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Infected hardware after surgical stabilization of rib fractures: Outcomes and management experience

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Abstract

Background—Surgical stabilization of rib fracture (SSRF) is increasingly used for treatment of rib fractures. There are few data on the incidence, risk factors, outcomes, and optimal management strategy for hardware infection in these patients. We aimed to develop and propose a management algorithm to help others treat this potentially morbid complication.

Methods—We retrospectively searched a prospectively collected rib fracture database for the records of all patients who underwent SSRF from August 2009 through March 2014 at our institution. We then analyzed for the subsequent development of hardware infection among these patients. Standard descriptive analyses were performed.

Results—Among 122 patients who underwent SSRF, most (73%) were men; the mean (SD) age was 59.5 (16.4) years, and median (interquartile range [IQR]) Injury Severity Score was 17 (13–22). The median number of rib fractures was 7 (5–9), and 48% of patients had flail chest. Mortality at 30 days was 0.8%. Five patients (4.1%) had a hardware infection on mean postoperative day 12.0 (6.6). Median Injury Severity Score (17 [13–42]) and hospital length of stay (9 [6–37] days) in these patients were similar to the values for those without infection (17 [13–22] and 9 [6–12] days, respectively). Patients with infection underwent a median (IQR) of 2 (2–3) additional operations, which included wound débridement (n=5), negative-pressure wound therapy (n=3), and antibiotic beads (n=4). Hardware was removed in 3 patients at 140, 190, and 192 days after index operation. Cultures grew only gram-positive organisms. No patients required reintervention after hardware removal, and all achieved bony union and were taking no narcotics or antibiotics at the latest follow-up.

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Author Contributions

Cornelius Thiels and Brian Kim designed the research. Cornelius Thiels, Johnathon Aho, and Nimesh Naik collected the data. Cornelius Thiels, Martin Zielinski, Henry Schiller, David Morris, and Brian Kim analyzed the data. All authors contributed to the writing and critical revision of the manuscript.

Conclusions—Although uncommon, hardware infection after SSRF carries considerable morbidity. With the use of an aggressive multimodal management strategy, however, bony union and favorable long-term outcomes can be achieved.

Level of Evidence—Therapeutic study, level V.

Keywords

flail chest; hardware infection; rib fracture; SSRF; surgical stabilization

Introduction

Worldwide, blunt trauma affects a substantial portion of the population, and more than 10% of these patients can expect to incur a rib fracture (1). Fixation of rib fractures with open reduction and internal fixation hardware, also known as surgical stabilization of rib fracture (SSRF), is being increasingly used to manage these injuries (2,3). The recently revised Eastern Association for the Surgery of Trauma guidelines recognize SSRF as a treatment option for flail chest (4). As a result, more institutions have started performing SSRF and are expanding the indications in selected patients (5). Although SSRF appears to be a safe procedure (6), the risks remain poorly described. As the use of SSRF increases, surgeons will need to be aware of associated complications and management options.

The reported risk of hardware infection after SSRF is low, but considerable variation exists (0%–10%) since most of the available data have been derived from case series (6–8).

Hardware infection, defined as a deep wound-space infection in the setting of implanted hardware, is well researched in the orthopedics literature (9), which suggests that infected hardware cannot be cured with the hardware in place (10). Removal of hardware in the presence of an unhealed fracture, however, results in poor outcomes. Therefore, standard practice is to temporarily decrease bacterial load, allowing fractures to heal in the presence of infection (11,12).

Given the limited information on outcomes of SSRF hardware infections and associated management strategies, we aimed to describe hardware infections after SSRF and determine incidence, risk factors, and outcomes in these patients and to develop a management algorithm.

Methods

Patient Cohort

After institutional review board approval, we searched a prospectively collected database for all patients older than 17 years who underwent SSRF at Mayo Clinic, Rochester, Minnesota, from August 2009 through March 2014. Additional data were abstracted from the medical records retrospectively.

Institutional SSRF Protocol

Our institution adopted SSRF for patients with flail chest in 2009. Preoperative testing for these patients includes blood gas and formal pulmonary function testing. Computed

tomography (CT) with 3-dimensional reconstruction is obtained to determine candidacy and for operative planning. Our guidelines recommend consideration of SSRF if patients meet certain criteria (Table 4). We attempt to perform SSRF early in the hospital course, as long as the patient can tolerate lateral decubitus positioning and if other injuries are not of higher priority.

SSRF is performed through a thoracotomy incision over the most severely displaced fractures. Typically, all fractures accessible through this incision are repaired. Muscle-sparing approaches are used when feasible. We use the RibLoc Rib Fracture Plating System (Acute Innovations) or the MatrixRIB Fixation System (Synthes). Patients receive one preoperative antibiotic dose unless otherwise indicated. Previously placed tube thoracostomies (TTs) are removed and replaced. If possible, the old TT site is excluded from the field, and we routinely use an iodine-impregnated incision drape.

Postoperative management includes pain management, aggressive pulmonary hygiene, and routine TT management. Follow-up includes clinic visits at 1, 3, 6, and 12 months, with chest radiographs and pulmonary function tests in patients with flail chest SSRF, and a clinic visit at 4 to 6 weeks with chest radiographs in patients with nonflail chest.

Statistical Analysis

We compared characteristics and outcomes between patients with and without hardware infection using descriptive statistics. Normally distributed data are expressed as mean (SD), and nonnormally distributed data are expressed as median (interquartile range [IQR]).

Results

Overall Patient Characteristics

We identified 122 patients who underwent SSRF during the study period, of whom 72.9% were men. Mean (SD) age was 59.5 (16.4) years, and median Injury Severity Score (ISS) was 17 (IQR, 13–22). Median body mass index was 30 (IQR, 27–43) kg/m²; 18% were diabetic, 28% were smokers, and 8% had chronic obstructive pulmonary disease. The median number of rib fractures was 7 (IQR, 5–9), and 48% had a flail chest. Median time to SSRF was 4 (IQR, 2–6) days, at which time a mean of 4.6 (2.0) ribs were plated. Operating room time was 166 (64) minutes. Median length of stay was 9 (IQR, 6–12) days, with a median intensive care unit stay of 1 (IQR, 0–4) days. Pneumonia developed in 19 patients (15.6%). One patient died within 30 days (0.8%) of a stroke secondary to a vertebral injury. Among all patients, the median follow-up was 7.3 (IQR, 3.2–13.1) months, with 94.3% (n=115) having at least 1 month of follow-up and 64.8% (n=72) having at least 6 months' follow-up.

Infection After SSRF

Among the 122 patients, 5 (4.1%) had a hardware infection, which was diagnosed on median postoperative day 12 (IQR, 7–18). The mean age of these 5 patients was 49.6 (13.1) years, and patients had a median of 7 (IQR, 5–9) fractured ribs. One patient was a smoker, and none had diabetes mellitus or chronic obstructive pulmonary disease. Some of the

patients with hardware infections had a high ISS, but the median ISS, 17, was the same as that for noninfected patients (Table 1). Two of the patients with infected hardware had a TT placed before arrival to the hospital, compared with 14 patients in the noninfected group.

Among the 5 patients with infection, 3 had purulent drainage and 2 had systemic signs of infection. One patient initially had a superficial wound infection that progressed to hardware infection. Cultures grew gram-positive organisms in all patients (Table 2).

All 5 of the patients underwent operative management of their infection on median postoperative day 14 (IQR, 13–19) after index SSRF, with a median of 2 (IQR, 2–3) additional operations. One patient had partial removal of the hardware on the first reoperation along with irrigation and negative-pressure wound therapy (NPWT). The other 4 patients underwent antibiotic bead placement; NPWT was used in 3 patients. All patients initially received intravenous antibiotics, followed by suppressive (oral or intravenous) antibiotics. Three patients eventually underwent complete hardware removal a mean of 190 (29) days after SSRF (Table 3). Reasons for hardware removal included patient preference for cessation of suppressive antibiotics (n=2) and pleural thickening on CT imaging concerning for ongoing inflammation or infection in the setting of bony union (n=1). The other 2 patients elected to stop antibiotics and did not undergo complete hardware removal, with neither having evidence of infection at last follow-up. All patients with infected hardware had at least 6 months' follow-up and were alive, off antibiotics, and had resolution of the infection. No patient underwent reintervention for stabilization of fracture nonunion, and bony healing was demonstrated on CT in all patients.

Discussion

Our study demonstrates that the incidence of hardware infection after SSRF is relatively low (4.1%). When hardware infection is encountered, our proposed multifaceted management strategy—including wound irrigation and débridement, temporary closure with NPWT, antibiotic-impregnated bead placement, and suppressive antibiotic therapy—appears to result in acceptable outcomes for both source control and long-term bony union.

Rate of Hardware Infection After SSRF and Potential Risk Factors

The rate of hardware infections after elective joint replacement in most centers ranges between 0.5% and 2% (13–15) and can be 2% to as high as 20% in open reduction and internal fixation for trauma (16). Rib fractures are rarely open fractures, but they do often communicate with the airways (via pulmonary lacerations) or with the environment (via TT), and therefore patients with SSRF may be at increased risk for infection. Wiese et al (6) reported on 2 patients with hardware infection after SSRF; both had diabetes mellitus and had sustained severe trauma with extensive soft-tissue contusions. Bacterial translocation from TTs placed before SSRF has been suggested as a mechanism. We cannot eliminate this hypothesis and suggest further study of antibiotic use before TT in patients who may require SSRF. In addition, we have recently placed antibiotic beads prophylactically in 2 patients with pre-existing TT, and although there is only anecdotal evidence at this time, this strategy may be of use in high-risk patients (17,18).

Definition of Hardware Infection After SSRF

There is no consensus on the definition or presentation of hardware infections after SSRF. For patients in our cohort, the hardware infection presented within the first month. Hardware infection should be suspected if incisions used for SSRF show evidence of spreading erythema, induration, skin separation, or purulent drainage. It is important to note that not all hardware infections present with a superficial infection, and thus surgeons should have a high index of suspicion if patients have worsening pain or evidence of systemic infection after SSRF. Delayed or late-onset infections, to our knowledge, have not been reported after SSRF.

Proposed Management Algorithm

On the basis of our study, we propose a management algorithm for hardware infection after SSRF (Figure 1). Cases in which only superficial skin infection is suspected should undergo wound exploration. If superficial skin infection is confirmed without evidence of deep-tissue seeding, tissue cultures should be obtained and the wound should undergo débridement, irrigation, and NPWT, with repeated operative débridement until delayed primary closure can be achieved. For deep space infections, full exploration and débridement is indicated. We routinely irrigate the wound with a pulse irrigator and use nonbiodegradable antibiotic beads placed on a polypropylene stringer adjacent to the hardware (19). In the absence of specific culture information, beads should contain a “double dose” of vancomycin (2 g) and gentamicin (2.4 g) mixed in bone cement and remain in place for 2 to 7 days, depending on the degree of contamination, exudate, and necrosis encountered.

Temporary wound closure with an NPWT should be considered in these patients (20). No attempt should be made to close muscular layers until there is no evidence of infection. If wounds remain infected, we consider long-term bead placement for 2 to 3 months, followed by replacement or removal once bony healing is demonstrated. Once the wound appears clean, primary closure with an incisional NPWT can be considered.

Antimicrobial Therapy

According to the orthopedic literature, *Staphylococcus* accounts for about 40% of orthopedic hardware infections; this is similar to our rate of staphylococcal infections after SSRF (60%). Beta-hemolytic streptococci (9%) and anaerobes (6%) are less frequently cited as pathogens, which is consistent with our findings (14). Although gram-positive coverage appears to be important, we propose that all wound explorations obtain aerobic/anaerobic cultures with sensitivities and that infectious disease consultation be considered. Our patients are initially treated with a 4- to 6-week course of intravenous antibiotics, at which point a transition to oral suppressive therapy may be appropriate until hardware removal.

Hardware Removal

Ideally, infected hardware should be removed only after bony healing of rib fractures has taken place. Our experience suggests that this will not occur until at least 3 months after stabilization; however, bony healing should be assessed by chest CT before definitive removal. In our study, 2 patients did not undergo complete hardware removal. Wiese et al (6) also demonstrated suitable outcomes in 2 patients who underwent partial removal. We

advocate that if hardware must be removed early, then partial hardware removal may be a suitable option.

Limitations

This study has several limitations. The prospective nature of this database allows for identification of patients with hardware infection. However, additional data were obtained retrospectively, and it is possible that not all complications are recorded, or patients may have been treated at different centers. Our ability to make generalizable conclusions regarding our algorithm is limited. Our small sample size also limits the conclusions that can be made—specifically, the study is not powered to make direct comparisons between the infected and noninfected cohorts. However, we believe there is utility in having an experience-driven management algorithm available to help others manage this uncommon and potentially morbid complication. Although the median follow-up was longer than 6 months, the literature suggests that patients remain at risk for infection for up to 10 years after hardware placement. Thus, our incidence of hardware infections after SSRF may underestimate the true incidence of hardware infections.

Conclusion

Although rare, hardware infection after SSRF carries substantial morbidity and necessitates additional operations and long-term antibiotics. Favorable outcomes result from a combination of surgical, antibiotic, and wound care strategies.

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Abbreviations

CT	computed tomography
IQR	interquartile range
ISS	Injury Severity Score
NPWT	negative-pressure wound therapy
SSRF	surgical stabilization of rib fracture
TT	tube thoracostomy

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Figure 1.

Proposed Management Algorithm for Suspected Hardware Infection After Surgical Stabilization of Rib Fracture (SSRF). CT indicates computed tomography; IV, intravenous; ±, with or without.

Table 1

Demographics, Preoperative and Operative Factors, and Outcomes of Patients Undergoing SSRF With and Without Hardware Infection

Variable	Patient Group ^a	
	No Infection (n=117)	Hardware Infection (n=5)
Demographics		
Men	87	2
Age, y	59 (50–73)	56 (37–59)
BMI, kg/m ²	30 (27–34)	35 (28–39)
Diabetes mellitus	22	0
Current smoker	33	1
COPD	10	0
Preoperative factors		
ISS	17 (13–22)	17 (13–42)
No. of ribs fractured	7 (5–9)	7 (5–8)
Flail chest	54	4
Pre-SSRF pneumothorax	72	5
Pulmonary contusion	49	2
Pre-SSRF TT	42	2
Prophylactic antibiotics at time of pre-SSRF TT	5	0
Prehospital TT	14	2
Operative factors		
Time to repair, d	4 (2–6)	3 (2–20)
No. of ribs plated	5 (3–6)	5 (3–5)
OR time	166.9 (64.7)	168.0 (53.5)
Outcomes		
Postoperative morphine equivalents	668.0 (497.3)	499.3 (407.1)
ICU LOS, d	1 (0–3)	5 (3–5)
Hospital LOS, d	9 (6–12)	9 (6–37)
30-day mortality	1	0

Abbreviations: BMI, body mass index; COPD, chronic obstructive pulmonary disease; ICU, intensive care unit; ISS, Injury Severity Score; LOS, length of stay; OR, operating room; SSRF, surgical stabilization of rib fractures; TT, tube thoracostomy.

^aValues are No. of patients, mean (SD), or median (interquartile range).

Table 2

Bacterial Culture Results From Infected Hardware					
Gram-Positive Bacteria	Patient				
	A	B	C	D	E
Aerobic					
<i>Staphylococcus aureus</i> (methicillin resistant)		X			
<i>aureus</i> (methicillin sensitive)		X			
<i>epidermidis</i>				X	
<i>Streptococcus</i> , group A					X
Anaerobic					
<i>Peptostreptococcus finegoldii</i> (<i>magna</i>)			X		

Table 3
Operative Data and Management Course Among Patients With Infected Hardware After SSRF

Treatment or Operative Factor	Patient				
	A	B	C	D	E
Pre-SSRF TT	No	No	Yes ^a	No	Yes ^a
Pre-TT antibiotics	N/A	N/A	No	N/A	No
Flail chest	Yes	Yes	No	Yes	Yes
No. of ribs stabilized	5	5	3	5	3
Duration of index operation, min	217	176	198	134	111
POD infection was noted	5	20	18	7	12
First return to OR, POD	14	22	18	7	13
Wound vacuum-closure device	Yes	Yes	Yes	Yes	No
Antibiotic beads	Yes	No	Yes	Yes	Yes
No. of returns to the OR	2	2	2	3	3
Hardware removed, POD	192	22 ^b	140	N/A	190

Abbreviations: N/A, not applicable; OR, operating room; POD, postoperative day; SSRF, surgical stabilization of rib fractures; TT, tube thoracostomy.

^aTT placed in nonhospital setting.

^bPatient underwent removal of 1 plate, but the remainder of hardware was left in situ.

Table 4**Indications for Surgical Stabilization of Rib Fractures**

1	Rib fractures associated with respiratory failure requiring mechanical ventilation
2	A nonintubated patient with deteriorating pulmonary function (with or without pulmonary contusion in association with rib fractures)
3	Nonflail rib fracture(s), with or without significant (at least 1 rib width) displacement
4	Impalement of ribs into pulmonary parenchyma or other solid organs (eg, hepatic or splenic parenchyma) or diaphragm
5	Substantial and refractory pain associated with rib fractures
6	Anticipated nonunion or malunion of rib fracture(s)