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Shoulder Dysfunction after Surgical Stabilization of Rib Fractures: An Underreported Functional Morbidity

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Research Article

Keywords: Rib fractures, Surgical stabilization, Shoulder, Physical therapy, Rehabilitation, Functional outcomes

Posted Date: August 25th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10451856/v1

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Additional Declarations: No competing interests reported.

Abstract

PURPOSE

To characterize postoperative shoulder dysfunction following surgical stabilization of rib fractures (SSRF), for which limited objective data exists.

METHODS

This was a single-center retrospective study of physical therapy referral patterns and shoulder-specific outcomes following SSRF. Data was collected from consecutive patients treated with SSRF for acute chest wall injury between 2017 and 2025 at a Level I trauma center. Analysis was conducted with patients referred to physical therapy.

RESULTS

After SSRF, 28 of 127 patients (22%) received outpatient physical therapy for persistent shoulder or scapulothoracic dysfunction. Dysfunction was ipsilateral to SSRF in 26 patients (93%) and associated with ipsilateral shoulder girdle fractures in 12 patients (43%). Among 15 patients with available data, physical therapy was associated with significant improvements in mean shoulder flexion (+ 48.9 $^\circ$, $p < 0.001$) and abduction (+ 60.2 $^\circ$, $p < 0.001$) ipsilateral to SSRF. However, 46% of patients either had persistent dysfunction or were lost to follow-up without recorded improvement. 6 of 8 patients with persistent dysfunction despite therapy (75%) had a concomitant shoulder injury, while 7 of 15 patients whose dysfunction resolved (47%) had a shoulder injury. Assessment of patient-reported outcomes was limited by variability in documentation practices.

CONCLUSIONS

Shoulder dysfunction is common following SSRF and frequently occurs in the absence of shoulder fractures, although concomitant shoulder injury seems to be the main modifier of recovery trajectory. These findings highlight an underreported functional morbidity and demonstrate the need for additional data to guide postoperative screening and rehabilitation.

INTRODUCTION

Rib fractures are a common traumatic injury, and surgical stabilization of rib fractures (SSRF) is increasingly used to manage patients with chest wall instability or respiratory failure refractory to nonoperative management [1]. A small but growing body of research suggests ipsilateral shoulder limitations are common after SSRF and that operative technique may influence recovery of shoulder mobility [2–4]. Shoulder dysfunction after SSRF can be related to the effects of chest deformity, pain,

scar tissue, immobilization, and concomitant shoulder fractures. Technical factors that may influence shoulder recovery include the location of implanted hardware, inadvertent nerve damage, and muscle division to access fractured ribs [5].

Current literature suggests that some degree of shoulder dysfunction is usual after SSRF, and that many early deficits quickly recover. One prospective study evaluated the postoperative trajectory of the Disabilities of the Shoulder, Arm, and Hand (DASH) score in patients who received SSRF [2]. They found severe baseline dysfunction which significantly improved by one week postoperatively, and again significantly improved at one month [2]. Another study reported outcomes of muscle-sparing SSRF in which mean ipsilateral shoulder strength and range of motion were both approximately 90% of the contralateral shoulder at 6 weeks postoperatively and recovered to 100% of contralateral strength by 6 months [3]. A third study reported that a muscle-sparing approach to SSRF results in improved long-term shoulder and thoracic mobility when compared to a non-muscle-sparing technique [4]. However, none of these three studies gave proportions of patients with chronic, persistent dysfunction. Thus, despite emerging evidence suggesting shoulder dysfunction is a real and potentially modifiable morbidity after SSRF, its incidence is incompletely described.

When shoulder dysfunction is diagnosed after SSRF, referral to outpatient physical therapy (PT) is one of the main ways a surgical team can influence functional recovery. Current expert consensus supports referral for ongoing therapy in patients with rib fractures who are found to have limitations or impairments in upper extremity function [6]. However, there are no best-practice guidelines to inform how or when clinicians ought to evaluate upper extremity dysfunction in the postoperative period after SSRF. Much of the current literature on post-SSRF shoulder dysfunction has involved routine outpatient PT, which is not a universal standard of care, as no evidence confirms this approach is superior to selective referral [2–4]. The broader SSRF literature has trended towards a focus on functional outcomes, but exactly how therapy may contribute to these functional outcomes remains undefined [7–14].

In summary, clinical experience and current evidence suggest that shoulder dysfunction is common after SSRF, but it is unclear how often dysfunction is chronic or severe enough to warrant ongoing PT. Additionally, little is known about the outcomes of PT after SSRF. Therefore, we conducted this exploratory study with the primary aim of estimating the incidence of referral to outpatient PT for shoulder dysfunction after SSRF. The secondary aim was to characterize the quality of dysfunction and the response to therapy among referred patients.

METHODS

Study design and population

Institutional Review Board approval was obtained, including waiver of informed consent (IRB#00004023). We performed a single-center exploratory retrospective chart review with consecutive

chest wall injury patients treated with SSRF between February 2017 and April 2025 at a Level I trauma center. Patients were identified with Current Procedural Terminology (CPT) codes 21811, 21812, and 21813. Patients were included if they were at least 18 years of age and received SSRF during an index hospitalization for acute traumatic rib fractures. To ensure that all patients had a reasonable opportunity for PT referral, those without documented postoperative follow-up at our institution's surgery clinic were excluded. Patients were also excluded if they received SSRF after hospital discharge, were discharged to hospice after SSRF, or died within 90 days of SSRF. The manuscript was prepared with the Strengthening Reporting of Observational Studies in Epidemiology (STROBE) checklist to enhance outcomes reporting [15].

Variables

Data recorded for all eligible patients included baseline patient and injury characteristics, operative details, inpatient outcomes, and discharge disposition. Patient characteristics included age, sex, and body mass index. Injury characteristics included the number and laterality of rib fractures, presence of flail segment (≥ 3 ribs fractured in ≥ 2 places each), and fractures of the shoulder girdle, defined as the clavicle, scapula, and proximal humerus. Operative details included the number of ribs fixed, the performance of muscle-sparing SSRF, and the subscapular placement of hardware. Muscle-sparing SSRF was identified from review of formal operative reports, and a strict rather than permissive definition was used: cases were not defined as muscle-sparing if it was explicitly stated that the latissimus dorsi, serratus anterior, or pectoralis major were divided to any degree, or if a thoracotomy was performed. Subscapular hardware placement was derived from operative reports and verified with visual assessment of plate positioning on postoperative chest radiography. For shoulder girdle fractures, we recorded whether they were managed operatively or nonoperatively during index hospitalization. Inpatient outcomes included the need for intensive care and the incidence of mechanical ventilation. Discharge disposition included home, acute rehabilitation facilities, skilled nursing facilities (SNF), and long-term acute care hospitals (LTACH).

A subgroup was created to focus on patients who received outpatient PT for indications of shoulder dysfunction. For all patients, we collected whether they were referred for outpatient PT at any time following discharge. The date of initial therapy referral was recorded, as well as the documented indication and the specialty of the referring provider. "Dysfunction" was defined by the indication for therapy and could have included specific strength or active range of motion (AROM) abnormalities, pain, or documentation of functional limitations. All patients who did not receive PT for shoulder dysfunction were excluded from further analysis, including patients who *were* referred but did not attend, and also those referred for non-shoulder indications.

Additional data was then collected from chart review of outpatient therapy encounters. The presence and laterality of shoulder dysfunction at the time of the first therapy visit was reported based on evidence from the therapy intake note. The date of the first and last therapy visits were recorded and were used to calculate time from SSRF to the start and end of therapy. The duration of therapy was

calculated as the time from the first to the last therapy visit on file for the initial referring indication. Instances where patients completed all insurance-approved therapy days but had persistent dysfunction and were further approved for additional therapy were handled as one combined therapeutic course.

Shoulder strength and active range of motion (AROM) data were obtained from therapy notes. Planes evaluated included forward flexion, abduction, internal rotation, and external rotation. Units of AROM measurement included degrees or spinal level (e.g. T2, L3, etc.) at therapists' discretion. Shoulder strength was measured with manual motor testing on a standard 0–5 scale [16]. In patients with available data, AROM was compared using baseline and most recent values. Strength testing was not evaluated in this way due to data incompleteness.

Response to treatment was descriptively assessed by clinical impression of PT documentation, factoring in symptomatic resolution, the attainment of specific therapy goals, and objective functionality as measured in strength or AROM. Based on clinical impression, patients were categorized into 1 of 3 groups. First, those *with* documented resolution of baseline shoulder dysfunction. Second, those *without* documented resolution of dysfunction but with adequate documentation to establish a trajectory. Third, those with insufficient data to inform trajectory, who were considered to have indeterminate resolution of dysfunction.

Patient-reported outcome measures (PROM) were collected as documented in therapy notes. These measures were recorded from the therapy intake note as well as from the latest note on file, similar to how strength and AROM were handled. For each PROM we recorded the specific outcome used as well as the patient's documented score for each measure.

Finally, we reported rates of rotator cuff tears (both full and partial) and labral tears diagnosed in the outpatient setting during the postoperative course. These diagnoses were considered present if they were documented in an outpatient clinical note by an orthopedic specialty provider at any time between hospital discharge and the final therapy visit on record.

Analysis

Continuous variables were reported as mean ± standard deviation or median [interquartile range] and compared with Student's t-test or the Wilcoxon rank-sum test, respectively. Categorical variables were reported as number (percentage) and compared using χ^2 testing or Fisher's exact test when estimated cell counts were $n < 5$. Paired t-testing was performed for the outcome of shoulder AROM ipsilateral to SSRF. All statistical analysis was performed in GraphPad Prism software (version 11.0.0).

RESULTS

A total of 216 patients underwent SSRF, and 127 patients were eligible for analysis after exclusion criteria were applied (Fig. 1). Of the 127 included patients, 28 (22%) received referral to outpatient PT for

indications of shoulder or scapulothoracic dysfunction (Table 1). Referred patients were significantly younger than those not referred, with a mean age of 55 vs. 62 years old (p = 0.03). Median total numbers of rib fractures were similar between groups, as were rates of bilateral fractures and flail segment. Patients with shoulder girdle fractures were more likely to be referred for therapy (46% vs. 24%, p = 0.023).

Table 1
Patient and Injury Characteristics

Variable	**Shoulder PT (n = 28)**	**No Shoulder PT (n = 99)**	***p*****
Age	55.0 ± 13.4	61.6 ± 14.3	0.032
Sex, *female*	6 (21%)	28 (28%)	0.630
BMI	30.5 ± 5.5	30.9 ± 6.6	0.736
Rib fractures	7 [5–9]	7 [5–9]	0.788
Bilateral rib fractures	8 (29%)	19 (21%)	0.429
Flail segment	14 (50%)	44 (44%)	0.602
Shoulder girdle fracture	13 (46%)	24 (24%)	0.023*
Scapula	7 (25%)	13 (13%)	0.128
Clavicle	8 (29%)	15 (15%)	0.104
Proximal Humerus	2 (7%)	1 (1%)	0.122

**p < 0.05. **Pearson's χ^2 test; Fisher's exact test when n ≤ 5.*

Values presented as number (percentage) for patient demographics and injury characteristics.

Inpatient outcomes showed the median number of ribs fixed was 3 [3–4] in both groups (Table 2). Physical therapy referral rates were not significantly different according to muscle-sparing SSRF, subscapular hardware placement, or operative shoulder fracture management. Rates of critical care and mechanical ventilation were similar between groups. There were no significant differences in overall discharge dispositions between groups, although out of 11 patients discharged to a long-term acute care hospital, none continued outpatient PT or were further referred within our system.

Table 2
Inpatient Outcomes

Variable	Shoulder PT (n = 28)*	No Shoulder PT (n = 99)*	*p***
Ribs fixed	3 [3–4]	3 [3–4]	0.591
Muscle-sparing SSRF	3 (11%)	14 (14%)	0.763
Subscapular hardware placement	6 (21%)	22 (22%)	0.929
Operative shoulder management	5 (18%)	8 (8%)	0.159
ICU admission	12 (43%)	45 (45%)	0.477
Mechanical ventilation	7 (25%)	23 (23%)	0.849
Discharge disposition			0.243
Home	18 (64%)	62 (63%)	-
Acute rehabilitation facility	9 (32%)	23 (23%)	-
Long-term acute care hospital	0	11 (11%)	-
Skilled nursing facility	1 (4%)	4 (4%)	-

** p < 0.05. **Wilcoxon rank-sum test; Pearson's χ^2 test or Fisher's exact test when n ≤ 5.*

Values presented as median [interquartile range] or number (percentage) for in-hospital outcomes. Muscle-sparing SSRF defined by review of operative dictation as no described muscle division whatsoever. ICU: Intensive care unit; SSRF: Surgical stabilization of rib fractures.

Subgroup analysis was conducted with the 28 patients who received therapy for shoulder or scapulothoracic dysfunction (Fig. 2, Table 3). The mean time from SSRF to therapy initiation was 9.0 ± 6.4 weeks, and the mean duration of therapy was 11.9 ± 10.5 weeks. Therapy was started within 1 month of SSRF for 7 patients (25%) and beyond 3 months from SSRF for 8 patients (29%). The full therapeutic course was completed, with documented formal discharge, in 21 cases (75%). Unexpected loss-to-follow-up occurred in 7 patients (25%).

Table 3
Therapy Data

Outcome	**Shoulder PT after SSRF (n = 28)***
Referral Source	
Chest Wall Surgeon	9 (32%)
Orthopedic Surgeon	8 (29%)
PCP	5 (18%)
Other	6 (21%)
Time from SSRF to Therapy	9.0 ± 6.4 weeks
< 1 month	7 (25%)
< 3 months	20 (71%)
> 3 months	8 (29%)
Shoulder Dysfunction	
Laterality	
Ipsilateral to SSRF	26 (93%)
Contralateral to SSRF	2 (7%)
Baseline Severity	
Flexion or Abduction AROM ≤ 70°	6 (21%)
Strength ≤ 3 in any plane	8 (29%)
Outcomes	
Documented resolution	15 (54%)
Documented persistent dysfunction	8 (29%)
Known dysfunction with indeterminate outcome	5 (18%)
Additional Outpatient Diagnoses	
Rotator cuff tear	5 (18%)
Full thickness	3 (11%)
Partial thickness	2 (7%)

Values presented as number (percentage) or mean ± standard deviation for therapy outcomes. AROM: Active range of motion; PCP: Primary care provider; PT: Physical therapy; SSRF: Surgical stabilization of rib fractures

Outcome	Shoulder PT after SSRF (n = 28)*
Labral tear	2 (7%)

Values presented as number (percentage) or mean ± standard deviation for therapy outcomes. AROM: Active range of motion; PCP: Primary care provider; PT: Physical therapy; SSRF: Surgical stabilization of rib fractures

Shoulder dysfunction was ipsilateral to SSRF in 26 patients (93%) and contralateral in 2 patients (7%). For functional outcomes, 15 patients (54%) had documented resolution of baseline dysfunction. There were 8 patients (29%) with documented persistent dysfunction that did not resolve by the end of therapy. An additional 5 patients (18%) had baseline dysfunction without documented resolution. The most common specific functional limitations included overhead use of the affected arm (n = 10; 36%) and lifting or carrying (n = 6; 21%).

Further analysis showed diversity of intake, with several types of referring providers. Nine patients (32%) were referred by the trauma or thoracic team responsible for SSRF, 8 (29%) by orthopedic specialists, and 5 (18%) by their primary care providers. Referral by personnel from an acute rehabilitation facility was a common route of alternative entry. Most referrals occurred within 3 months of SSRF (20 patients, 71%), with 7 patients (25%) referred within 1 month of surgery.

Paired analysis of AROM ipsilateral to SSRF was possible in 15 patients for forward flexion and abduction (Fig. 3). Mean forward flexion improved from 101º ± 38º at the start of therapy to 150º ± 21º at the end of therapy (+ 49º, $p < 0.001$). Similarly, mean abduction improved from 84º ± 27º at the start of therapy to 144º ± 28º at the end of therapy (+ 60º, $p < 0.001$). Paired analysis for other planes and for strength testing was not performed due to low data availability.

Data missingness is presented in Table 4. Documentation of AROM was common for flexion and abduction, occurring at baseline in most patients, and with paired analysis possible in 17 patients (61%). Documentation of internal and external rotation was also common, with baseline values available for 21 patients (75%) and 20 patients (71%), respectively. However, because these two planes were variably measured in either degrees or spinal level (e.g., L5, T12), paired statistical testing was possible for internal rotation in 2 patients (7%) and for external rotation in 7 patients (21%). A similar pattern was observed for strength testing; the number of patients with baseline values greatly exceeded the number for whom paired analysis was possible.

Table 4
Documentation Patterns

Outcome	Measure	Baseline documentation	Any follow-up documentation	Paired analysis possible
AROM	Flexion	26 (93%)	18 (65%)	17 (61%)
AROM	Abduction	26 (93%)	18 (65%)	17 (61%)
AROM	IR	21 (75%)	15 (54%)	2 (7%)
AROM	ER	20 (71%)	15 (54%)	6 (21%)
Strength	Flexion	20 (71%)	13 (46%)	9 (32%)
Strength	Abduction	19 (68%)	13 (46%)	7 (25%)
PROM	Any validated PROM	7 (25%)	7 (25%)	4 (14%)

AROM: Active range of motion; ER: External rotation; IR: Internal rotation; PROM: Patient-reported outcome measure

A patient-reported outcome measure was documented at baseline in 7 patients (25%), and paired analysis of PROMs was possible in 4 patients (14%). There were 4 different PROMs used (Supplemental Table 1). The most common were the Shoulder Pain and Disability Index (SPADI) and the Patient-Specific Functional Scale (PSFS), each used in 5 patients (18%).

DISCUSSION

In this exploratory retrospective chart review of patients undergoing SSRF for acute indications, we found a 22% rate of outpatient referral to physical therapy for clinically significant shoulder dysfunction. Entry into therapy was facilitated by multidisciplinary efforts. Among referred patients, most shoulder dysfunction was ipsilateral to SSRF and tended to improve with therapy, although persistent dysfunction and loss-to-follow-up were both common. The success of therapy was not obviously dependent on early referral or duration of therapy. Finally, the lack of standardized documentation limited paired statistical analysis of several key outcome measures.

These findings represent some of the first data characterizing shoulder dysfunction after SSRF. Importantly, these results represent usual clinical practice patterns in the absence of intentional experimental conditions. Our observed referral rate does not represent the exact incidence of postoperative shoulder dysfunction. Instead, this number represents a floor estimation for the true rate of dysfunction in our population, which could be higher due to underdiagnosis and exclusion of patients who did not follow up with our surgical clinics. Among referred patients, the phenotype of dysfunction was highly nonuniform. The broad spectrum of limitations ranged from pain without obvious mechanical impairment to functional deficits compromising basic self-care. We recommend prospective study

designs to more accurately map the incidence and severity of post-SSRF shoulder dysfunction, as data completeness poses a genuine barrier to quality retrospective work.

Our findings raise the key question of whether providers ought to screen for upper extremity dysfunction in the postoperative period following SSRF. One alternative to screening would be to routinely refer all patients for physical therapy follow-up after hospital discharge. This strategy was found to be safe and feasible in a pilot study for a SSRF-specific therapy protocol by Pelo et al [2]. We observed a 22% rate of referral for dysfunction, suggesting that most patients who undergo SSRF make good recovery without needing ongoing therapy. Therefore, our data supports early identification of dysfunction and selective rather than routine PT referral. However, the true rate and natural trajectory of shoulder dysfunction after SSRF remain undefined, so it remains unclear whether routine or selective referral is optimal.

Of the several patient and injury factors we evaluated, co-injury of the shoulder girdle seemed to have the greatest influence on both the severity of limitations and the response to therapy, although we did not statistically evaluate this. Shoulder injuries included fractures diagnosed during the index admission for trauma, as well as isolated labral or rotator cuff injuries diagnosed after discharge. Some patients experienced delayed diagnosis of soft tissue shoulder injuries because orthopedic follow-up was not arranged at discharge due to the absence of shoulder girdle fractures, providing additional impetus for standardized shoulder screening. The term *forequarter lateral implosion injury* (FLII) is increasingly used to describe co-injury of the chest wall and shoulder girdle, and not much literature describes how treatment or follow-up of patients with FLII ought to differ from that of chest or shoulder injury in isolation [17–20]. Some authors advocate for lower operative thresholds in the context of FLII, in order to expedite rehabilitation [18–20]. The road to establishing optimal management of FLII will eventually lead to evaluation of long-term follow-up outcomes–which, as our study indicates, is not a straightforward endeavor in this patient population. Our study lays groundwork to inform future designs by demonstrating the heterogeneity of real-world outcomes documentation, suggesting an urgent need for agreement upon a shoulder assessment tool for use in FLII, as none currently exists. The Chest Wall Quality of Life Questionnaire (C-QoL) is used to evaluate chest trauma patients, although its specificity for shoulder pathology is unknown and it may need to be modified or paired with a separate shoulder assessment tool to obtain optimal results [21]. The ideal shoulder assessment tool should be transportable for trauma/thoracic surgical clinic environments, as post-SSRF patients may not follow up with orthopedic providers unless a shoulder fracture is present. Screening also may not need to be overly detailed or complicated, as we found dysfunction was recognized and PT referral placed by several nonsurgical specialists.

Finally, the quality-of-life benefit attributable to SSRF remains unclear. Prospective randomized studies evaluating functional PROM's after SSRF usually have not controlled for shoulder co-injury through study design or statistical analysis [11–14]. The field at large ought to seriously consider this methodological point. We found 6 of 8 patients with persistent shoulder dysfunction (75%) had a concomitant shoulder injury. In contrast, 7 of 15 patients whose dysfunction resolved (47%) had a shoulder injury. This suggests the presence of a shoulder fracture is a major modifier of rehabilitation trajectory after SSRF.

Further work is needed to more robustly characterize the relationship between shoulder injury and post-SSRF outcomes. Attempting to establish the functional benefit of SSRF without controlling for shoulder injury may mean ignoring a very influential confounding variable.

Several limitations affect the interpretation of our data. The primary outcome was referral to therapy rather than the incidence of dysfunction itself. Dysfunction was defined through clinical judgement, as there is no clear definition or best-practice assessment tool for post-SSRF shoulder dysfunction. We cannot infer whether any specific dysfunctions were due to SSRF itself rather than from the antecedent trauma. We lacked a control group of patients managed nonoperatively. Evaluation was limited to patients with documented follow-up within our system, which may have over- or underrepresented referrals. We found no therapy referrals for patients discharged to LTACH facilities; it is unknown whether this represents a true gap in our follow-up strategies, or if all these patients were genuinely well-recovered. Therapy referral was subject to clinical judgement and selection bias. We observed small sample sizes for several specific outcomes including strength testing and PROMs. This was often due to documentation of 'WNL' or 'WFL' (within normal / functional limits) which improved clinical efficiency but limited retrospective analysis. Finally, shoulder range of motion and strength do not necessarily correspond to improvements in functionality, which could not be assessed due to lower reporting of PROMs.

In conclusion, we found in our practice over 1 in 5 patients were referred to outpatient physical therapy for shoulder dysfunction after SSRF. Most dysfunction was ipsilateral to SSRF and resolved with therapy. However, some patients showed no documented improvement despite therapy, and some soft tissue shoulder injuries were diagnosed in delayed fashion. The presence and severity of dysfunction seemed correlated with, but not exclusive to, shoulder co-injury. These findings inform the epidemiology of shoulder dysfunction after SSRF in non-experimental conditions and highlight the need for additional evidence to guide postoperative assessment and rehabilitation.

Declarations

Funding

None to declare.

Competing Interests

None to declare.

Ethics & Consent

This retrospective observational study was conducted in accordance with the Declaration of Helsinki and received Sanford Health Institutional Review Board approval (#00004023) including a waiver of the informed consent process for all participants. The research was deemed to involve no more than minimal risk.

Data Availability

Study data available upon direct request pending institutional approval.

Authorship

All listed study authors made significant contributions to the conception and design of the work or to the acquisition, analysis, and interpretation of data; all authors participated in drafting the work or revising it critically for important intellectual content; all authors approved of the version to be published; and all authors agree to be 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.

Conflict of Interest: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Declaration of Interest Statement: This work is currently not being reviewed and has not been accepted or published by any other journals. This study is scheduled for presentation at the Chest Wall Injury Society International Meeting, September 1, 2026, in Barcelona, Spain.

Author Contributions:

Conception and Study Design: WH, CB

Literature Review: WH

Data Acquisition: WH, JR, JK, CW

Data Analysis and Interpretation: WH, JR, BF, CB, CD

Drafting of the Manuscript: WH, JR

Critical Revision: WH, JR, BF, CB, CD

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Figures

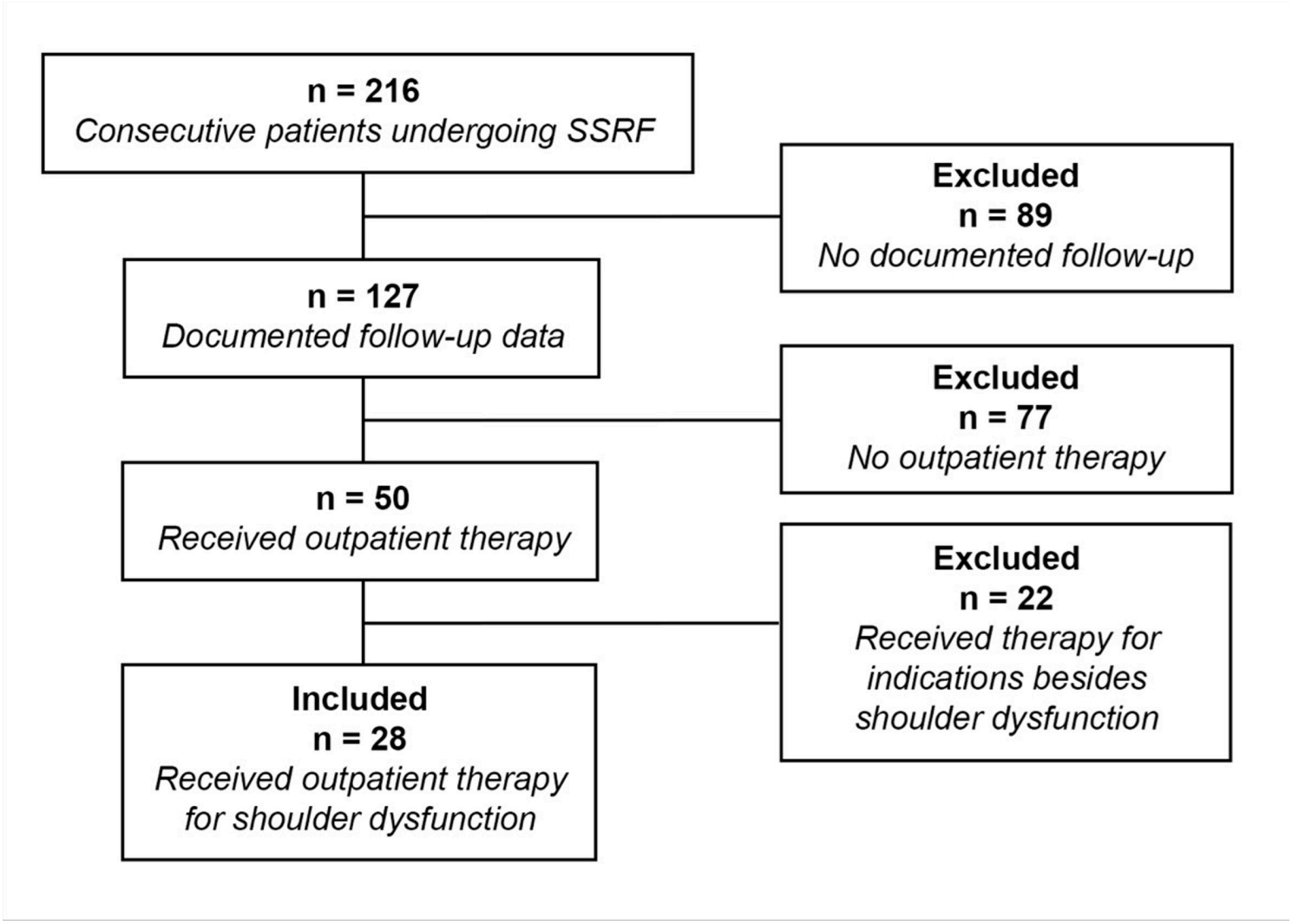


Figure 1

Study Design

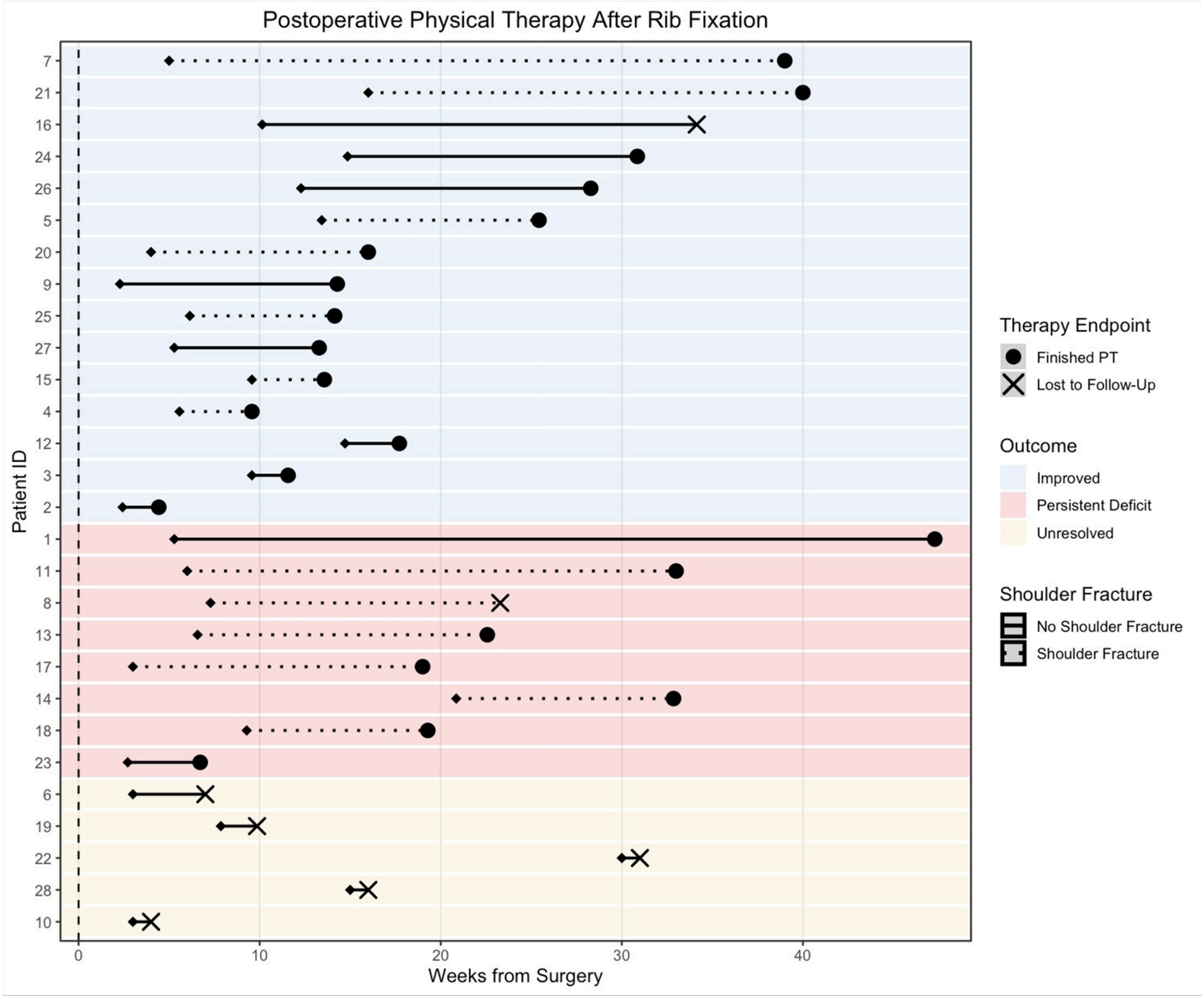


Figure 2

Therapy Timelines

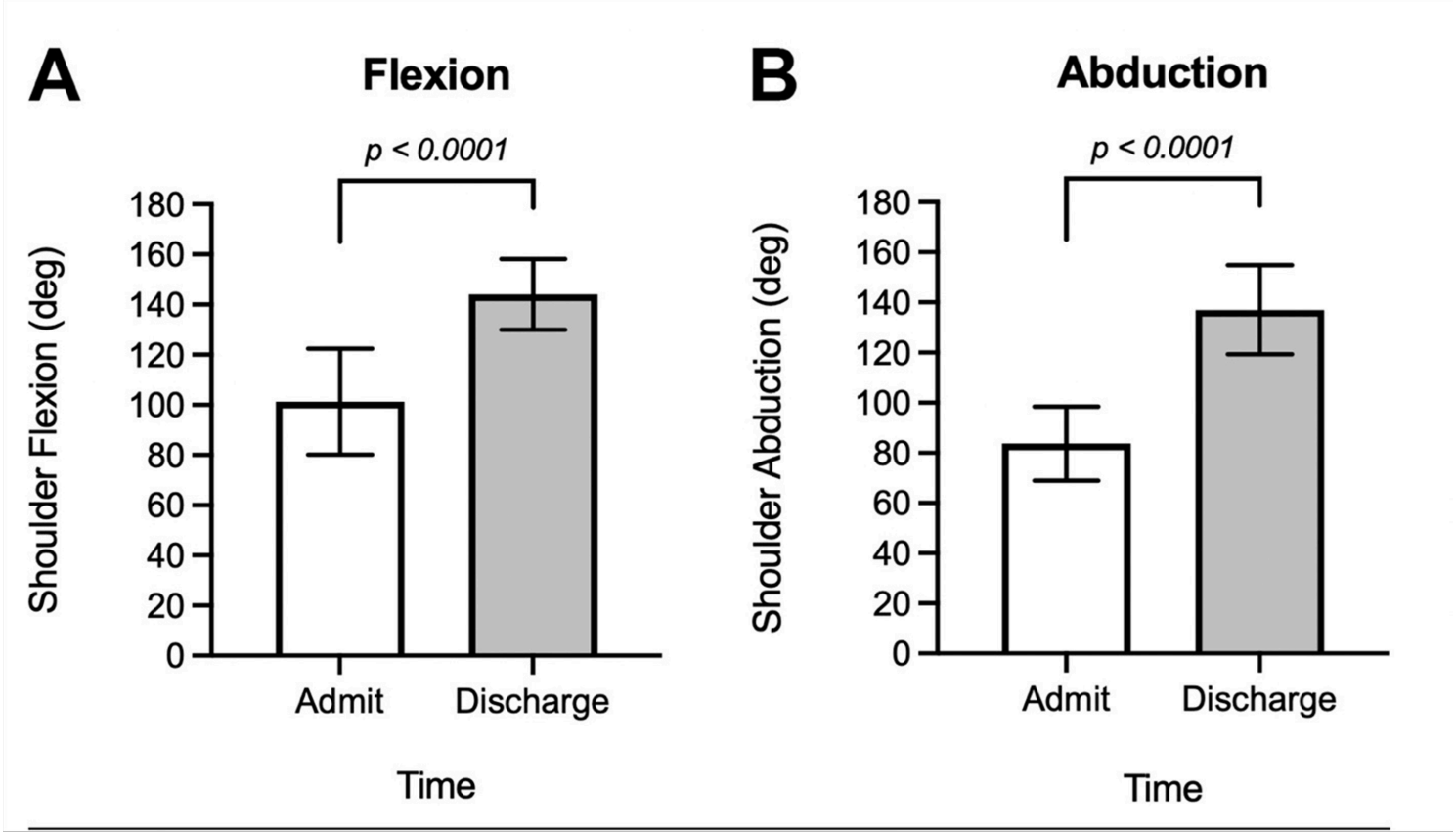


Figure 3

Shoulder Range of Motion Ipsilateral to SSRF

Average shoulder range of motion for forward flexion (A, n = 15) and abduction (B, n = 15) at time of admission and discharge from outpatient physical therapy. Error bars represent 95% confidence intervals. Statistical analysis performed with paired t-tests.

Supplementary Files

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