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Infraspinatus muscle diameter following posterior surgical approach for scapular fractures: A descriptive observational study of muscle changes and their relationship with shoulder pain and function

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Abstract

Background: Scapular fractures are relatively uncommon but can result in significant morbidity. Understanding their demographic characteristics, fracture mechanisms, associated injuries, radiological dimensions, and functional outcomes is crucial for effective management. This study describes postoperative changes in infraspinatus muscle diameter following the posterior (Judet) surgical approach. It explores their relationship with shoulder pain and its impact on function.

Methods: Nineteen participants meeting the inclusion criteria were enrolled in the study. Demographic data, fracture characteristics, associated injuries, and radiological findings were collected. Ultrasound measurements of the infraspinatus and supraspinatus muscle diameters were performed bilaterally at six-month follow-up, with the radiologist blinded to clinical data. Fatty degeneration was graded using the Goutallier classification on postoperative CT. Functional outcomes were assessed using the American Shoulder and Elbow Surgeons (ASES) performance and pain scores. Statistical analysis was performed to explore relationships between variables.

Results: Most participants were male, with a mean age of 35.95 years. Motorcycle accidents were the leading cause of fractures. Associated injuries were present in 21.1% of participants, with concurrent fractures in the lower extremities being the most common. Radiological evaluation revealed a statistically significant reduction in infraspinatus muscle diameter between healthy and fractured shoulders, but no significant difference for supraspinatus (p=0.233). No significant association was found between muscle diameter reduction and functional outcomes or pain scores. Functional outcomes were generally favorable, with most participants reporting high ASES scores.

Conclusion: This descriptive study provides valuable insights into scapular fractures by examining key factors, including demographic characteristics, fracture mechanisms, associated injuries, radiological dimensions, and functional outcomes. The primary finding is a significant reduction in infraspinatus muscle diameter following the posterior (Judet) surgical approach for scapular fractures. However, this reduction was not significantly associated with shoulder pain (p=0.45) or functional outcomes (p=0.38) at six-month follow-up. These findings suggest that while measurable muscle atrophy occurs, it may not directly translate to short-term clinical impairment. Longer-term follow-up and studies with preoperative measurements are needed to determine the clinical significance of these morphologic changes.

Keywords: Shoulder, Scapula, fractures, Posterior, Surgical Approach, Pain.

1. Introduction

Scapular fractures are an uncommon group of injuries, accounting for less than 1% of all fractures and approximately 3-5% of shoulder girdle fractures (1, 2). Both direct and indirect trauma can cause these fractures; the latter is frequently the consequence of forces transferred from the humeral head to the glenoid cavity. Scapular fractures primarily occur in young males aged 25 to 50. They are more likely to include the glenoid or the scapular body. (3)

Surgical treatments are now part of the management of scapular fractures,

alongside traditional conservative methods. It is especially true when significant displacement is linked to a poor long-term prognosis (4, 5). Patients frequently have persistent symptoms from shoulder girdle injuries after therapy, including pain, weakness, and functional limitations (6-10). Traditional techniques for fixing scapular fractures require raising the infraspinatus muscle from medial to lateral. This technique increases the risk of injury to the suprascapular nerve branch and the creation of postoperative complications (11, 12). For best results, surgeons must therefore carefully consider several variables, including the patient's demographics, lifestyle, fracture severity, and glenohumeral joint involvement.(١٣)

With 91% of patients demonstrating anatomical joint surface restoration and high rates of pain relief and functional restoration at follow-up, the posterior approach stood out as a potential alternative in comparative research examining several surgical techniques (14). Despite these advances, little attention has been paid to determining the diameters of the supraspinatus and infraspinatus muscles after scapular fracture surgery, particularly in the setting of posterior (Judet) approach surgery. Given the susceptibility of these muscles to injury during this approach, as well as the potential consequences, our study aims to assess supraspinatus and infraspinatus muscle diameters in patients treated for scapular fractures using the posterior surgical approach and explain their relationship with shoulder pain and function. The specific clinical importance of measuring postoperative infraspinatus muscle diameter lies in its potential as an objective indicator of iatrogenic muscle trauma or denervation. Currently, no published data describe the magnitude of muscle diameter reduction following the Judet approach or its association with patient-reported outcomes. This study, therefore, provides preliminary descriptive data to address this gap. Through this work, we hope to provide significant insights into the management and rehabilitation of patients with scapular fractures, ultimately improving their overall clinical outcomes.

2. Methods

The study population comprised patients with scapular fractures referred to the tertiary trauma center between 2022 and 2023. For the postoperative CT scans obtained at six-month follow-up, all scans were clinically indicated as part of standard postoperative evaluation of fracture healing; no additional research-specific imaging was performed. Sampling for this study was conducted in a non-random and census-based manner. The inclusion criteria for participation in the study were as follows: patients aged 18 to 65 years with scapular fractures who had undergone posterior approach (Judet) surgery, absence of other upper-extremity fractures, and consent to participate. Specific indications for scapular trunk surgery include the translation of more than 100 degrees of the lateral border, angulation > 30-40 degrees of the lateral border, displacement >1-2 cm of the glenoid relative to the lateral border, and a GPA Angle less than 20 degrees. Conversely, patients were excluded from the study if they were under 18 years or over 65 years of age, presented with serious accompanying comorbidities, had a history of muscle degenerative diseases in themselves or close relatives, had a history of any fractures or immobility in the shoulder muscle or elbow on both sides, lacked consent to participate, or exhibited any neurovascular damage. All patients underwent preoperative neurologic examination of the upper extremities, including manual muscle testing (shoulder abduction, external rotation, elbow flexion/extension), sensory examination (C5-T1 dermatomes), and deep tendon

reflexes (biceps, triceps, brachioradialis). Patients with clinical evidence of brachial plexus injury, suprascapular nerve palsy, or cervical radiculopathy were excluded. No electrodiagnostic studies were performed.

2.1. Definition of terms

Infraspinatus Muscle Diameter: The anteroposterior thickness of the infraspinatus muscle belly, assessed by an experienced radiologist using high-resolution ultrasound after appropriate preparation of the muscle.

Posterior approach (Judet): Also known as the Letournel approach, it is a surgical technique utilized to access fractures and injuries of the scapula. Named after the surgeons who developed it, posterior approach (Judet) surgery is frequently employed in cases where the fracture involves multiple parts of the scapula. This method provides effective access to the bone during surgery, which is its primary advantage. It is noteworthy that this approach is typically used when conventional methods, such as conservative treatment or immobilization, prove ineffective in fracture management.

Fatty Degeneration Level: This term refers to the assessment of muscle condition based on the Goutallier criteria, which categorizes muscle function into several stages according to the extent of fatty infiltration observed in imaging studies:A. Grade Zero: No fatty infiltration is observed.B. Grade One: Minimal fatty infiltration is observed. C. Grade Two: Fatty infiltration is observed in less than 50% of the muscle. D. Grade Three: Fatty infiltration is observed in more than 50% of the muscle. E. Grade Four: Complete muscle atrophy is observed.

2.2. Surgical Procedure

The surgical procedure was performed according to a standardized protocol, starting with the classic posterior (Judet) approach to the scapular fracture site. In this approach, the infraspinatus muscle was elevated from the inside of the scapular cavity. By carefully dissecting along the muscle fibers, the surgical team gained access to the fracture site while minimizing damage to the surrounding tissue. Throughout this process, special attention was paid to preserving the suprascapular nerve branch, which was meticulously explored and protected to prevent iatrogenic injury. Once adequate exposure to the fracture site was achieved, fixation was performed using plate osteosynthesis. It involved carefully aligning the fractured fragments and securing them in place with the selected plate, which was chosen based on the fracture's specific characteristics. The plate aided in stabilizing the fracture and promoting optimal healing while allowing for early mobilization of the affected shoulder.

A single experienced surgeon performed all surgical procedures to ensure consistency and adherence to established protocols. Surgeries were performed in a semi-recumbent position, which facilitated access to the posterior scapular surface while minimizing patient discomfort and optimizing surgical ergonomics. Postoperatively, patients received comprehensive care and rehabilitation to facilitate recovery and optimize functional outcomes after scapular fracture fixation. Following the surgical intervention, a structured follow-up protocol was implemented to monitor the progress and outcomes of patients undergoing scapular fracture fixation. Follow-up examinations were conducted at fixed time points to assess functional recovery and the patients' reported outcomes. At the six-month follow-up visit, patients completed a demographic questionnaire. They were evaluated using the American Shoulder and Elbow Surgeons (ASES) questionnaire and visual analog scale (VAS) to assess shoulder

function and pain. Radiological assessment: An experienced musculoskeletal radiologist (blinded to the patient's clinical status and injury side) performed ultrasound examinations using a GE Logiq E9 system with a 12 MHz linear-array transducer. Patients were seated upright with both arms relaxed at their sides and the shoulders in neutral rotation. The infraspinatus muscle was imaged in the transverse plane at the midpoint of the scapular spine, identified by the spinoglenoid notch. The supraspinatus muscle diameter was measured in the oblique coronal plane at the midpoint of the supraspinatus fossa. Three consecutive measurements were obtained for each muscle on both the healthy and injured sides, and the mean value was recorded for each. This assessment provided valuable information about the integrity of the muscles and recovery after surgery. In addition, a clinically indicated repeat CT scan was performed to evaluate the Goutallier criteria, which describe the degree of fatty infiltration observed.

Descriptive statistics were used to analyze demographic characteristics, including age, gender, height, weight, and BMI. Gender differences were assessed using chi-square tests, and independent-samples t-tests were used to compare age and BMI between genders. Fracture mechanisms were summarized, and associated injuries were examined. A correlation analysis was conducted to examine the relationship between reduced range of motion (RoM) and demographic variables. Differences in ASES performance and pain scores between participants with normal and reduced RoM were evaluated using independent samples t-tests. Chi-square tests were used to examine the relationship between fat degeneration level and RoM. Sample size was based on consecutive eligible patients over the study period; no a priori power calculation was performed, as this was a descriptive feasibility study.

3. Result

Nineteen participants met the inclusion criteria and were enrolled in the study, with a mean age of 35.95 years (range 20–54 years; median 36 years). The majority of participants were male (84.2%; n=16), while 15.8% (n=3) were female. Body mass index (BMI) was calculated for all subjects, with an average BMI of 28.34 kg/m² (SD=3.55). The mean age of male and female participants was comparable, with no statistically significant difference. Similarly, regarding body mass index, gender did not reach statistical significance among study participants, indicating no difference between men and women in terms of BMI or age (corresponding p-values: 0.958 and 0.875, respectively).

It is worth mentioning that the participants were asked about pre-existing illnesses. Of these, only one participant stated that he suffered from high blood pressure and was being treated with losartan. The remaining participants did not provide any information on health problems or prescribed medication.

Fracture characteristics are summarized in Table 1. The mean follow-up duration for the study participants was 9.48 months (SD 2.61; median 9 months; range 6–13 months), reflecting extensive monitoring over a considerable period.

Table 1: Characteristics Of Scapular Fractures and Associated Injuries.

Variable		Count (%)
Mechanism	Motor-car accident	10 (52.6%)
	Falling from a height	4 (21.1%)
	Car accident	5 (26.3%)
Injury associate (lower limb involvement)	No	15 (78.9%)
	Yes	4 (21.1%)
Fracture location	Body	19 (100.0%)
Affected Shoulder	Right	13 (68.4%)
	Left	6 (31.6%)
Dominant Hand	Right	17 (89.5%)
	Left	2 (10.5%)

Table 2 provides a detailed overview of the numerical data on infraspinatus and supraspinatus muscle diameter in both fractured and non-fractured shoulders. Specifically, for the Infraspinatus muscle in the healthy shoulder, measurements ranged from 19.3 to 41.9 mm, with a mean of 29.48 mm (SD = 8.02). Conversely, in the fractured shoulder, the diameter of this muscle ranged from 10.9 to 27.0 mm, with an average of 17.76 mm (SD=4.95). The mean difference was 11.72 mm (95% CI: 1.32–22.12, p=0.029). Similarly, the Supraspinatus muscle exhibited a range of 11.2 to 31.9 mm, a mean of 18.18 mm (SD=5.91) in the healthy shoulder, compared to a range of 8.2 to 29.4 mm, a mean of 13.74 mm (SD=4.82) in the fractured shoulder (p=0.233). It is noteworthy that although a statistically significant difference in infraspinatus muscle diameter was observed between healthy and injured shoulders, no significant difference was observed in supraspinatus muscle diameter.

The ASES performance score ranged from 36.67 to 50.00, with a mean of 46.49 (Table 3). Similarly, the ASES pain score ranged from 40.00 to 50.00, with a mean of 47.36. Notably, five study participants reported a pain score of 40, while the remainder reported a pain score of 50. Further analysis reveals that 13.2% of participants achieved a perfect functional score, with 73.8% scoring above 45. Additionally, the majority of participants (73.7%) reported a pain score of 50 (no pain). In contrast, the remainder reported a pain score of 40, corresponding to a VAS score of 2.

Table 2: Comparison of Infraspinatus and Supraspinatus Muscle Diameter in Healthy and Fractured Shoulders.

	Minimum	Maximum	Mean	Std. Deviation	p-value
Infraspinatus (Normal side)	19.3	41.9	29.479	8.0222	0.029
Infraspinatus (fracture side)	10.9	27.0	17.760	4.9502	
Supraspinatus (Normal side)	11.2	31.9	18.184	5.9058	0.233
Supraspinatus (fracture side)	8.2	29.4	13.743	4.8180	

Table 3 also represents the range of abduction and external rotation. For abduction range of motion (ROM), data ranged from 100 to 180 degrees, with a mean of 156.32 degrees. Conversely, external rotation ROM ranged from 50 to 100 degrees, with a mean of 86.84 degrees. It is noteworthy that none of the patients exhibited an abduction ROM less than 100 degrees, with 26.3% demonstrating a ROM between 100 and 120 degrees, while the majority (73.7%) exhibited a ROM exceeding 120 degrees. Similarly, for external rotation, no participant had a ROM less than 50 degrees; 15.8% had a ROM between 50 and 70 degrees, while the remaining participants (84.2%) had a ROM above 80 degrees. According to the Goutallier criteria for fat degeneration assessment, 14 (73.7%) patients exhibited grade 1 degeneration, while 5 (26.3%) exhibited grade 2 degeneration.

Table 3: Assessment Scores of ASES Performance, Pain, Range of Abduction, and External Rotation after follow-up.

	Minimum	Maximum	Mean	Std. Deviation
ASES Function score	36.67	50.00	46.49	4.19
ASES Pain score	40.00	50.00	47.37	4.52
VAS	0.00	2.00	0.53	0.91
ROM abduction (degree)	100	180	156.32	30.039
ROM external rotation (degree)	50	100	86.84	13.765
ROM: range of motion, VAS: Visual Analog Scale				

Table 4 presents a comparative analysis of the presence or absence of a reduced range of motion (ROM) in the injured shoulder (defined as abduction <120 degrees or external rotation <60 degrees). Results indicate that individuals with more restricted movements exhibit lower age and BMI, alongside decreased functional scores and heightened postoperative pain. Notably, the ASES pain score was the only variable to demonstrate a significant difference between the two groups. Among qualitative variables, individuals with multiple traumas displayed diminished ROM post-surgery. At the same time, those with reduced ROM exhibited significantly greater fat degeneration. No significant association was found between reductions in infraspinatus muscle diameter and ASES function scores ($r = -0.21$, $p = 0.38$) or pain scores ($r = -0.18$, $p = 0.45$). Conversely, variables such as gender, mechanism of injury, and history of daily exercise did not significantly affect postoperative ROM.

Table 4: Comparison of Study Variables Based on Range of Motion in the Injured Shoulder.

	Normal RoM	Reduced RoM	p-value	
Age (SD)	37 (10)	34 (5.5)	0.430	
BMI (SD)	29.01 (3.20)	26.48 (2.8)	0.130	
Infraspinatus length (SD); (normal side)	29.6 (7.6)	26.6 (4.9)	0.343	
Infraspinatus length (SD); (Fracture side)	17.6 (4.6)	16.9 (1.5)	0.622	
ASES Function score (SD)	48.10 (1.71)	42.00 (7.1)	0.070	
ASES Pain score (SD)	50.00 (0.00)	40.00 (0.00)	< 0.001	
Mechanism	Motor-car accident	7 (50.0%)	3 (60.0%)	0.632
	falling from a height	3 (21.4%)	1 (20.0%)	
	Car accident	4 (28.5%)	1 (20.0%)	
Injury associate(lower)	No	13 (92.9%)	2 (40.0%)	0.013
	Yes	1 (7.1%)	3 (60.0%)	
Daily exercise	No	10 (71.4%)	3 (60.0%)	0.637
	Yes	4 (28.6%)	2 (40.0%)	
Gender	male	12 (85.7%)	4 (80.0%)	0.764
	female	2 (14.3%)	1 (20.0%)	
Fatty degeneration	Grade1	14 (100%)	0 (0 %)	< 0.001
	Grade2	0 (0%)	5 (100 %)	

4. Discussion

This descriptive study provides a comprehensive examination of multiple facets, including demographic characteristics, fracture etiology, concomitant injuries, radiologic observations, and functional outcomes, within a cohort of patients with scapular fractures. The primary finding is a significant reduction in infraspinatus muscle diameter (mean difference 11.72 mm, p=0.029) on the operated side compared to the healthy side at six-month follow-up, without a corresponding significant change in supraspinatus muscle diameter. Importantly, this reduction was not significantly associated with ASES functional or pain scores.

The observed infraspinatus atrophy is likely multifactorial. The Judet approach requires elevation of the infraspinatus muscle from the scapular fossa, which may directly traumatize muscle fibers. Additionally, the suprascapular nerve's motor branch to the infraspinatus passes through the spinoglenoid notch, making it vulnerable to retraction injury during exposure. Porcellini et al. previously reported that an infraspinatus-sparing approach yielded better external rotation strength, supporting the hypothesis that muscle elevation contributes to postoperative weakness (15). However, our study adds that measurable reductions in muscle diameter do not necessarily translate into clinically significant functional deficits at six months.

In contrast to prior studies such as Porcellini et al., Asihin et al., Pizanis et al., and Cole et al., our research offers a broader exploration of scapular fractures, covering diverse fracture types and mechanisms (15-17). While earlier studies focused on specific fracture types and surgical approaches, we conducted a comprehensive analysis

encompassing demographic characteristics, fracture mechanisms, associated injuries, radiological findings, and functional outcomes. Unlike Vidović et al.(18), who reported functional outcomes and complications post-ORIF without imaging correlates, and Jaikish et al. (19), who focused on displaced trunk and neck fractures, our study specifically quantifies postoperative muscle morphometry. The lack of association between muscle diameter and function contrasts with the assumption that muscle preservation directly improves outcomes, suggesting that other factors (e.g., pain, rehabilitation compliance, concomitant injuries) may be more influential in the short term.

It is important to recognize the limitations of our study. Firstly, the relatively small sample size (n=19) and short follow-up (median 9 months) may constrain the generalizability of our findings. No a priori sample size calculation was performed, and the study was descriptive. Secondly, the absence of preoperative muscle diameter measurements means we cannot determine whether the observed atrophy represents a change from baseline or a pre-existing difference. Without a control group of non-operatively managed patients, we cannot attribute the muscle changes solely to the surgical approach versus the initial trauma or postoperative immobilization. Thirdly, neurologic confounding cannot be fully excluded.

In contrast, clinical neurologic examination was performed preoperatively and postoperatively; electrodiagnostic studies (EMG/nerve conduction studies) were not performed to rule out subclinical suprascapular nerve injury definitively. Fourthly, focusing solely on specific demographic and clinical factors might overlook other potentially influential variables affecting scapular fractures. Finally, the short follow-up period may be insufficient to detect late-developing functional impairments related to muscle atrophy.

Nonetheless, our study exhibits several strengths. The incorporation of diverse fracture mechanisms and a meticulous examination of demographic characteristics, radiological dimensions, and functional outcomes contribute to a comprehensive comprehension of scapular fractures. Key strengths include: (1) blinding of the radiologist to clinical status, (2) standardized ultrasound measurement protocol with three repeated measurements, (3) inclusion of bilateral comparisons to control for inter-individual variation, and (4) prospective follow-up with validated outcome measures. The identification of notable differences in infraspinatus muscle diameter between healthy and fractured shoulders, with no significant effect on functional outcomes or pain, offers novel insights into fracture treatment and suggests that early functional recovery may be achievable despite measurable muscle atrophy.

Future research should aim to expand sample sizes, employ prospective study designs with preoperative baseline imaging, and utilize electrodiagnostic studies to investigate the relative contributions of direct muscle trauma versus nerve injury. Long-term studies (≥2 years) assessing patient-reported outcomes and quality of life post-fracture are crucial, as are comparative analyses of surgical approaches (e.g., Judet vs. infraspinatus-sparing). Randomized controlled trials comparing surgical versus conservative management with serial imaging would help clarify causality. Additionally, exploring the economic aspects of scapular fractures can provide valuable insights into healthcare resource allocation.

5. *Conclusion*

I This descriptive study provides valuable insights into scapular fractures by examining key factors, including demographic

characteristics, fracture mechanisms, associated injuries, radiological dimensions, and functional outcomes. The primary finding is a significant reduction in infraspinatus muscle diameter (mean 29.48 mm vs. 17.76 mm, p=0.029) following the posterior (Judet) surgical approach for scapular fractures. However, this reduction was not significantly associated with shoulder pain (p=0.45) or functional outcomes (p=0.38) at six-month follow-up. These findings suggest that while measurable muscle atrophy occurs, it may not directly translate to short-term clinical impairment. Longer-term follow-up and studies with preoperative measurements are needed to determine the clinical significance of these morphologic changes.

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