Original Research

Utility of MRI in the Evaluation of Acute Greater Tuberosity Proximal Humeral Fractures

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Background: Understanding soft tissue injury patterns associated with greater tuberosity (GT) fractures may help clinicians provide guidance to patients.

Hypothesis: Evaluating magnetic resonance imaging (MRI) findings in patients with suspected isolated GT fractures will help elucidate the role of MRI in the diagnosis and treatment of these patients.

Study Design: Case series; Level of evidence, 4.

Methods: We performed a retrospective review of medical records from 2010 to 2014 for patients presenting with acute isolated GT fractures and MRI. Uncomplicated and delayed recovery groups were established according to the need for delayed procedural intervention or persistent symptoms past last recorded follow-up. Multivariate regression analysis was used to analyze the relationships between MRI findings and delayed recovery.

Results: A total of 32 patients met the inclusion criteria (mean age, 47 years [range, 24-88 years]; mean follow-up, 30 weeks [range, 33 days–4 years]). There was no significant difference in the estimation of fracture displacement as measured on radiography and compared with MRI (radiography, 2.8 mm; MRI, 3.5 mm; $P = .16$). There was a high incidence of full-thickness rotator cuff tears (9%), partial-thickness rotator cuff tears (72%), partial biceps tendon tears (41%), and labral tears (50%). Presence of biceps pathology or partial-thickness rotator cuff tear was predictive of delayed recovery in a multivariate model.

Conclusion: There is a high incidence of soft tissue injury found by MRI following GT fracture. MRI did not appreciably change the measure of displacement of the fracture fragment. In the multivariate analysis, presence of a partial-thickness rotator cuff tear or biceps tendon injury was associated with delayed recovery.

Keywords: greater tuberosity fracture; MRI; rotator cuff; biceps; labrum

Isolated greater tuberosity (GT) fractures are a common injury pattern, representing 19% of all proximal humeral fractures.[5] Because the GT is the primary insertion point for the supraspinatus, infraspinatus, and teres minor, preservation of its position relative to the humeral head is central to shoulder function. Operative fixation consisting of a variety of open and arthroscopic fixation techniques[1,8,10,15,17] is recommended for displacement >5 mm (>3 mm in overhead users).[5] Substantially less is known about the implications of injury characteristics other than displacement, and clinical decision making is complicated by shortcomings in radiographic analysis.

In 2014, Mutch et al[12] proposed a GT fracture–specific classification system based on fracture morphology with the premise that injury mechanism may be reflected in resultant bony injury pattern, but this new system has not been validated regarding its prognostic significance. Advanced imaging modalities such as computed tomography (CT) have also been examined as a means of more precisely characterizing the extent of bony injury GT fractures. However, a 2016 study demonstrated that there is no incremental benefit to a CT scan versus standard radiographs with regard to estimations

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of displacement and morphology and that a CT scan did not change recommendations of operative versus nonoperative management of GT fractures.[7]

Magnetic resonance imaging (MRI) may be used to provide additional information by assessing soft tissue injuries or identifying missed fractures. Previous studies have demonstrated that rotator cuff injury severity increases with increasing bony injury severity in proximal humeral fractures,[4] and they have also shown a high prevalence of occult fractures that were missed on initial radiographic examination (up to 59% in 1 series).[6,11,14,20] There is still no consensus regarding indications for this advanced imaging,[3] as the utility of this additional information in providing prognostic guidance for patients is unclear. The expanding options for procedural management, with undefined indications and expectations, justify a closer look at our ability to use advanced imaging to improve clinical decision making and identify patients at risk for suboptimal recovery by evaluating associated concomitant soft tissue injuries.

The purpose of this study was to (1) determine if MRI adds diagnostic accuracy to the degree of displacement found for isolated GT fractures as identified on standard radiographs; (2) describe the patterns of soft tissue injury associated with isolated GT fractures; and (3) identify patient- and injury-related risk factors for delayed recovery. We hypothesized that MRI for isolated GT fractures does not appreciably change estimation of fracture displacement relative to standard radiographs and therefore does not assist in clinic decision making. Additionally, we hypothesized that soft tissue findings on MRI add limited prognostic value through correlation with suboptimal recovery.

METHODS

This was a retrospective case series examining the patterns of soft tissue injury and their prognostic value in isolated GT fractures, in the setting of an urban academic referral center. This study was granted exempt status by our institutional review board. Consecutive medical billing records for patients seen by orthopaedic surgery staff in the emergency department or outpatient setting from 2010 to 2014 were reviewed for a diagnosis of proximal humeral fracture. These patients were then screened for the existence of ipsilateral shoulder MRI against the billing database, indicating that MRI had been performed within the facility or images had been uploaded into the patient's medical record for assessment by a fellowship-trained musculoskeletal radiologist. Patient charts and radiography were then reviewed retrospectively. Patients with GT fractures associated with other osseous injury, patients with fewer than 30 days of follow-up or with significant neurologic injuries, and patients presenting after 6 weeks from injury were excluded.

Demographic data including sex and age were extracted during chart review. Injury mechanism (including associated dislocation) was recorded according to the clinical history as reported in the initial patient history and physical examinations. Clinical time course consisting of subjective assessment of patient satisfaction and the need and timing for all procedural intervention (including injection) was extracted from the documented follow-up visits.

Standard MRI sequences included T1 and fat-suppressed T2 weighted spin echo images in oblique coronal, sagittal, and axial alignment. The diagnostic criterion for soft tissue injury was identification by the radiologist performing the formal read. All reading radiologists were fellowship-trained staff in the associated musculoskeletal radiology department. Descriptive information on soft tissue injury was extracted from the radiology reports as formalized during their initial reading. This included the presence and location of full- and partial-thickness rotator cuff tears, biceps pathology (including incomplete tears and degenerative changes), and labral tears. Fragment displacement on MRI and radiography were measured separately and prior to chart review. Fracture morphology was assigned on the basis of fragment geometry according to the system described by Mutch et al.[12]

For the purposes of statistical analysis, patients were divided into those who had an uncomplicated recovery and those who had a delayed recovery. Delayed recovery was defined as having persistent subjective symptoms that resulted in delayed procedural intervention (including corticosteroid injection) or persistent symptoms at the time of the patient's final recorded clinic visit if more than 90 days from the time of injury. In the univariate analysis, statistical significance was assessed with a Student t test for continuous variables, including displacement, age, and duration of follow-up, and with chi-square analysis for categorical variables, including nature of recovery (uncomplicated vs complicated) and the presence of soft tissue injury. Fisher exact testing was used if the number of samples was <5 for any comparison. Multivariate regression analysis was subsequently performed with the R programming language utilizing the "mice" package for multiple imputations on missing demographics data. The significance level was set at .05 for all tests.

RESULTS

Cohort Demographics

There were 107 patients with proximal humeral fractures and MRI of the affected shoulder; 38 patients had isolated GT fractures with complete radiographic and clinical documentation. After filtering for exclusion criteria, 32 patients were included in the final cohort (Figure 1).

The mean patient age was 47 years (range, 24-88 years), with a male predominance of 1.5:1 (59% male). The energy associated with the injury mechanism was inversely related with age, with the most frequent being fall from standing (38%; mean age, 59 years), sporting activity (25%; mean age, 47 years), and vehicular trauma (25%; mean age, 31 years); 28% of all injuries were associated with a dislocation (Table 1).

Patients were seen at their first encounter a mean 11 days following injury (range, 2-34 days). Patients described as having "early" MRI were those obtaining MRI in less than 6 weeks from the injury (n = 31; mean delay from injury, 16 days [range, 1-37 days]). Patients obtaining MRI after this point were described as receiving "late" MRI (n = 5; mean delay from injury, 452 days [range, 82-1542 days]). Mean follow-up was 30 weeks (range, 33 days–4 years).

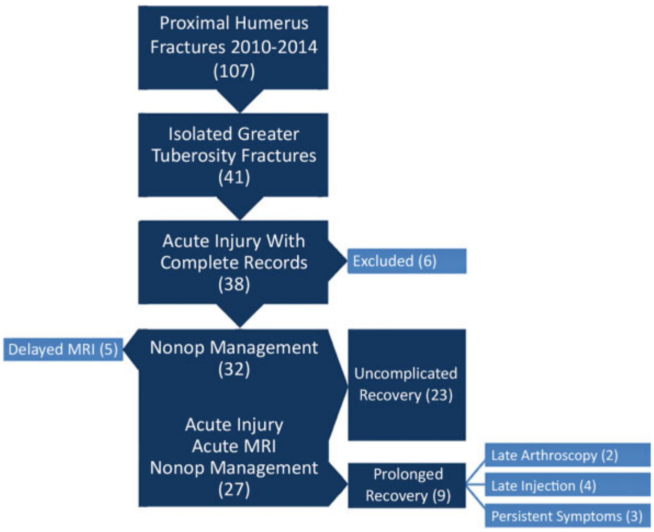

Figure 1. Patient selection flowchart. MRI, magnetic resonance imaging.

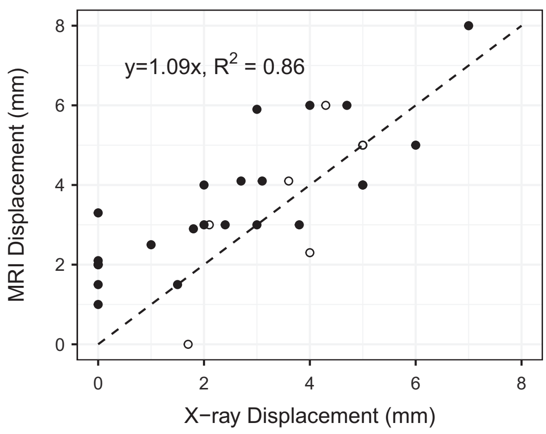

Figure 2. Fracture displacement as measured by MRI versus radiography. Closed circles represent patients with routine recovery, while open circles represent those who experienced delayed recovery. MRI, magnetic resonance imaging.

TABLE 1
Cohort Demographics[a]

Demographic	n (%)	Mean Age, y	SD
Total	32	47.2	15.9
Male	19 (59)	43.7	13.5
Female	13 (41)	42.2[b]	18.2
Mechanism			
Fall from standing	12 (38)	59.1	14.7
Sport	8 (25)	47.4	12.1
Vehicular trauma	8 (25)	31.3	6.4
Clinic follow-up, d	214 (281)		
Time to MRI, d	84 (273)		

[a]MRI, magnetic resonance imaging.
[b]*P* = .16.

TABLE 2
Radiographic Features[a]

	Mean	Total (N = 32)	Early MRI (n = 27)	Late MRI (n = 5)
Displacement, mm				
Radiography	2.8			
MRI	3.5			
P value	.156			
Rotator cuff tear				
Full thickness		3 (9)	2 (7.4)	1 (20)
Partial thickness		23 (72)	18 (67)	5 (100)
Biceps tendon tear		13 (41)	9 (33)	4 (80)
Labral tear		16 (50)	16 (59)	0 (0)
Capsular tear		9 (28)	9 (33)	0 (0)

[a]Values are presented as n (%) unless noted otherwise. MRI, magnetic resonance imaging.

Radiographic Findings

The mean displacement on standard radiographs was 2.8 mm. On MRI, the mean displacement was increased to 3.5 mm, but the change was not statistically significant (*P* = .16) (Figure 2). Other findings on MRI were common, including labral tears (50%), full-thickness rotator cuff tears (9%), partial thickness rotator cuff tears (72%), and biceps tendon injury (41%) (Table 2). Patients with an MRI finding of a partial rotator cuff tear were found to have a significantly larger amount of displacement (3.36 vs 1.45 mm, *P* = .012). No other MRI findings were associated with a statistically significant difference in fracture displacement.

Uncomplicated vs Delayed Recovery

There were 23 patients who had full, uncomplicated recovery (72%; mean age, 44 years; mean fracture displacement, 2.5 mm). The mean follow-up for all patients with uncomplicated recovery was 17 weeks. The remaining 9 patients (28%) had a complicated recovery. This cohort was older (55 years, *P* = .085), had a trend toward greater displacement (3.6 mm, *P* = .20), and had a longer follow-up (65 weeks, *P* = .055). Of these patients with complications, 4 (44%) had impingement symptoms, 3 (33%) had persistent pain, and 2 (22%) developed adhesive capsulitis. Six patients (19%) ultimately required late intervention (2 received late arthroscopic rotator cuff repair, and 4 received a corticosteroid injection). One of the patients who underwent arthroscopic repair had a complex injury mechanism involving a multistaged fall that included twisting and direct impact, resulting in full-thickness tears in the infraspinatus, supraspinatus, and subscapular muscles. The other patient had persistent pain following an occult GT fracture with partial-thickness supraspinatus tear with delamination.

Multivariate Analysis

In the univariate analysis, no individual MRI findings were found to be correlated with delayed recovery. In the multivariate analysis, female sex (*P* = .028), partial-

TABLE 3
Results of Regression Analysis Analyzing Relationship of Fracture Displacement and Presence of Soft Tissue Findings on MRI[a]

Variable	Estimate (SE)	P Value
Sex (male)	–0.409 (0.168)	.028[b]
Age	–0.011 (0.007)	.124
Dominant injury	–0.052 (0.158)	.748
Displacement		
Radiography	0.225 (0.104)	.048[b]
MRI	–0.093 (0.091)	.324
Radiography:MRI	–0.011 (0.020)	.583
Soft tissue injury		
RCT	0.055 (0.261)	.837
Partial RCT	0.396 (0.169)	.034[b]
Labral tear	–0.478 (0.146)	.005[c]
Biceps injury	0.371 (0.155)	.031[b]
Capsular injury	0.217 (0.177)	.24
Mechanism of injury		
Fall from standing	–0.270 (0.271)	.336
Sport	0.044 (0.258)	.866
Vehicular trauma	–0.526 (0.266)	.068

[a]MRI, magnetic resonance imaging; RCT, rotator cuff tear.
[b]Statistically significant, $P < .05$.
[c]Statistically significant, $P < .01$.

thickness rotator cuff tears ($P = .034$) and biceps tendon injuries ($P = .031$) were found to be predictive of delayed recovery, while labral tears were found to be predictive of uncomplicated recovery ($P = .005$) (Table 3). Full-thickness rotator cuff tears and capsular injuries were not found to be associated with delayed recovery. Mechanism of injury was not found to be directly associated with delayed recovery.

DISCUSSION

MRI is commonly used to assess displacement following isolated GT fractures, as well as to screen for soft tissue injuries that may require procedural management. However, it is not clear that MRI adds diagnostic accuracy or changes treatment plans for patients. This study found that acute MRI demonstrated a wide variety of injuries to the soft tissue envelope around the shoulder. While this information did not change the measure of fracture displacement, it did allow us to identify several MRI findings as independent risk factors for delayed recovery. The significance of this finding with regard to clinical decision making remains unclear however, as the treatment of these soft tissue injuries is dependent on a wide range of other factors.

Previous work has shown that isolated GT fractures occur in a younger, healthier subset of the population.[9] In accordance with this, we found that the population of individuals sustaining GT fractures is composed of subsets of individuals, with younger patients sustaining higher-energy injuries that can result in greater displacement (Table 1) and with older patients being at greater risk of having delayed recovery. These individuals may have different therapeutic goals and expectations than those who sustain more comminuted proximal humeral fractures, a majority of which are traditionally thought of as fragility fractures.[9,14]

We identified a trend toward delayed recovery with increased displacement on injury radiography (2.5 mm for uncomplicated recovery vs 3.6 mm for delayed recovery, $P = .20$), but this did not reach significance. This likely occurred because our analysis excluded patients who appropriately underwent open reduction internal fixation for displaced fractures that met operative criteria and also excluded patients who presented late and who may have already developed complications from their nonoperatively treated displaced injuries. The delayed group was also small, limiting the conclusions that could be made from this cohort.

MRI did not appreciably change the measured fracture displacement (Figure 2), nor did the MRI change the estimate of displacement in the subset of patients with delayed recovery (3.43 mm by radiography vs 3.6 mm by MRI, $P = .86$). If displacement is used as the primary indication for open reduction internal fixation, this slight increase would not appreciably change clinical decision making. This is consistent with other studies indicating that advanced 3-dimensional imaging does not change clinical decision making for these injuries. A 2016 study[7] demonstrated that the addition of 2-dimensional CT scan and 3-dimensional reconstructions did not change physician estimation of fracture displacement magnitude or direction, nor did the authors change the recommendation to manage surgically. Therefore, MRI is likely not indicated to help with displacement and surgical management decisions alone.

Other studies of soft tissue injury in proximal humeral fractures with sonographic,[19] MRI,[2,4] and arthroscopic examinations[16] have shown that the severity of soft tissue injury correlates with the severity of bony injury in proximal humeral fractures. How clinical outcomes depend on associated soft tissue injuries remains the subject of debate.[2,13,18,19] Of the 9 patients in our cohort with delayed recovery, all were found to have partial-thickness rotator cuff tears (100%), as opposed to only 14 of the 23 patients with normal recovery (61%). This finding is echoed in the literature. In 1 study,[10] 23 patients with persistent pain after isolated GT fracture were examined with MRI and arthroscopically. Soft tissue injuries identified included partial-thickness rotator cuff tears in 3 patients and tendinopathy in 6 patients, with normal findings in 14 patients. Patients with articular-sided partial tears that were treated with arthroscopic debridement subsequently experienced recovery, indicating that there may be some utility to early identification of this injury pattern. Our findings here were similar, with patients having partial-thickness rotator cuff tears being more likely to have delayed recovery in our multivariate analysis.

Ultimately, radiography provides only a static view of the shoulder after an injury. The dynamic displacement of the fragment at the time of injury may have been much greater than that shown on radiography afterward, contributing to soft tissue disruptions that would not be evident on radiography. In support of this theory, we found that partial-thickness cuff tears correlated with displacement, indicating that these 2 features are at least interrelated.

Labral tears were found to be predictive of an uncomplicated recovery in our cohort. It is unclear mechanistically why labral pathology would appear to be protective. It may be that labral tears may be a part of a constellation of MRI findings in patients who consider themselves asymptomatic but who actually have a number of chronic changes on MRI prior to their GT fracture. In such patients, the MRI would generate an overestimation of their acute soft tissue trauma.

In general, patients who underwent uncomplicated recovery followed up for 17 weeks. Past a 3-month time point, patients appear less likely to recover normally on their own. This is suggestive that a more optimal treatment paradigm for patients with GT fractures is expectant management for 3 months, with MRI followed by therapeutic injection or possible surgical management for delayed return of function past that point. In cases where MRI is already available at the time of the initial clinic visit, the presence of biceps tendon pathology or partial-thickness rotator cuff tears may be useful in counseling the patient regarding expected recovery.

There are a number of limitations to the current retrospective observational study. Of note, there is a selection bias in that we included only patients who were eligible to be seen in the clinic and receive MRI readings by musculoskeletal radiologists in our health system. Patients without MRI may have been less symptomatic, and thus our results here may overestimate the prevalence of soft tissue findings in a generalized population. Additionally, the radiology reports were generated by multiple musculoskeletal-trained radiologists, who were reading the MRI without any specific injury pattern in mind. This improves the extent to which these results can be generalized, as this more closely resembles the context of MRI interpretation in a practice environment. However, it may decrease the sensitivity of the reads regarding subtle or incomplete injuries, as well as diminish the efficacy of systematically collating the results. Varying availability of specialized musculoskeletal radiologists and quality of MRI scanners may make it difficult to generalize such results. Finally, the granularity of our study is limited by the absence of a graded and validated patient-reported outcome score. The persistence of symptoms was identified according to the clinical documentation, which was obtained by multiple interviewers using nonstandardized interview and documentation techniques.

CONCLUSION

We sought to establish if there was any role for advanced imaging in determining the likelihood of a delayed recovery or the need for procedural intervention. In our series of 32 patients, we identified that MRI did not change the estimation of fracture displacement. Female sex, presence of partial-thickness rotator cuff tears, and biceps tendon pathology on MRI were predictive of delayed recovery. Our findings suggest that acute MRI is not necessary for evaluation of GT fractures but should be considered for patients with persistent symptoms after 3 months, given the high incidence of clinically relevant soft tissue injuries associated with this scenario. The optimal timing of MRI and the possibility of early intervention based on its findings require additional study.

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