotomy with the chest wall muscles retracted. Four implants are fixed across fractures of adjacent ribs, with the hooks of each implant grasping the superior and inferior borders of the rib. A chest tube is visible at the top of the image.

Fixation was extrapleural. Three patients already had a chest tube placed before surgery; in these patients, single-lung ventilation was used, and the hemopneumothorax was aspirated through the chest tube incision during the operation. In the other patients, the pleura was not opened, single-lung ventilation was not required, and hemothorax and hemopneumothorax were managed by observation because thoracoscopy was not available at our hospital. Because the hooks encircle the rib, the intercostal neurovascular bundle is released from the rib at each fixation site before the implant is placed. Postoperative analgesia consisted of dipyrone (metamizole) 1 g every 6 hours, ketoprofen 100 mg every 12 hours, and tramadol 100 mg every 8 hours for the shortest possible time, with morphine 2 mg as rescue analgesia.

Variables and data sources

Data were collected on a standardized form (Appendix) that combined medical record review with a structured in-person interview conducted at the outpatient clinic by members of the research team. Demographic and clinical variables included age, sex, comorbidities, smoking history, and anticoagulant use. Injury variables included the mechanism of injury; fracture pattern; number, side, and location of fractured ribs on chest CT; preoperative pleural complications; and chest drainage before surgery. Fracture patterns were classified as isolated (one fractured rib), multiple (two or more fractured ribs without a flail segment), flail chest (three or more consecutive ribs fractured in two or more places), or bilateral. Operative variables included time from injury to surgery (less than 24 hours, 24-72 hours, or more than 72 hours), number of implants, and number of ribs with release of the neurovascular bundle. The surgical indication was obtained from the medical records and classified as flail chest, three or more ipsilateral displaced fractures, or pain refractory to analgesia. In-hospital outcomes included hospital length of stay, ICU admission and ICU length of stay, and postoperative complications. Patient-reported outcomes included severe pain at the fracture site after discharge, current pain on a 0-10 numeric rating scale, satisfaction with treatment on a five-point scale (very dissatisfied to very satisfied), and overall recovery on a five-point scale (very poor to excellent).

Questionnaire development

The structured questionnaire (Appendix) was developed by the research team for this study and combined items abstracted from medical records with patient-reported items. It was submitted to and approved by the research ethics committee as part of the study protocol. It was not pilot-tested or formally validated. Pain was measured using the 0-10 numeric rating scale, and satisfaction and overall recovery were measured using five-point ordinal scales.

Data handling and statistical analysis

Data were tabulated in Microsoft Excel (Microsoft Corporation, Redmond, WA, USA) and analyzed using Python 3 (Python Software Foundation, Wilmington, DE, USA). Several items were prefilled on the blank data collection form, including recalled preoperative pain and dyspnea, surgical technique, chest wall stability at the end of surgery, implant handling difficulty, and implant replacement. These items were not analyzed because prefilled values could not be distinguished from recorded responses. Pain scores outside the 0-10 range were treated as missing. Missing data were not imputed, and the denominator is reported for each variable. Categorical variables are presented as counts and percentages, and continuous variables as mean ± standard deviation or median with interquartile range (IQR) and range, according to their distribution. Outcomes were also described separately for patients who underwent surgery within 72 hours of injury and those who underwent surgery after 72 hours. Given the sample size and the absence of a comparison group, no inferential tests were performed.

Results

Patient and injury characteristics

Of 20 eligible patients, two declined to participate in the interview and were excluded, and 18 were included. Surgery dates ranged from February 2023 to March 2025. The mean age was 52.8 ± 13.4 years (range 31-83), and 15 patients (83.3%) were between 40 and 70 years old. Thirteen patients (72.2%) were men. Eight of 16 patients with available data (50.0%) had at least one comorbidity, most often hypertension or diabetes mellitus (four patients each). Six of 15 (40.0%) had a history of smoking, and two of 15 (13.3%) used anticoagulants, one of whom had sustained a traumatic limb amputation in the same event. Car or motorcycle collisions were the most frequent mechanisms of injury (n=10, 55.6%), followed by falls from height and bicycle falls (n=3 each, 16.7%) (Table *1*).

Characteristic	Value
Age, years, mean ± SD (range), n=18	52.8 ± 13.4 (31-83)
Male sex	13/18 (72.2)
Any comorbidity	8/16 (50.0)
Hypertension	4/16 (25.0)
Diabetes mellitus	4/16 (25.0)
Hypothyroidism	2/16 (12.5)
Chronic obstructive pulmonary disease	1/16 (6.3)
Cardiac arrhythmia	1/16 (6.3)
History of smoking	6/15 (40.0)
Anticoagulant use	2/15 (13.3)
Mechanism: car or motorcycle collision	10/18 (55.6)
Mechanism: fall from height	3/18 (16.7)
Mechanism: bicycle fall	3/18 (16.7)
Mechanism: roof collapse onto the patient	2/18 (11.1)
Pattern: multiple, non-flail	12/17 (70.6)
Pattern: flail chest	3/17 (17.6)
Pattern: isolated	1/17 (5.9)
Pattern: bilateral	1/17 (5.9)
Fractured ribs on CT, median (IQR; range), n=17	5 (3-6; 1-7)
Three or more fractured ribs	15/17 (88.2)
Hemothorax or hemopneumothorax before surgery	12/16 (75.0)
Chest drain before surgery	3/17 (17.6)

TABLE 1: Baseline characteristics and injury profile

Values are n/N (%) unless otherwise indicated; N is the number of patients with available data.

SD: standard deviation; IQR: interquartile range; CT: computed tomography

Twelve of 17 patients (70.6%) had multiple non-flail fractures, and three (17.6%) had flail chest. A median of five ribs was fractured per patient (IQR 3-6; range 1-7), and 15 of 17 patients (88.2%) had three or more fractured ribs. Before surgery, 12 of 16 patients (75.0%) had a hemothorax or hemopneumothorax, but only three of 17 (17.6%) had a chest drain placed before the operation.

Operative data and in-hospital outcomes

The surgical indication was three or more ipsilateral displaced fractures in 12 patients (66.7%), flail chest in three (16.7%), and pain refractory to analgesia in three (16.7%), including the patient with an isolated fracture. Surgery was performed within 24 hours of injury in two patients (11.1%), between 24 and 72 hours in five (27.8%), and after 72 hours in 11 (61.1%). A median of three implants was used per patient (IQR 2-4; range 1-5). In the 16 patients with both values recorded, 47 implants were placed for 72 fractured ribs. In the 13 patients with both items recorded, the number of ribs with neurovascular bundle release equaled the number of implants. The median hospital stay was 7.5 days (IQR 6.0-11.5; range 2-31). Eight patients (44.4%) were admitted to the ICU, with a median ICU stay of six days (range 3-18). The patient with the longest ICU and hospital stays (18 and 31 days) had sustained a traumatic amputation in the same event. Five patients (27.8%) had postoperative complications: pneumonia in three, including one who also developed complete atrioventricular block requiring a pacemaker, and reintervention in two, one for retained hemothorax and one for hemothorax with atelectasis (Table *2*).

Variable	Value
Indication: three or more ipsilateral displaced fractures	12/18 (66.7)
Indication: flail chest	3/18 (16.7)
Indication: pain refractory to analgesia	3/18 (16.7)
Injury to surgery, less than 24 hours	2/18 (11.1)
Injury to surgery, 24-72 hours	5/18 (27.8)
Injury to surgery, more than 72 hours	11/18 (61.1)
Implants per patient, median (IQR; range), n=16	3 (2-4; 1-5)
Implants placed/fractured ribs, n=16	47/72
Hospital stay, days, median (IQR; range), n=18	7.5 (6.0-11.5; 2-31)
ICU admission	8/18 (44.4)
ICU stay, days, median (range), n=8	6 (3-18)
Any postoperative complication	5/18 (27.8)
Pneumonia	3/18 (16.7)
Reintervention	2/18 (11.1)
Atelectasis	1/18 (5.6)
Complete atrioventricular block requiring a pacemaker	1/18 (5.6)

TABLE 2: Operative data and in-hospital outcomes

Values are n/N (%) unless otherwise indicated; N is the number of patients with available data.

IQR: interquartile range; ICU: intensive care unit

Patients operated on within 72 hours had a shorter median hospital stay and fewer complications than those operated on later, with similar rates of ICU admission (Table 3). These groups were small and differed in injury pattern, so no statistical comparison was made.

Outcome	Within 72 hours (n=7)	After 72 hours (n=11)
Hospital stay, days, median (IQR)	6 (6-10)	8 (5-11)
ICU admission, n (%)	3 (42.9)	5 (45.5)
Any complication, n (%)	1 (14.3)	4 (36.4)
Pneumonia, n (%)	1 (14.3)	2 (18.2)

TABLE 3: In-hospital outcomes by time from injury to surgery

Descriptive data only; no statistical tests were performed.

IQR: interquartile range; ICU: intensive care unit

Patient-reported outcomes

Interviews took place about six to 32 months after surgery. Ten of 15 patients (66.7%) reported no severe pain at the fracture site after discharge. Twelve patients had a valid current pain score: six (50.0%) reported no pain, three reported scores of 1-3, and three reported scores of 4-5 (median 0.5; range 0-5). Ten of 15 patients (66.7%) were very satisfied with the treatment, and 11 of 15 (73.3%) rated their overall recovery as

excellent (Table 4).

Outcome	Value
Severe pain at the fracture site after discharge	5/15 (33.3)
Current pain score (0-10), median (range), n=12	0.5 (0-5)
Current pain score 0	6/12 (50.0)
Current pain score 1-3	3/12 (25.0)
Current pain score 4-5	3/12 (25.0)
Satisfaction: very satisfied	10/15 (66.7)
Satisfaction: satisfied	3/15 (20.0)
Satisfaction: neutral	1/15 (6.7)
Satisfaction: very dissatisfied	1/15 (6.7)
Overall recovery: excellent	11/15 (73.3)
Overall recovery: good	2/15 (13.3)
Overall recovery: fair	2/15 (13.3)

TABLE 4: Patient-reported outcomes at follow-up

Values are n/N (%) unless otherwise indicated; N is the number of patients with available data.

Discussion

In this series of 18 patients, SSRF with a parallel-hook clamp system was performed mostly in middle-aged men with multiple non-flail fractures after traffic collisions, usually more than 72 hours after injury. All indications were among those recommended by current guidelines: flail chest, three or more ipsilateral displaced fractures, or failure of nonoperative management because of refractory pain [11,12]. The median hospital stay was 7.5 days, 44.4% of patients required ICU care, and 27.8% had a postoperative complication. At follow-up, half of the patients with a valid pain score were pain-free, and two-thirds were very satisfied with the treatment.

The demographic profile is similar to that of a multicenter randomized trial of 403 patients undergoing SSRF, in which the mean ages were 49.7 and 50.3 years and 68.2% and 70.8% of patients were men in the early and delayed groups, respectively [15]. It also matches the predominance of men injured in traffic collisions in Brazilian chest trauma [2].

Our complication rate and hospital stay fall within the ranges reported for SSRF, but they do not show that surgery was better than nonoperative care. A systematic review of 1,952 patients reported surgery- or implant-related complications in 10.3% and pulmonary complications in 30.9% after SSRF [16]. Mean hospital stays after SSRF were 10.2 and 12.4 days in the randomized trial cited above [15] and 13.0 days in a propensity-matched Asian cohort, compared with 8.0 days with conservative treatment [17]. In a large nonoperative cohort, the median stay was seven days, and pneumonia occurred in 13.3% [5]. These populations differ in injury severity and case mix, and randomized data comparing SSRF with nonoperative care remain mixed [6-8]. The 2025 meta-analysis found lower mortality with SSRF, no overall difference in pneumonia, and a slightly longer hospital stay, except when surgery was performed within 72 hours of injury [10]. Our data are therefore descriptive and should not be read as evidence of superiority.

The most notable finding is the timing of surgery: 61.1% of patients were operated on after 72 hours. Guidelines recommend SSRF within 48-72 hours of injury. When early surgery is contraindicated, they advise operating within three to seven days and note no evidence of benefit when surgery is performed after seven to 14 days [11]. In a multicenter study, each additional day before SSRF was associated with 31% higher odds of pneumonia and higher odds of prolonged ventilation and tracheostomy [18]. Early fixation within 48 hours reduced pneumonia (3.0% vs. 7.4%) and hospital stay in a randomized trial [15], and fixation within 72 hours was associated with less pneumonia (18% vs. 58%) in a retrospective series [19]. Fracture displacement also increases over the first days after injury [20]. In our series, patients operated on within 72 hours had a shorter median hospital stay (six vs. eight days) and fewer complications (one of seven vs. four of 11). These groups were small and unadjusted, but the pattern is consistent with the literature. Reasons for delay were

not systematically recorded; at least one patient was first treated at an emergency care unit and transferred later. Earlier referral of patients who meet guideline criteria could shorten this interval.

Pleural complications were frequent. Three-quarters of the patients with available data had a hemothorax or hemopneumothorax before surgery, but only three had a chest drain placed before the operation. In the other patients, pleural collections were observed because fixation was extrapleural and thoracoscopy was not available; both reinterventions were associated with hemothorax. The World Society of Emergency Surgery (WSES) and CWIS position paper does not recommend routine thoracoscopy during SSRF, but it advises considering thoracoscopy when a significant hemothorax or pneumothorax is detected preoperatively and recommends draining significant collections as part of the operation, through the SSRF incision or with thoracoscopic assistance [11]. The volume of the collections was not recorded, so we cannot determine how many were significant. In centers without thoracoscopy, drainage of significant collections through the thoracotomy or with a chest tube at the time of fixation could reduce the need for reintervention. Future reports should describe pleural management alongside the other core variables recommended by the CWIS [14].

Guidelines accept plates and screws, claw-shaped plates, and intramedullary splints for SSRF and advise choosing the method according to fracture type and location and surgeon experience [11]. Data on clamp-type systems are scarce. In our series, 47 implants were placed for 72 fractured ribs, reflecting fixation limited to displaced fractures of ribs 3 to 10 accessible through the incision. Because the hooks encircle the rib, the intercostal neurovascular bundle was released at each fixed rib. Whether this contributes to persistent pain is unknown and deserves study, since one-third of our patients reported severe pain after discharge.

Prolonged pain and disability are common after rib fractures, affecting more than half of patients in a prospective cohort [4]. In our series, half of the patients with a valid score were pain-free at follow-up, and satisfaction was high. However, satisfaction was measured using a nonvalidated questionnaire, the interval between surgery and interview varied from about six to 32 months, and there was no nonoperative comparison group. These outcomes therefore cannot be attributed to surgery alone.

These findings should be interpreted as descriptive and hypothesis-generating. Without a comparison group, the outcomes cannot be attributed to the implant or to surgery itself, and they may reflect patient selection and the natural course of rib fracture healing. Outcome assessment was incomplete: pulmonary function, return to work, and quality of life were not measured with validated instruments, and fracture healing and implant position were not assessed on follow-up imaging. Follow-up ranged from about six to 32 months, so long-term results, including late implant loosening or migration and chronic pain, remain uncertain. The implant also has specific technical features that need further evaluation, including release of the intercostal neurovascular bundle at each fixation site, which may expose the intercostal nerve to injury, and limited access through a posterolateral thoracotomy to fractures near the spine or sternum.

Limitations

This study has important limitations. The sample was small and came from a single center. The design was retrospective and had no control group, so no comparative inference is possible. Only patients who returned for follow-up and agreed to be interviewed were included, which may favor patients with better outcomes. Patient-reported data were collected using a nonvalidated questionnaire. Several items were prefilled on the data collection form and could not be analyzed, and some variables had missing data, so denominators vary. The volume of pleural collections, ventilator days, tracheostomy, mortality among all operated patients, and standardized functional outcomes were not available [14]. Prospective studies with consecutive patients, a nonoperative comparison group, validated instruments, and standardized definitions of pneumonia and other complications are needed.

Conclusions

In this single-center series of 18 patients, SSRF with a parallel-hook clamp system was performed through a posterolateral thoracotomy with extrapleural fixation, mainly for multiple displaced rib fractures, and most operations took place more than 72 hours after injury. The complication rate was 27.8%, the median hospital stay was 7.5 days, residual pain at follow-up was low, and most patients were very satisfied. These descriptive results suggest that the technique is feasible in this setting, but they do not establish its efficacy or a benefit over nonoperative management or other fixation systems. Patients operated on within 72 hours had shorter stays and fewer complications, but the numbers were too small for comparison. Earlier referral, attention to pleural collections at the time of fixation, and prospective comparative studies with standardized outcomes and imaging follow-up are needed to define the role of clamp-type SSRF.

Appendices

Structured questionnaire applied to patients who underwent surgical stabilization of rib fractures (translated from Portuguese)

Demographic information

1. Age

2. Sex: male, female, other

Health history

3. Do you have any pre-existing comorbidity or chronic medical condition? No; yes: hypertension, diabetes, heart failure, chronic obstructive pulmonary disease, active malignancy or other terminal illness, previous empyema, previous chest radiation, traumatic brain injury, other spinal injuries, other

4. Do you have a history of smoking? Yes, no

5. Do you use, or have you used, anticoagulants? Yes, no

Injury details

6. How did you sustain the rib fracture? Car accident, fall from height, sports injury, firearm, sharp object, occupational injury, spontaneous fracture, other

7. How many ribs did you fracture? One (isolated fracture), bilateral fractures, flail chest (three or more consecutive ribs broken in two or more places), other

8. Based on chest computed tomography, indicate the location, fracture type, and side of each affected rib (ribs 1-12). Location: posterior, posterolateral, lateral, anterolateral, anterior, or at or near the costochondral junction and sternum. Fracture type: undisplaced, offset, or displaced. Side: right or left.

Preoperative symptoms and status

9. Did you experience severe pain? Yes, no

10. What was your pain level on a scale from 0 (no pain) to 10 (unbearable pain)?

11. Did you have breathing difficulties? Yes, no

12. Did you have any of these complications before surgery? Pulmonary compromise, open fracture or contaminated cavity, pneumothorax, pleural effusion, hemothorax, hemopneumothorax, none of these

13. Before surgery, did you have a chest complication (pneumothorax or hemothorax) that required placement of a chest drain? Yes, no, do not know

14. What was the indication for surgery? Trauma or fracture, tumor resection, pectus deformity, other chest wall deformity, other

Treatment and interventions

15. Did you undergo surgery to stabilize the fractures? Yes, no

16. When was surgery performed in relation to the injury? Within 24 hours, within 72 hours, more than 72 hours

17. Which surgical technique was used? Externally applied fixation plates, internally applied fixation plates, minimally invasive (video-assisted thoracoscopic) technique, other

18. Date of the procedure

Surgical procedure with the parallel-hook fixation system

19. Was the procedure performed with the implant system designed for chest wall stabilization and reconstruction? Yes, no

20. Total number of parallel-hook fixators used, and ribs fixed

21. Approximate time of product analysis: one to eight hours, other

22. Qualitative assessment of chest wall stability at the end of the procedure, from 1 (worst) to 5 (best)

23. Was there any difficulty using the parallel-hook fixators? No; yes, number of implants involved

24. Did any implants need replacement because of intraoperative events? No; yes, number of implants

25. In how many ribs was the neurovascular bundle released?

26. In case of an intraoperative event, what technique or action was taken? Describe suggestions for improvement.

Recovery

27. Total length of hospital stay

28. Did you require an intensive care unit stay? No; yes, number of days

29. Did you have complications after surgery? None, pulmonary infection or pneumonia, need for mechanical ventilation, need for reintervention, pulmonary embolism, deep vein thrombosis, acute kidney injury, sepsis, other

30. After discharge, did you have persistent severe pain at the fracture site? Yes, no

31. What is your current pain level after treatment, from 0 to 10?

32. Were you able to return to your usual activities?

Final questions

33. How would you rate the effectiveness of the treatment you received? Very dissatisfied, dissatisfied, neutral, satisfied, very satisfied

34. How would you rate your overall recovery? Excellent, good, fair, poor, very poor

35. Do you have any comments or suggestions about the treatment?

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Marcelo Rizon, Monica Celezinsky, Kerima D. Cabrini, Bruno D. Alvarez, Dante A. Prado

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Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Research Ethics Committee of Faculdade Evangélica Mackenzie do Paraná (CEP/FEMPAR) issued approval 7.784.434. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **AI use statement:** The authors used Claude as follows: language polishing, translation, data cleaning or exploratory analysis in the entire manuscript and the coding of the data collection forms into the analysis dataset. The manuscript was drafted in English with AI assistance, using the authors' Portuguese thesis and the original data collection forms. The authors checked all descriptive statistics in the text and tables against the original forms, confirmed each reference against its DOI and source article, and reviewed all clinical interpretations and conclusions. The authors confirm that they have reviewed and verified all AI-assisted content and take full responsibility for the work. **Conflicts of**

interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** MB Indústria e Comércio de Produtos para Saúde Ltda. (Marlex) provided the demonstration model shown in Figure 1. The company had no role in the study design, data collection, analysis, interpretation, or writing of the manuscript. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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