**TRAUMA**

Is serial radiological evaluation of one-part proximal humeral fractures necessary?

**Aims**
In order to determine whether and for whom serial radiological evaluation is necessary in one-part proximal humerus fractures, we set out to describe the clinical history and predictors of secondary displacement in patients sustaining these injuries.

**Patients and Methods**
Between January 2014 and April 2016, all patients with an isolated, nonoperatively treated one-part proximal humerus fracture were prospectively followed up. Clinical and radiological evaluation took place at less than two, six, 12, and 52 weeks. Fracture configuration, bone quality, and comminution were determined on the initial radiographs. Fracture healing, secondary displacement, and treatment changes were recorded during follow-up.

**Results**
In 100 patients (59 female, 41 male; mean age 57 years), 91 of the fractures (91%) remained stable. In five of nine patients (55%) with secondary displacement, surgery was recommended. Comminution, present in 23 patients (23%), was identified as a predictor of secondary displacement (p < 0.001). Patients' age, sex, fracture configuration, and bone quality were not associated with secondary displacement (p ≥ 0.438). Nonoperative treatment resulted in a mean absolute Constant score (CS) of 80 (49 to 98), relative CS of 101% (63% to 138%), median subjective shoulder value of 95% (interquartile range (IQR) 90% to 100%), and median EuroQol five-dimensional questionnaire score of 0.89 (IQR 0.80 to 1.00) with bone union in all cases at one-year follow-up.

**Conclusion**
Radiological re-evaluation was only necessary in patients presenting with comminution and may be redundant for 77% of patients with one-part proximal humerus fractures. Nonoperative treatment of one-part proximal humerus fractures remains the mainstay of treatment with a low rate of secondary surgery, a high union rate, and good clinical results.

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all patients with one-part proximal humerus fractures should undergo such surveillance.1,8-10,13,15-18

We sought, therefore, to determine whether and for whom such management was necessary in minimally displaced proximal humerus fractures. The aim of this study was to describe the natural history of one-part proximal humerus fractures and to identify risk factors for secondary fracture displacement. The primary outcome was secondary fracture displacement. Secondary outcomes included conversion to operative treatment, Constant score (CS), subjective shoulder value score (SSV), and the EuroQol five-dimensional questionnaire (EQ-5D) score.

**Patients and Methods**

Since 2014, we have prospectively entered, with consent, clinical and radiological data into our institutional registry on all patients admitted to our level 1 trauma centre with proximal humerus fractures. These patients are treated according to an evidence-based algorithm that differentiates between younger, active, socially and physically independent patients, and older, frail, dependent patients.19 Whereas the first group undergoes routine clinical and radiological evaluation at set intervals post-injury, the second group is only reassessed if in persistent pain. The routine follow-up is primarily to check for secondary fracture displacement, especially at the one- to two-week and six-week checks, while monitoring also for fracture consolidation at 12 and 52 weeks. All active patients with minimally displaced one-part fractures are managed by this regimen, undergoing a rehabilitation protocol involving use of a sling for six weeks. Pendulum exercises are started in the third week, with passive and active-assisted motion from week five. After six weeks, full active range of movement is permitted, and strengthening is begun at 12 weeks after injury.

**Patient selection.** To conduct this study, our registry was queried to identify all patients admitted between January 2014 and April 2016. All skeletally mature patients with an isolated, closed, minimally displaced, nonpathological proximal humerus fracture that was treated nonoperatively were included. For inclusion, these patients must have a complete radiological evaluation prior to two weeks and at six, 12, and 52 weeks postinjury. Those with concomitant injuries were excluded. The majority of the eligible patients have been part of a prior study assessing compliance with this treatment algorithm.19

**Outcomes.** Basic demographic and clinical information was available from the registry record. The fracture classification was retrospectively and independently evaluated by two investigators (MJ and JS) based on the initial (anteroposterior (AP) and outlet view) and the follow-up (AP in neutral/internal rotation, outlet and axial view) radiographs. In case of disagreement, a consensus was agreed. Fracture configuration was classified into seven groups based on all possible segments involved (Fig. 1).20 Comminution was defined by the presence of three or more fragments within one segment.13 The deltoid tuberosity index (DTI) determined local bone quality with a threshold for low bone mineral density (BMD) set at < 1.44.21 All subsequent follow-up radiographs were evaluated for secondary fracture displacement. This was defined by a separation of > 1 cm or angulation of > 45° over time, reclassifying the fracture to a two-, three-, or four-part fracture.12 The cut-off for separation of fragments was reduced to > 5 mm for active patients with an isolated greater tuberosity fracture, as suggested in the current literature.12-14 Union was defined by the disappearance of fracture lines on the AP and outlet view at latest follow-up.15 The radiological criteria of the Ficat classification modified by Cruess was used to diagnose osteonecrosis.22

On first admission, patients were asked to complete the EQ-5D with reference back to their state of health one week before the injury, to determine the baseline EQ-5D score. The questionnaire was repeated at one-year postinjury. The SSV and absolute CS of the affected and contralateral shoulder were assessed by an independent, experienced physiotherapist at three months and one year. The absolute CS was then adjusted for age and sex by expressing it as a percentage of the respective age- and sex-matched reference values, to give the relative CS.23

**Statistical analysis.** Statistical analyses were performed using R (R Foundation for Statistical Computing, Vienna, Austria; http://www.R-project.org/). Descriptive statistics are presented as means with ranges for parametric data, and as medians with
interquartile ranges (IQRs) for nonparametric data. Pairwise comparisons were performed using paired Student’s t-tests and Wilcoxon’s signed-rank tests, as appropriate. Logistic regression analysis determined predictors of secondary displacement. Included variables included age, sex, fracture configuration, comminution, and bone quality. p-values ≤ 0.05 were considered statistically significant.

Results
Of the consecutive series of 142 patients admitted with a one-part proximal humerus fracture between January 2014 and April 2016, eight patients declined to participate, six patients died before the last follow-up, nine patients had multiple fractures, 13 patients were too frail for follow-up, and five patients had inadequate radiological follow-up. A total of 101 patients therefore met the inclusion criteria. One patient was excluded due to concomitant axillary nerve palsy, resulting in a study cohort of 100 patients. The cohort included 41 men and 59 women with a mean age at time of injury of 57 years (19 to 97 years; 35 patients over 65 years of age; Table I). Complete clinical evaluation using the CS was achieved in 93 patients. Complete SSV and EQ-5D follow-up was obtained from 89 and 92 patients, respectively. A total of 13 patients underwent additional CT imaging of the affected shoulder at first admission.

The surgical neck was involved in 76 cases (76%) and the greater tuberosity was involved in 63 cases (63%). The most frequent fracture configuration was a combined fracture pattern of the greater tuberosity and surgical neck, in a total of 33 cases (33%; Table I). An isolated fracture of the greater tuberosity was seen in 24 cases (24%), of which five cases (21%) were associated with shoulder dislocation. In 23 cases (23%), all segments were involved. Isolated fracture of the surgical neck was found in 13 patients (13%). Comminution was seen in 23 cases (23%). In total, 37 patients (37%) had low BMD.

In total, 91 of the fractures (91%) remained stable. Nine patients (9%) showed secondary fracture displacement. One was associated with reinjury two days after the index injury and diagnosed outside routine follow-up. In all other patients, displacement was identified at the routine radiological evaluation (Table II). Of the nine patients with secondary displacement, four proceeded to operative treatment, and one refused the recommended surgery. Union was seen in all nonoperatively treated fractures by the one-year follow-up. No radiographs showed any signs of osteonecrosis within the study period.

The mean absolute CS improved from 57 at three months (8 to 94) to 80 at one-year follow-up (49 to 98; p < 0.001, paired Student’s t-test). Similarly, the mean relative CS improved from 71% at three months (8% to 123%) to 101% at one-year follow-up (63% to 138%; p < 0.001, paired Student’s t-test). Mean differences of six points in absolute CS and 7% in relative CS were noticed when comparing the affected side with the contralateral side at one-year follow-up (mean 80 (49 to 98) vs mean 86 (45 to 99), and mean 101% (63% to 138%) vs mean 108% (54% to 144%); p < 0.001, paired Student’s t-test). SSV increased from a median 70% at three months (IQR 60% to 80%) to a median 95% at one-year follow-up (IQR 90% to 100%; p < 0.001, Wilcoxon’s signed-rank test). At final evaluation, the median EQ-5D score of 0.895 (IQR 0.796 to 1.000) was similar to the median baseline score of 0.919 (IQR 0.796 to 1000; p = 0.372, Wilcoxon’s signed-rank test).

Logistic regression analysis demonstrated comminution to be an independent risk factor for secondary fracture displacement (p < 0.001), whereas age, sex, fracture configuration, and bone quality were not associated with late displacement (p = 0.883, p = 0.617, p = 0.438, and p = 0.848, respectively).

Discussion
The findings of this study confirm that nonoperative treatment of one-part proximal humerus fractures results in good-to-excellent clinical outcomes and a high rate of union at one year postinjury. Four of the nine patients with secondary displacement underwent later operative treatment. The main finding of this study was that within our cohort, comminution was the sole predictor of secondary fracture displacement and therefore patients with such comminution require subsequent serial radiological evaluation at routine intervals.

The secondary displacement rate of 9% found in the present study is broadly in keeping with rates reported by other authors (0% to 15%). Our study emphasizes that routine serial radiological evaluation is useful in those cases presenting with comminution on the initial radiograph. If all patients with comminution in the study cohort had undergone radiological surveillance, we would have diagnosed all secondary displaced fractures that were identified during routine controls. Given that only 23% of patients presented with comminution, a potentially
An important reduction in radiation and healthcare costs could be achieved if routine radiological controls were restricted to this group of patients.

Seven of nine patients with secondary displacement presented with displacement of the surgical neck (Fig. 2). All seven were diagnosed within the first six weeks. Apart from the patient sustaining reinjury, all had comminution at this level, suggesting that direct mechanical support of the bone around the calcar is undermined by fragmentation in this area. Comminution may also, however, be the indirect indicator of disruption of the medial periosteal hinge, proven to be key for fracture stability around the surgical neck.

Two patients exhibited a gradual proximal and medial migration of a small fragment of the proximal greater tuberosity (Fig. 3). These small fragments have been associated with partial rotator cuff tears, and may be the radiological hallmark of progressive medial retraction of the partially torn rotator cuff tendon. Hébert-Davies et al. reported that secondary displacement of the greater tuberosity was more common in those with associated shoulder dislocation. These authors found comminution in almost half of these patients. In our study, three of the five patients with isolated greater tuberosity fractures and associated shoulder dislocation had comminution, yet none of those five showed secondary displacement. Given that half of those with comminution had an associated shoulder dislocation (3/6) in our study, we presume that shoulder dislocation is an important cause for comminution, thereafter leading to secondary displacement.

At one-year follow-up, we found predominantly good-to-excellent clinical results and quality of life, comparable to those reported in current literature. A mean difference between sides of six points in absolute CS, favouring the noninjured shoulder, is in keeping with Hanson et al. (74.3 vs 82.5) and Bahrs et al. (85.2 vs 92.7), who reported comparable results.

Table II. Characteristics of patients with secondary displacement

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age, yrs</th>
<th>Sex</th>
<th>Fracture configuration</th>
<th>Comminution</th>
<th>Low BMD</th>
<th>Displacement time, wks</th>
<th>Displaced segment</th>
<th>Treatment</th>
<th>Absolute/relative CS at one-year follow-up</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td>Female</td>
<td>LT+SN</td>
<td>Yes</td>
<td>No</td>
<td>6</td>
<td>SN</td>
<td>Nonoperative</td>
<td>92/94</td>
</tr>
<tr>
<td>2</td>
<td>75</td>
<td>Male</td>
<td>GT+SN</td>
<td>Yes</td>
<td>Yes</td>
<td>6</td>
<td>SN</td>
<td>Nonoperative</td>
<td>83/110</td>
</tr>
<tr>
<td>3</td>
<td>49</td>
<td>Female</td>
<td>GT</td>
<td>Yes</td>
<td>No</td>
<td>≤ 2</td>
<td>GT</td>
<td>Nonoperative</td>
<td>87/108</td>
</tr>
<tr>
<td>4</td>
<td>79</td>
<td>Female</td>
<td>AN+GT+LT+SN</td>
<td>Yes</td>
<td>Yes</td>
<td>≤ 2</td>
<td>SN</td>
<td>RTSA</td>
<td>65/95</td>
</tr>
<tr>
<td>5</td>
<td>79</td>
<td>Female</td>
<td>AN+GT+LT+SN</td>
<td>No</td>
<td>No</td>
<td>≤ 2'</td>
<td>SN</td>
<td>RTSA</td>
<td>75/82</td>
</tr>
<tr>
<td>6</td>
<td>55</td>
<td>Male</td>
<td>LT+SN</td>
<td>Yes</td>
<td>No</td>
<td>6</td>
<td>SN</td>
<td>ORIF</td>
<td>63/78</td>
</tr>
<tr>
<td>7</td>
<td>57</td>
<td>Female</td>
<td>GT+SN</td>
<td>Yes</td>
<td>Yes</td>
<td>≤ 2</td>
<td>SN</td>
<td>HSA</td>
<td>62/84</td>
</tr>
<tr>
<td>8</td>
<td>49</td>
<td>Male</td>
<td>GT</td>
<td>Yes</td>
<td>No</td>
<td>12</td>
<td>GT</td>
<td>Nonoperative</td>
<td>58/63</td>
</tr>
<tr>
<td>9</td>
<td>54</td>
<td>Female</td>
<td>SN</td>
<td>Yes</td>
<td>No</td>
<td>≤ 2</td>
<td>SN</td>
<td>ORIF</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*Fracture displacement secondary to reinjury at one week
†The recommended arthroscopic refixation was rejected by the patient
‡The Constant score was not assessed at one-year follow-up
BMD, bone mineral density; CS, Constant score; LT, lesser tuberosity; SN, surgical neck; GT, greater tuberosity; AN, anatomical neck; RTSA, reversed total shoulder arthroplasty; ORIF, open reduction internal fixation; HSA, shoulder hemiarthroplasty; N/A, not available

A 75-year-old male patient (patient 2 in Table II) with a comminuted fracture of the surgical neck demonstrated early secondary displacement leading to impaction of the humeral head, as seen on the anteroposterior radiographs. This patient was treated nonoperatively, with union seen at latest follow-up.
side differences in absolute CS. This difference seems to have minimal impact on quality of life, given that the EQ-5D score did not differ between baseline and latest follow-up.

Based on our results, a reduced and simplified treatment protocol seems reasonable. An alternative treatment protocol could maintain clinical and radiological control within two weeks of injury, so that a shoulder and/or trauma specialist may re-evaluate the fracture pattern, as primary radiographs may be of limited quality. If comminution of any segment cannot be ruled out, routine radiographs should follow at six weeks and three months. Lacking evidence of comminution, further radiological evaluation is not needed but clinical evaluation at six weeks and three months seems reasonable, as function may still be limited at this point. If radiological re-evaluation seems to be appropriate for any reason during these clinical evaluations (e.g. unexpected symptoms, compliance problem, concerned patient/clinician), clinicians should not hesitate to repeat the radiological evaluation. Thereafter, patients can decide if further appointments are needed. If the patient reports a reinjury within the first three months postinjury, a radiological assessment is indicated. Further research will have to determine whether this protocol is valuable and applicable.

Although it is still the most used fracture classification system for proximal humerus fractures in clinical practice, the present study is limited by the low inter- and intrarater reliability associated with the Neer classification. We tried to overcome this limitation by reviewing the radiographs twice by two different investigators (MJ and JS). Our treatment algorithm allows clinicians to obtain a CT scan if the fracture classification is uncertain. Given that only 13 such scans (13%) were performed, most of the fractures could be classified clearly. Despite the fact we presented one of the largest cohorts of patients with one-part fractures currently reported in the literature, grouping according to fracture configuration led to low sample sizes in some subgroups. This reflects, however, the natural distribution of the segments typically involved in proximal humerus fractures. Comminution was assessed solely on radiographs and might therefore be underestimated, but it must be borne in mind that this reflects clinical practice and hence makes the results of this study more generalizable.

In conclusion, nonoperative treatment of one-part proximal humerus fractures remains the mainstay of treatment with a low rate of secondary surgery, a high rate of union, and good clinical results. A displacement rate of 9% was of clinical relevance, as it resulted in a recommended change of treatment in 55% (5/9) of those showing secondary displacement. Apart from those reinjuring the index shoulder, serial radiological evaluation seems indicated only in patients presenting with comminution. Applied to clinical practice, approximately three in every four patients may not need subsequent radiological evaluations.

**Take home message**
- Serial radiological evaluation of patients with one-part proximal humerus fractures is only necessary in those presenting with comminution.
- Approximately three of four patients with a one-part fracture may not need subsequent radiological evaluation.
- Nonoperative treatment of one-part proximal fractures results in good clinical outcomes with a high union rate and a secondary displacement rate of 9%.

**References**


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