Original Article

Door to door in 24: factors that allow surgical stabilization of rib fractures within 24 hours of admission

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Background: Surgical stabilization of rib fractures (SSRF) should be performed early after injury. Factors that influence timing remain unknown. Our objective was to identify inherent variables that allow for early identification and treatment. We hypothesized that certain demographic, injury, and logistical factors are associated with SSRF <24 hours from admission.

Methods: Retrospective review from an urban level 1 trauma center (10/2010–8/2019). Patients were grouped as SSRF <24 hours from admission *vs.* ≥24 hours. Demographics, transfer from an outside hospital (OSH), timing documentation, injury descriptors, surgeon on-call, and operative surgeon were collected. SSRF for chronic non-union was excluded.

Results: Data from 173 patients were analyzed. Eighty-five patients (49%) were in the <24 hours group and 88 (51%) were in the ≥24 hours group. Baseline demographics were similar between groups. Injury severity was significantly higher in the late group: increased Injury Severity Score (ISS; 16.5 *vs.* 21.0, P<0.01), lower Glasgow Coma Scale (GCS; 15 *vs.* 14, P<0.01), more rib fractures (7 *vs.* 9, P=0.01), and increased incidence of face (6% *vs.* 16%, P=0.03), spine (22% *vs.* 47%, P<0.01), and pelvis fractures (8% *vs.* 25%, P<0.01). Patients admitted on a Wednesday were more likely to undergo early SSRF as compared to other days of the week (P=0.01) There was also a shorter time from the decision to perform SSRF to the actual operation in the early group, as compared to the late group (13 *vs.* 44 hours, P<0.01). Fifty (28.9%) SSRF cases were performed by the on-call surgeon; this percentage did not differ in the early *vs.* late group (33% *vs.* 25%, P=0.25). Patients needing pelvic fixation were more likely to be in the late group. Patients transferred from an OSH for SSRF were more likely to be in the early group (29% *vs.* 10%, P<0.01). Finally, likelihood of early surgery increased with increasing study year.

Conclusions: Approximately one-half of SSRF cases were performed within 24 hours of admission. Factors that influence surgery within 24 hours of admission appear related to overall injury severity and systems issues, including day of admission, transfer from another facility, additional urgent pelvic surgery, and institutional experience with SSRF. Surgeon availability did not drive this disparity.

Keywords: Surgical stabilization of rib fractures (SSRF); rib fractures; timing; operative treatment

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Introduction

Rib fractures remain common, occurring in 10–20% of all trauma patients and can result in malunion, chronic pain, pneumonia, and death (1-3). Current data suggest that surgical stabilization of rib fractures (SSRF) benefits patients with flail chest (4,5). The exact benefit of SSRF in patients with a non-flail fracture pattern remains a matter of debate and studies in this population are conducted extensively (6-11).

As experience with SSRF has grown, timing of surgery has shifted significantly from late (>48–72 hours from admission) to early surgery (<24 hours from admission). Scoring systems, such as the radiographic RibScore and the Sequential Clinical Assessment of Respiratory Function (SCARF) score, have been developed in part to aid in early identification of patients who would benefit from SSRF (12,13). Additionally, earlier time to surgery has been associated with both shorter surgery and improved outcomes, and recent studies have shown that late SSRF defined as 2–3 days after admission, might actually correlate with outcomes inferior to nonoperative management (14,15).

Currently, factors that influence the ability to achieve SSRF within the early timeframe remain unknown. Although intuitively it would appear that injury severity is the most important consideration, it is likely that additional parameters, such as operative room and surgeon availability, are involved. Our objective was to identify the inherent factors that allow for early identification and treatment of chest wall injury patients eligible for SSRF. We hypothesized that certain demographic, injury, and logistical factors are associated with accomplishing SSRF within 24 hours of admission. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-857/rc).

Highlight box

Key findings

- Factors which impact surgical stabilization of rib fractures (SSRF) <24 hours are related to overall injury severity and systems variables including day of admission, transfer from outside hospital and additional urgent procedures as well as institutional experience with SSRF.

What is known and what is new?

- Variables that influence the ability to achieve SSRF within the early timeframe remain unknown.
- This study identifies inherent factors that allow for early SSRF in patients with rib fractures.

What is the implication, and what should change now?

- When assessing patients with rib fractures for early SSRF, surgeons should be aware of both injury-related factors and system issues. Future studies might evaluate whether combining operative cases with other subspecialties provide a clinical benefit when including SSRF in the damage control bracket.

Methods

A retrospective review was performed of a prospectively-maintained SSRF database at Denver Health Hospital, Denver, CO, USA from October 2010 to August 2019. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was sent for IRB approval and exempted from IRB review by the Colorado Multi-Institutional Review Board (No. IRB00000650). Operative indications for SSRF were ≥3 bicortically displaced rib fractures, radiographic or clinical flail chest, pulmonary derangement and/or poorly controlled rib pain despite optimal medical management, including use of loco-regional analgesia as well as ketamine and lidocaine infusions. Operative technique was standardized to include fiber-optic bronchoscopy, single lung ventilation, muscle sparing exposure, open reduction and internal fixation (ORIF) of ribs 3–10, pleural cavity irrigation with concomitant thoracoscopic drainage of hemothorax, and tube thoracostomy placement (16). Exclusion criteria were: (I) younger than 18 years; (II) acute ventilator-dependent respiratory failure; (III) severe pulmonary contusion, defined as Blunt Pulmonary Contusion 18 (BPC 18) score >12; (IV) spinal cord injury; (V) inability to accomplish activities of daily living prior to injury; and (VI) life expectancy less than 6 months.

Patients were divided into two groups: those who underwent SSRF <24 hours from admission *vs.* those who underwent SSRF ≥24 hours from admission. Demographic data, including age (years), gender, Injury Severity Score (ISS), body mass index (BMI; kg/m^2), history of asthma, chronic obstructive pulmonary disease, and smoking were collected and analyzed. Timing documentation, such as date of injury, date of admission, operative dates and times, duration spent in the emergency department (ED), transfer from outside hospital (OSH), and time of decision to take patient for SSRF, were collected and analyzed. Time of decision for SSRF was defined as the first mention in the patient's medical record that the treatment of their rib fractures would include operative management.

Injury data, such as mechanism, RibScore, BPC 18 score (17), ISS, Glasgow Coma Scale (GCS), number and location of rib fractures, additional non-rib injuries/surgeries, and surgeon data, such as surgeon on-call and operative surgeon, were also collected and analyzed.

Due to the prospectively-maintained database, there were no missing variables. As this was a retrospective database study, no formal sample size was calculated and no informed consent was required.

Statistical analysis

Data were analyzed using SAS version 9.4 (SAS, Inc., Carey, NC, USA). Continuous data are expressed as median (interquartile range) and categorical data as number (%). Differences in continuous data were assessed using Wilcoxon-Mann-Whitney test and differences in categorical data were assessed using the chi-squared test, unless expected cell counts were <10, in which case Fischer's exact test was used. Statistical significance was defined as P<0.05.

Results

One hundred and seventy-eight records were identified; 5 were excluded for incomplete data or operation for chronic nonunion, leaving 173 cases to analyze. Eighty-five patients (49%) were in the <24 hours group and 88 patients (51%) were in the ≥24 hours group. Baseline demographics were similar between groups, except for asthma, which although relatively rare, was more prevalent in the early group (14% *vs.* 5%, P<0.03) (*Table 1*).

Except for fall, which was higher in the early group (38% *vs.* 20%, P=0.01), mechanism of injury did not differ significantly between the two groups. More patients were transferred from an OSH in the early group but this finding was not statistically significant (43% *vs.* 35%, P=0.34). Injury severity was significantly higher in the late group: median (interquartile range) increased ISS [16.5 (12.0) *vs.* 21.0 (12.0), P<0.01], lower GCS [15 (0.0) *vs.* 14 (4.8), P<0.01], high number of rib fractures [7 (4.5) *vs.* 9 (6.0), P=0.01], and increased incidence of face (6% *vs.* 16%, P=0.03), spine (22% *vs.* 47%, P<0.01), and pelvic fractures (8% *vs.* 25%, P<0.01).

A total of 18 (21%) patients in the early group required mechanical ventilation *vs.* 46 (52%) in the late group (P<0.01). Median hours of time spent in ED before admission to the ward was similar between groups [2.2 (2.2) *vs.* 1.8 (2.6), P=0.42].

Of the patients that arrived from OSH, more were transferred specifically for SSRF *vs.* for further work-up and management of other injuries in the early group (29% *vs.* 13%, P<0.01) while the reverse occurred in the late group (10% *vs.* 25%, P<0.01). While patients were hospitalized, additional surgeries beyond SSRF did not differ between the two groups except for pelvic fixation, which occurred more in the late group *vs.* the early group (15% *vs.* 4%, respectively, P<0.02). The day of the week in which patients underwent SSRF did not differ between the two groups, however, patients admitted on a Wednesday were more likely to undergo early SSRF as compared to other days of the week (P=0.01) (*Figure 1*). Patients admitted on a Thursday or a Sunday had a significantly higher ISS in the late group *vs.* the early group [Thursday early *vs.* late: 10 (10.8) *vs.* 21 (9.5), P=0.03 and Sunday early *vs.* late: 15 (9.3) *vs.* 22 (16.0), P=0.01]. There was also a shorter time from admission to the actual operation in the early group, as compared to the late group (13 *vs.* 44 hours, P<0.01). Fifty (28.9%) SSRF cases were performed by the on-call surgeon; this percentage did not differ in the early *vs.* late group (33% *vs.* 25%, P=0.25). Lastly, time from admission to SSRF as a function of year from 2010 to 2019, progressed to be shorter as the years went on (*Figure 2*).

Discussion

This retrospective review looked at the processes that influence the timing of SSRF for patients admitted with severe rib fractures. Overall, patients who were able to undergo SSRF within 24 hours were less severely injured, with mechanisms of injury that were of a lower energy of impact, were admitted midweek on a Wednesday, and/or were transferred to our facility specifically for SSRF. Patients who required additional resuscitation and/or urgent stabilization of their other injuries upfront were more common in the late group, even though the decision to SSRF had already been made. Finally, as our center's experience with SSRF increased, more patients underwent early surgery, suggesting that institutional familiarity with the surgery impacts time to the operating room (OR) (18,19). Overall, our data suggest that the ability to undergo very early SSRF is dependent upon multiple, inter-related parameters.

Our findings have implication for interpreting the literature surrounding timing of SSRF. Specifically, this predominantly retrospective literature has found that earlier SSRF is associated with improved outcomes, the implication

Table 1 Study population and OR characteristics in patients who underwent surgical stabilization of rib fractures within 24 or ≥24 hours following admission

Characteristics	Time to OR		P
	<24 hours (n=85)	≥24 hours (n=88)	
Demographics			
Male	59 [69]	71 [81]	0.09
Age (years)	55 (26.0)	54 (17.5)	0.75
BMI (kg/m^2)	26.04 (7.2)	21.14 (6.9)	0.12
Comorbidities			
Asthma	12 [14]	4 [5]	<0.03*
COPD	4 [5]	2 [2]	0.65
Smoker/ex-smoker	45 [53]	54 [61]	0.26
Transfer from OSH	36 [43]	31 [35]	0.34
Median ED time (hours)	2.2 (2.2)	1.8 (2.6)	0.42
Injury			
Mechanism			
MVC/MCC	29 [34]	32 [36]	0.88
Auto-pedestrian	9 [11]	17 [19]	0.11
Auto-bike/ski/BCC	13 [15]	14 [16]	0.91
Fall	32 [38]	18 [20]	0.01*
Crush	0 [0]	5 [6]	0.06
GSW	1 [1]	1 [1]	0.49
Unknown/assault/ trampled	1 [1]	1 [1]	0.98
ISS	16.5 (12.0)	21.0 (12.0)	<0.01*
GCS (at admission)	15 (0.0)	14 (4.8)	<0.01*
Intracranial hypertension	11[13]	12 [14]	0.89
Face fracture	5 [6]	14 [16]	0.03*
Sternum fracture	7 [8]	7 [8]	0.82
Clavicle fracture	14 [16]	23 [26]	0.12
Scapula fracture	13 [15]	21 [24]	0.16
Spine fracture	19 [22]	41 [47]	<0.01*
Pelvic fracture	7 [8]	22 [25]	<0.01*
Long bone fracture	6 [7]	14 [16]	0.07
Solid organ injury	12 [14]	22 [25]	0.07
Blunt cerebrovascular injury	4 [5]	4 [5]	0.10
BPC 18 score	4 [4]	4 [5]	0.19
Pneumothorax (admission)	65 [76]	70 [80]	0.63
Hemothorax (admission)	50 [59]	51 [58]	0.91
Chest tube (admission)	58 [68]	68 [77]	0.18
Number ribs fractures	7 (4.5)	9 (6.0)	0.01*
Number of total fractures	11 (8.0)	12 (8.8)	<0.01*
Flail chest	48 [56]	59 [67]	0.15
RibScore	3 (2.5)	4 (3.0)	0.08
Rib fracture location			
Anterior	45 [53]	61 [69]	0.03*
Lateral	76 [89]	73 [83]	0.22
Posterior	62 [73]	73 [83]	0.11
Bilateral	24 [28]	36 [41]	0.08
First rib	26 [31]	30 [34]	0.62
Other surgeries			
Exploratory laparotomy	4 [5]	7 [8]	0.57
Craniotomy	0 [0]	1 [1]	1.00
Thoracotomy	1 [1]	3 [3]	0.63
Pelvic operation	3 [4]	13 [15]	0.02*
Spine operation	5 [6]	7 [8]	0.59
Long bone operation	8 [9]	14 [16]	0.20
Day of week of admit			
Monday	13 [15]	12 [14]	0.76
Tuesday	9 [11]	13 [15]	0.41
Wednesday	22 [26]	10 [11]	0.01*
Thursday	10 [12]	9 [10]	0.75
Friday	8 [9]	12 [14]	0.38

Table 1 (*continued*)

Characteristics	Time to OR		P
	<24 hours (n=85)	≥24 hours (n=88)	
Saturday	9 [11]	16 [18]	0.16
Sunday	14 [16]	16 [18]	0.77
Weekday	62 [73]	56 [64]	0.19
Weekend	23 [27]	32 [36]	0.19
Admission to OR time (hours)	13.4 (11.1)	44.3 (34.3)	<0.01*
Day of week of decision to SSRF			
Monday	14 [16]	15 [17]	0.92
Tuesday	11 [13]	19 [22]	0.13
Wednesday	19 [22]	17 [19]	0.62
Thursday	19 [22]	13 [15]	0.20
Friday	6 [7]	7 [8]	0.82
Saturday	9 [11]	9 [10]	0.94
Sunday	7 [8]	8 [9]	0.42
Weekday	69 [81]	71 [81]	0.93
Weekend	16 [19]	17 [19]	0.93
SSRF decision to OR time (hours)	5.3 (7.1)	15.6 (2.5)	<0.01*
Day of week of SSRF			
Monday	14 [16]	21 [24]	0.23
Tuesday	10 [12]	12 [14]	0.71
Wednesday	17 [20]	20 [23]	0.66
Thursday	19 [22]	12 [14]	0.14
Friday	8 [9]	7 [8]	0.73
Saturday	11 [13]	8 [9]	0.40
Sunday	6 [7]	8 [9]	0.64
Weekday	68 [80]	72 [82]	0.76
Weekend	17 [20]	16 [18]	0.76
SSRF			
Number of ribs fixed	4 (2.0)	5 (2.0)	0.06
Number of plates	4 (2.5)	5 (2.0)	<0.05*

Table 1 (*continued*)

Characteristics	Time to OR		P
	<24 hours (n=85)	≥24 hours (n=88)	
On call surgeon			
1	5 [6]	3 [3]	0.68
2	2 [2]	2 [2]	0.64
3	4 [5]	8 [9]	0.40
4	8 [9]	3 [3]	0.19
5	6 [7]	3 [3]	0.46
6	3 [4]	3 [3]	0.71
7	6 [7]	12 [14]	0.16
8	1 [1]	2 [2]	0.98
9	6 [7]	8 [9]	0.62
10	1 [1]	9 [10]	0.03*
11	12 [14]	6 [7]	0.12
12	6 [7]	5 [6]	0.71
13	20 [24]	19 [22]	0.76
14	3 [4]	3 [3]	0.71
15	2 [2]	2 [2]	0.64
On call to OR match	28 [33]	22 [25]	0.25

Continuous data are expressed as median (interquartile range) and categorical data as number [%]. *, P<0.05. OR, operating room; BMI, body mass index; COPD, chronic obstructive pulmonary disorder; OSH, outside hospital; ED, emergency department; MVC, motor vehicle collision; MCC, motorcycle collision; BCC, bicycle collision; GSW, gunshot wound; ISS, Injury Severity Score; GCS, Glasgow Coma Scale; BPC 18, Blunt Pulmonary Contusion 18; SSRF, surgical stabilization of rib fractures.

of which is a causal relationship between early fixation of unstable fractures leading to improved pain control and pulmonary mechanics (14,15,20). However, these analyses are subject to confounding by severity of injury which, in turn, influences the period of resuscitation in a damage control approach, likelihood of additional urgent procedures, and ability to obtain consent for SSRF (21). It was our intention that a more robust abstraction of these

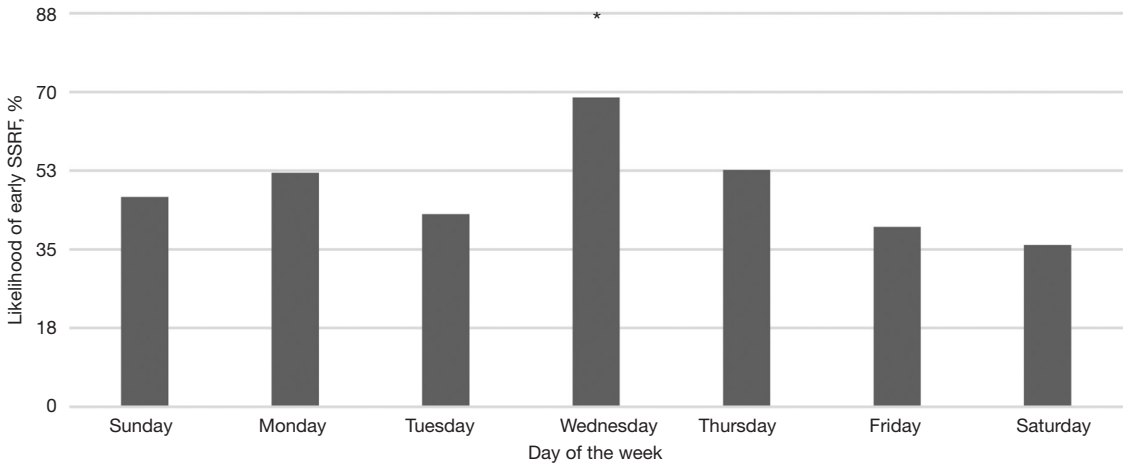

Figure 1 Likelihood of early (<24 hours) SSRF by day of admission. *, P=0.01. SSRF, surgical stabilization of rib fractures.

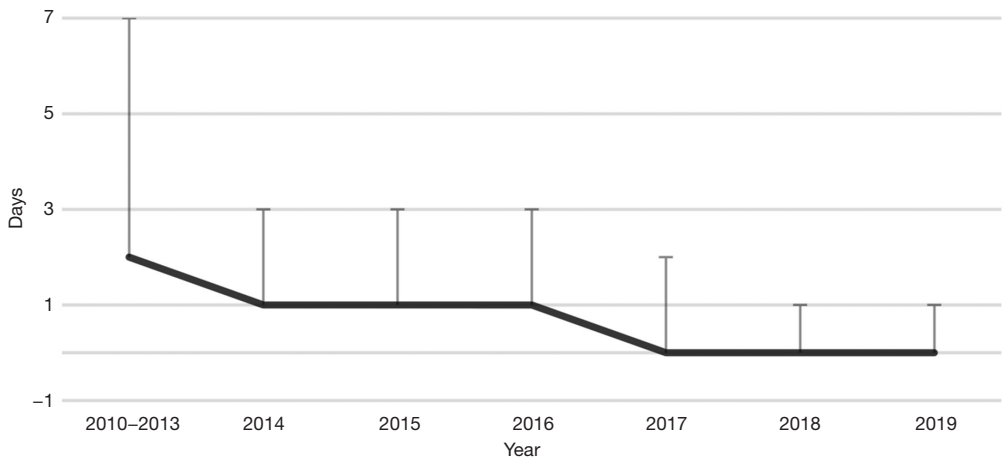

Figure 2 Time to SSRF from admission according to year, P=0.03. SSRF, surgical stabilization of rib fractures.

variables, typically absent from the investigational literature of SSRF, would elucidate these potential biases.

Our first finding was that patients who underwent early SSRF were less severely injured as compared to late SSRF, as evidenced by a lower ventilation rate and lower ISS, likely due to the decreased incidence of associated injuries of the spine, pelvis, and face. The exact rationale to perform early *vs.* late SSRF in patients with concurrent spine and pelvic fractures was not known but likely due to the complexity of the associated injuries, the stabilizing of possibly hemodynamically unstable patients, and possible inability to properly position the patient for SSRF. A first step towards early SSRF in polytraumatized patients with multiple injuries was recently undertaken through demonstrating that early SSRF is safe in patients with non-urgent operative pelvic injuries (22). This should be further investigated, for example spine fractures and more complex fractures which might preclude perioperative positioning.

Early SSRF patients also had fewer rib fractures which might be due to our increasing familiarity with SSRF leading to a broadening patient population, other than those with the most severe and complex thoracic injuries, as our indications for SSRF include amongst others rib fracture displacement and flail chest/segment presence instead of the number of fractures. Finally, although the incidence of additional urgent procedures was relatively low in our sample, the two that occurred most commonly, pelvic and long bone ORIF, were performed more frequently in

the late group. Preference in performing these other non-thoracic forms of fixation early in the damage control process also have shown to improve outcomes (23). The need for additional urgent procedures likely affects timing of SSRF, particularly early on in a center's experience with chest wall injury surgery, as non-SSRF urgent procedures are prioritized. One shift in the practice pattern that we have observed at our center with increased SSRF volume, is the ability to coordinate combined surgeries with our orthopedic and neurosurgery colleagues (19). Particularly, if the need for operative intervention on both ribs and pelvis/spine/long bone is identified early, the services may coordinate a combined procedure, decreasing the time to both.

Additional logistical factors appeared to contribute to the ability to undergo early SSRF, particularly the day of admission and/or referral to our hospital specifically for SSRF. Interestingly, while the existence of a "weekend effect" in trauma admissions has been disputed, our institution did find differences in the admitted population depending on the day of the week, and when more severely injured patients were admitted, they were more prevalent in the late group (24). Over time, and with increased volume, we have witnessed a gradual normalization of SSRF; OR staff are more familiar with the procedure and more trauma surgeons in our group perform the surgery. Operative room access for SSRF remained relatively constant over time in the form of a single 24-7 urgent/emergent room that was however shared with multiple other specialties. However, familiarity with the procedure might have allowed for a subtle shift in allowing operative room access for a known service. Furthermore, within our group, there was an early champion of SSRF, who was able to perform the operation after hours when the on-call surgeon was otherwise unable. This situation might explain why we did not find a discrepancy between on-call surgeon and operating surgeon in terms of timing to SSRF. In summary, in order to maximize the ability to deliver SSRF patients to the OR early, we recommend education of OR staff regarding the procedure, identification of an SSRF champion within the surgeon group, and coordination with ancillary specialties regarding the possibility of combined procedures with other specialties, which can allow opportunity for earlier SSRF and may confer less of a neurotoxicity risk in otherwise multiple anesthesia events (19,25). Also, prior to the study period, the senior author managed to move SSRF from a priority 4 procedure (<24 hours in the OR) to priority 3 (<12 hours) which allowed for earlier and more consistent OR access (priority 1 is emergent; priority 2 <4 hours).

An additional finding was that patients transferred to our hospital specifically for SSRF were more likely to be in the early group. This finding is likely related to the lead time available prior to the patient arriving to our facility. As these patients often have the indication for SSRF for which they are referred, planning of the operation can already be facilitated before arrival, positively affecting time to the OR. The specific time from admission at the peripheral center or duration to transfer was not known and might have impacted decision to perform SSRF as early as possible after referral. In general, these patients were less severely injured, and had already been stabilized at the outside facility. In this sub-population, accounting for patients presenting directly to the operating facility *vs.* transferred to another admitted location, is likely an important consideration to mitigate confounding.

This study was limited by retrospective analysis at a single center, although the database was maintained prospectively. Retrospective analyses of the relationship between timing of SSRF and outcomes should be interpreted with caution, with attention to the issues that we found to be related to early surgery. As a result, a possible confounding effect of variables not collected could not be distilled including for example other injuries attributing to the ISS, the use of anticoagulants, or specifics on the severity of the pelvic, solid organ, or spine injuries. Also, the primary operative indication for SSRF was not documented. For example, the indication of poor pain control despite optimal medical analgesia might have led to patients being operated on at least >24 hours after admission. It must be noted that the operative indication was likely often a combination of factors such as ≥3 bicortically displaced ribs with a radiographic or clinical flail segment/chest other than solely poorly controlled thoracic pain. In addition, some cases occurred prior to the adoption of an electronic medical record at our institution thus, it is possible that there was a change in the documentation and calculation of certain variables. While the inclusion period of 10 years provides a large sample size improving the power of this study, a previously demonstrated possible effect of study year on outcomes was not accounted for (19). The mentioned study did however only assess the effect of study year on outcomes following SSRF and an effect of study year on SSRF decision making has not previously been studied and requires future research. Furthermore, our data reflect findings at a level 1, academic trauma center with a high case volume, which

may present issues with generalizability to other centers that preform SSRF either more or less frequently (26,27).

Conclusions

In conclusion, in this single institution analysis, time to SSRF, depended on the injury severity of the patient, the need for additional urgent procedures, day of admission, institutional experience with SSRF, and presentation directly to the hospital. Neither surgeon availability nor time of decision to undergo the procedure affected the timing of SSRF. Future direction of study may investigate if there is clinical benefit of combining operative cases with other subspecialties to include SSRF in the damage control bracket. Ultimately, the ability to successfully perform surgery within 24 hours of admission appears related to both overall injury severity and systems issues.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-857/rc

Data Sharing Statement: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-857/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-857/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was sent for IRB approval and exempted from IRB review by the Colorado Multi-Institutional Review Board (No. IRB00000650). As this was a retrospective database study, no formal sample size was calculated and no informed consent was required.

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