A new classification for combined greater tuberosity fracture and anterior shoulder dislocation: A study of fracture configurations and displacement after reduction

Phob Ganokroj, Narin Pakawech, Bavorrat Vanadurongwan, Thos Harnroongroj, Thossart Harnroongroj, Ekavit Keyurapan

Department of Orthopaedic Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand

ABSTRACT

Objective: The aim of this study was to propose a new classification of combined greater tuberosity (GT) fractures and anterior shoulder dislocation and studied the degree of displacement, functional outcomes, and need for additional surgery after reduction.

Methods: A cross-sectional study was conducted. We evaluated radiographs of patients treated for combined GT fractures and anterior shoulder dislocation. Three morphologies were proposed; type 1 (a small avulsion), type 2 (GT fractures without articular head involvement), and type 3 (GT associated with articular head fractures). Two orthopedic surgeons independently measured all radiographs and classified fractures into three types. Patients were interviewed by telephone to assess functional outcomes (the simple shoulder test (SST) and EQ-5D-5L), and additional shoulder surgery was also performed.

Results: There were 52 eligible patients; 32 were male (61.5%) and the mean age was 57.3 ± 17.1 years. Most cases were low-energy injuries (61.5%). Of all the cases, 32.7% were type I, 59.6% type II, and 7.7% type III cases. There were differences in the degree of displacement in each group at pre, post-reduction (both horizontal and vertical planes) and at two weeks post-reduction for HD (P < 0.05). Type III had more displacement than type I at pre- and post-reduction with a P value of less than 0.05. Type III also had higher rates of displacement than type II at post-reduction and at two-week postreduction (vertical plane). The intra and inter-rater reliabilities of measurement (ICC > 0.8) were in good to excellent agreement with the kappa value (>0.9). There out of 52 cases (5.8%) required an additional surgery after closed reduction. Patients had good functional outcomes (SST score of 8) with an excellent utility index of EQ-5D-5L (0.9).

Conclusion: This new classification exhibited good-to-excellent intra-and inter-rater reliabilities, with an ability to determine injury type. Type III seems to be linked to higher risk of fracture displacement and may require additional surgery.

Level of Evidence: Level IV, Diagnostic Study

Introduction

Proximal humeral fractures are common osteoporotic fractures in the elderly. Its incidence has increased to 82 per 100 000 people per year and is 2 times higher in females than in males and the elderly. In isolated tuberosity fractures, greater tuberosity (GT) fractures are more common than lesser tuberosity fractures, with an estimated incidence of 20% of proximal humeral fracture. The mechanisms of isolated GT fractures are multifactorial and include shearing force from anterior shoulder dislocation or impaction injury against acromion or the superior glenoid. Therefore, GT fractures and anterior shoulder dislocations are common, with an estimated incidence of 5%-30% in shoulder dislocations.

There are several classifications of GT or fracture dislocations. However, there is only one type of anterior dislocation associated with one-part fractures in group VI as per the Neer classification, which is the most accepted classification. There is also no combined GT and shoulder dislocation as per the Arbeitsgemeinschaft für Osteosynthesefracht/Orthopaedic Trauma Association’s (AO/OTA) classification. Three morphologic types of isolated GT have been proposed: avulsion, split, and depression. These have higher intra- and inter-rater reliability than the classic Neer and AO/OTA classification. However, this classification does not include shoulder dislocations. The treatment for combined GT fractures associated with anterior shoulder dislocations is not clear. Surgical fixation is indicated for high-grade GT displacements depending on the fracture pattern. Therefore, our aim was to study GT fractures associated with anterior shoulder dislocation under the hypothesis that different types of GT fragments may lead to different results after reduction. Thus, we proposed a new classification of combined GT fractures and anterior shoulder dislocation by studying the extent of GT fractures to the articular surface of the humerus and its association with the degree of GT displacement and functional outcomes after shoulder reduction.

Materials and Methods

The hospital review board approved this cross-sectional study. Medical records and radiographs of...
patients who had combined GT fractures and anterior shoulder dislocation between December 2008 and December 2019 were included and reviewed. The participants were required to review the information sheet and give informed consent. Patients who had an open fracture, pathologic fracture, concomitant upper extremity fracture, associated neurovascular deficits, or insufficient data were excluded from the study. Sixty-eight patients met the inclusion criteria, but 16 were excluded due to insufficient data. There were 52 eligible patients for this study. The demographic data, including age, gender, affected side, and mechanisms of injury, were collected from the hospital's database. The mechanisms of injury were subdivided into low energy (i.e., low-level falls) and high energy (i.e., motor vehicle accident).

The authors proposed 3 morphologic types of combined GT fracture and anterior shoulder dislocation. All radiographs were classified into 3 proposed classifications. Type I (a small avulsion) is defined as incomplete GT fractures with a fracture line lateral to the GT-head junction (Figure 1A and B). Type II (GT fracture without articular head involvement) were those in which the fracture line passed through the GT-head junction as a complete GT fragment (Figure 1D and E). For type III (GT associated with articular head fracture), the fracture line passed medially to the GT-head junction through the articular surface of the humeral head. (Figure 1G and H).

At the emergency department, diagnoses of fracture-dislocation were confirmed by the standard anteroposterior (AP) and lateral transcapular view. The hospital's standard protocol required AP radiographs. Patients were made to stand in a neutral shoulder position while an x-ray cassette behind beamed 45° from medial to lateral. For the lateral transcapular view, the x-ray was beamed tangentially across the postero- longitudinal chest and parallel to the scapular spine. All patients received closed reduction under intravenous sedation either across the posterolateral chest and parallel to the scapular spine. All patients received closed reduction under intravenous sedation either through the traction-counter traction method or modified Milch maneuver. The success of reduction was confirmed by post-reduction radiographs using the same technique. Patients had scheduled radiographs taken at 2 weeks and 4 weeks post-reduction.

Two orthopedic surgeons, 1 resident (NP) and 1 staff (PG), independently reviewed all radiographs and classified fractures into the 3 types mentioned above. The degrees of displacement were also measured using a ruler from the picture archiving and communication system at pre-, post-reduction, and 2-week follow-up in both the horizontal and vertical planes. Horizontal displacement (HD) was defined as the distance between the inner margin line of the GT fragment and the lateral margin line of the fracture along the transverse axis of the humerus (Figure 2A). For measuring displacement in the vertical plane, 2 lines were made perpendicular to the humeral axis at the inferior margin of the GT fragment and the lowest point of fracture. The distance between these 2 lines was vertical displacement (VD) (Figure 2B). Two orthopedic surgeons independently evaluated all measurements to assess the intra- and inter-rater reliabilities. Each surgeon did this twice, with a 2-week interval between each count.

For the functional outcome assessment of each injury, patients were interviewed with the following questionnaires via telephone: the simple shoulder test (SST), EQ-5D-5L, and history of additional shoulder surgery after reduction [yes or no].12,13 All questionnaires were assessed according to the patients' outcome at least 1 year after the injury. The SST is a self-reporting shoulder questionnaire that consists of 12 questions (yes or no options) ranging from 0 (the worst) to 12 (the best).12 The EQ-5D-5L (Thai version), which was developed by the EuroQol group, is a popular instrument for assessing the quality of life in relation to health.13 It covers 5 aspects: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. Each aspect has 5 further levels (5L) of impairment ranging from no problem (1) to unable/extreme problems (5). A utility score of 0-1 was also calculated to determine general health, with 1 being full health and 0 indicating death. To calculate the utility score and health profile, 1 was subtracted from the coefficient of the 5 aspects of EQ-5D-5L.14

Statistical analyses
Mean and standard deviation (SD), median and range, and 95% CI were used to describe continuous data, while frequency and percentage were used for categorical data. In addition, the intra-class correlation coefficient (ICC) was used to determine the inter- and intra-observer reliabilities of all measurements. Based on the 95% CI of the ICC, the reliability values were classified as excellent (ICC ≥0.9), good (ICC 0.75-0.89), fair (ICC 0.5-0.75), and poor (ICC <0.5).15 Differences between each group (each type of injury) were analyzed with the chi-square test, Fisher's exact test, or Mann–Whitney U test as appropriate. The Kruskal–Wallis test was used to detect differences in the distribution between the groups. Statistical analysis was performed using R version 4.0.3 (R Foundation for Statistical Computing, Vienna, Austria). The level of significant difference was set at 0.05.

Results
Of the 52 eligible patients in the study, 32 were male (61.5%) with a mean age of 57.3 ± 17.1 who mostly had injuries on the right side (31, 59.6%). Most of the cases were low-energy injuries (32 cases, 61.5%), and type I and type II had more high-energy injuries than high-energy injuries (64.7% and 61.4%, respectively). Type III showed an equal percentage of both high- and low-energy injuries (50% each). According to the proposed criteria, there were 17 cases of type I (32.7%), 31 cases of type II (59.6%), and 4 cases of type III (7.7%). The demographic data for each injury type are listed in Table 1.

The degree of displacement at the pre-, post-reduction, and 2-week follow-up period is shown in Table 2 for both the horizontal and vertical planes. There were differences in the degree of displacement between each group at pre-, post-reduction (both HD and VD), and at 2-weeks post-reduction for HD (P < .05). There were more displacements in both HD and VD in type III and type I at pre- and post-reduction with a P value less than .05 (Table 2). Type III also showed higher displacement rates than type II at post-reduction (HD and VD) and at 2-week post-reduction (VD). Type II also had a larger amount of HD compared to type I at pre-reduction and 2-week post-reduction (17.9 mm vs. 12.33 mm and 2.72 mm vs. 1 mm) with a

HIGHLIGHTS

- GT fractures and anterior shoulder dislocations are relatively common injuries however there is no classification to guide the treatment for these. This study proposes a new classification of combined GT fractures and anterior shoulder dislocation by studying the extent of GT fractures to the articular surface of the humerus and its association with the degree of GT displacement and functional outcomes after shoulder reduction.
- Three morphologic types were proposed: type I (a small avulsion), type II (GT fractures without articular head involvement), and type III (GT associated with articular head fracture). Moreover, most patients did not require additional surgery after closed reduction.
- This new classification had good-to-excellent intra- and inter-rater reliabilities with an excellent agreement in determining the type of injury. Type III was associated with a higher risk of further fracture displacement and may require additional surgery.

Statistical analyses
Mean and standard deviation (SD), median and range, and 95% CI were used to describe continuous data, while frequency and percentage were used for categorical data. In addition, the intra-class correlation coefficient (ICC) was used to determine the inter- and intra-observer reliabilities of all measurements. Based on the 95% CI of the ICC, the reliability values were classified as excellent (ICC ≥0.9), good (ICC 0.75-0.89), fair (ICC 0.5-0.75), and poor (ICC <0.5). Differences between each group (each type of injury) were analyzed with the chi-square test, Fisher's exact test, or Mann–Whitney U test as appropriate. The Kruskal–Wallis test was used to detect differences in the distribution between the groups. Statistical analysis was performed using R version 4.0.3 (R Foundation for Statistical Computing, Vienna, Austria). The level of significant difference was set at 0.05.

Results
Of the 52 eligible patients in the study, 32 were male (61.5%) with a mean age of 57.3 ± 17.1 who mostly had injuries on the right side (31, 59.6%). Most of the cases were low-energy injuries (32 cases, 61.5%), and type I and type II had more low-energy injuries than high-energy injuries (64.7% and 61.4%, respectively). Type III showed an equal percentage of both high- and low-energy injuries (50% each). According to the proposed criteria, there were 17 cases of type I (32.7%), 31 cases of type II (59.6%), and 4 cases of type III (7.7%). The demographic data for each injury type are listed in Table 1.

The degree of displacement at the pre-, post-reduction, and 2-week follow-up period is shown in Table 2 for both the horizontal and vertical planes. There were differences in the degree of displacement between each group at pre-, post-reduction (both HD and VD), and at 2-weeks post-reduction for HD (P < .05). There were more displacements in both HD and VD in type III and type I at pre- and post-reduction with a P value less than .05 (Table 2). Type III also showed higher displacement rates than type II at post-reduction (HD and VD) and at 2-week post-reduction (VD). Type II also had a larger amount of HD compared to type I at pre-reduction and 2-week post-reduction (17.9 mm vs. 12.33 mm and 2.72 mm vs. 1 mm) with a
Figure 1. A-I. Three morphologies of combined greater tuberosity (GT) fracture and anterior shoulder dislocation. (A) The drawing figure. (B) An anteroposterior (AP) radiograph of the shoulder showing type I (a small avulsion) defined fracture line lateral to the GT-head junction. (C) An AP radiograph of the shoulder showing minimal displacement after reduction. (D) The drawing figure. (E) An AP radiograph of the shoulder showing type II (GT fracture without articular head involvement) determined as a fracture line passing through the GT-head junction. (F) An AP radiograph of the shoulder showing slight displacement after reduction. (G) The drawing figure. (H) An AP radiograph of the shoulder showing type III (GT associated with articular head fracture), with the fracture line passing medially to the GT-head junction or an associated articular head fracture. (I) An AP radiograph of the shoulder showing significant displacement after reduction.

Figure 2. A, B. Shoulder measurement was performed on an anteroposterior (AP) radiograph on the horizontal and vertical axes. (A) The horizontal displacement (HD) was the distance between the inner margin line of the greater tuberosity (GT) fragment (H2) and the lateral margin line of the fracture (H1). Both lines (H1 and H2) were parallel to the humeral axis (H). (B) While measuring the vertical displacement (VD), 2 lines (V1 and V2) were made perpendicular to the humeral axis (H) at the inferior margin of the GT fragment (V2) and the lowest point of fracture (V1). The distance between these 2 lines was the VD.
Regarding the amount of displacement that might compromise shoulder function in minimally displaced tuberosity fracture, a displacement of more than 3 mm is believed to be significant for GT fractures. We also subdivided the fracture into a low displacement group (displacement less or equal to 3 mm) and a high displacement group (displacement more than 3 mm). Type III showed more percentage of significant displacements (>3 mm) in both the horizontal and vertical planes at 2-week post-reduction (75%) and more HD at 4-week post-reduction (100%). However, these differences were not statistically significant (P > .05). All displacements at 2 weeks and 4 weeks post-reduction are shown in Table 3.

The intra- and inter-rater reliabilities of the 2 measurements (HD and VD) are shown in Table 4. Both showed good to excellent reliability at different time points with an ICC >0.8. In addition, the classification system (type I to III) showed excellent agreement with the kappa value of 1 (100%) for intra-observer and 0.92 (0.82-1, 96.1%) for inter-observer agreement.

The clinical outcome of each injury type is listed in Table 5. Most patients did not require additional surgery after closed reduction. The arm sling was used for 4 weeks and physical therapy focused on a range of motion exercises. Three patients required additional surgery after closed reduction (open reduction and internal fixation with screw). According to the study, 5.8% of cases (3 out of 52) needed additional surgery after closed reduction. The main reason for surgery was severe displacement (more than 10 mm). There was also a greater percentage of patients in type III (1 out of 4 cases, 25%) that needed extra surgery compared to type II and type I (3.2% and 5.8%). An SST score of 8 (8 out of 12 points) in this series was coupled with an excellent utility index of EQ-5D-5L (0.9). The example radiographs and clinical progression of type III are demonstrated in Figure 3.

### Discussion

The authors proposed a new classification for combined GT and anterior shoulder dislocation based on the morphology of GT. This new classification uses a combination of the mechanism of injury and the degree of displacement to better understand the clinical outcomes and surgical decisions.
Table 3. Degree of greater tuberosity displacement in patients after post-reduction, stratified by fracture type

| Greater tuberosity displacement | At 2 weeks post-reduction | At 4 weeks post-reduction |
|--------------------------------|---------------------------|---------------------------|
|                                | Type I (n = 17)           | Type II (n = 31)          | Type III (n = 4)          | Type I (n = 12) | Type II (n = 26) | Type III (n = 2) |
| Horizontal displacement         |                           |                           |                           |                |                   |                  |
| ≤3 mm                          | 14 (82.4%)                | 18 (58.1%)                | 1 (25.0%)                 | 9 (75.0%)      | 21 (80.8%)        | 0                 |
| >3 mm                          | 3 (17.6%)                 | 13 (41.9%)                | 3 (75.0%)                 | 3 (25.0%)      | 5 (19.2%)         | 2 (100%)          |
| P value<sup>2</sup> for pairwise comparison Type I vs. Type II Type I vs. Type III Type II vs. Type III Vertical displacement ≤3 mm 9 (52.9%) 22 (71.0%) 1 (25.0%) 10 (83.3%) 20 (76.9%) 1 (50.0%) >3 mm 8 (47.1%) 9 (29.0%) 3 (75.0%) 2 (16.7%) 6 (23.1%) 1 (50.0%) P value<sup>2</sup> for pairwise comparison Type I vs. Type II Type I vs. Type III Type II vs. Type III

HD, horizontal displacement (mm); VD, vertical displacement (mm); ICC, intraclass correlation coefficient.

Intraobserver measurements

| Reliability of measurements | Pre-reduction | Post-reduction | At 2-weeks post-reduction |
|-----------------------------|---------------|----------------|---------------------------|
| Intraobserver (examiner 1)  |               |                |                           |                |                   |                  |
| ICC                         | 0.97 (0.94, 0.99) | 0.97 (0.94, 0.99) | 0.97 (0.94, 0.99) | 0.84 (0.81, 0.87) | 0.97 (0.94, 0.99) | 0.97 (0.94, 0.99) |
| 95% CI                      | 0.84 (0.78, 0.90) | 0.84 (0.78, 0.90) | 0.84 (0.78, 0.90) | 0.91 (0.84, 0.98) | 0.91 (0.84, 0.98) | 0.91 (0.84, 0.98) |

Interobserver measurements

| Reliability of measurements | HD | VD | HD | VD |
|-----------------------------|----|----|----|----|
| ICC                         | 0.86 (0.80, 0.92) | 0.88 (0.82, 0.94) | 0.83 (0.77, 0.90) | 0.84 (0.78, 0.90) |
| 95% CI                      | 0.79 (0.72, 0.87) | 0.81 (0.75, 0.88) | 0.82 (0.76, 0.89) | 0.84 (0.78, 0.90) |

This classification offers some benefits in determining the degree of displacement in each injury type. Type III showed more displacement across all study periods (pre-, post-reduction, at the 2-week, and 4-week follow-up periods) than type II and type I and had more GT fragment displacement and increased deltoid forces that altered the mechanics of the glenohumeral joint. In addition, displacement of GT fragments might correlate with a malfunction of the rotator cuff and impingement syndrome. Therefore, type III is supposed to be worse than type II and type I. In this study, type III also demonstrated a higher percentage of significant GT displacement (>3 mm) in the horizontal and vertical planes compared to type II and I. There was heterogeneity in the acceptable level of GT displacement ranging from 3 mm to 10 mm. The authors chose 3 mm of displacement as the threshold for sufficient reduction. Plater et al. studied the association between GT displacement and functional outcomes and found that displacement greater than 3 mm led to worse results. However, the authors stated that these thresholds were designed for isolated GT fractures. Most cases in this study had a pre-reduction displacement of more than 10 mm. Moreover, these levels of displacement should be measured at post-reduction for combined anterior shoulder dislocation and GT fractures.

Most GT fractures were treated successfully with conservative methods, especially in cases of no or minimal displacement. Nevertheless, classification is visible on plain AP shoulder radiographs with an excellent agreement for intra- and inter-rater reliabilities. In addition, according to the current literature, this classification is the first to have the morphological classification of GT fracture combined with anterior shoulder dislocation.

In previous literature, Neer proposed group VI as fracture dislocation in his classification, including 2, 3, and 4-part fracture dislocations and articular surface injuries. This classification mainly determined the injury and the remaining vascularity of the humeral head to assess prognosis. However, there is a lack of ability to determine GT fracture morphology and displacement. In addition, the classification of GT fractures based on fracture morphology had better agreement than the Neer or AO/OTA classification. We also compared our results to Mutch et al.'s study, which also demonstrated 3 morphologic types of GT fractures (avulsion, split, and depression). Type I and type II in our system were comparable to the classification in Mutch et al. However, the author's clinical experience showed that type III in our proposed classification had either small fragments or depressed fractures, which involved the articular surface. One-third of the cases in our series were type I (17 out of 52 patients), similar to the previous study showing 17%-39% for avulsion injury of GT fractures. The most common morphologic type in our study was type II (60%). Other studies also support this finding. Bahr et al. studied the mechanism of injury and pattern of GT fractures and found that 57.3% of cases in their series were associated with anterior shoulder dislocation. Thirty-four out of 60 cases (57%) were from isolated GT fractures. Most cases in this study had a pre-reduction displacement of more than 10 mm. Moreover, these levels of displacement should be measured at post-reduction for combined anterior shoulder dislocation and GT fractures.

Table 5. Clinical outcome of patients after closed reduction in each injury type

| Clinical outcome | Total patients (n=52) | Type I (n=17) | Type II (n=31) | Type III (n=4) |
|------------------|-----------------------|---------------|----------------|----------------|
| Additional surgery after closed reduction |                     |               |                |                |
| No               | 32 (61.5%)            | 10 (58.8%)    | 19 (61.3%)     | 3 (75.0%)      |
| Yes              | 3 (5.8%)              | 1 (5.9%)      | 1 (3.2%)       | 1 (25.0%)      |
| Not available    | 17 (32.7%)            | 6 (35.3%)     | 11 (35.5%)     | 0              |
| Simple shoulder test score (point) |                     |               |                |                |
| Median (range)   | 8.0 (1-12)            | 8.0 (6-12)    | 8.0 (1-12)     | 11.5 (11-12)   |
| EQ-SD-5L |                     |               |                |                |
| Median (range)   | 0.90 (0.32-1)         | 0.87 (0.57-1) | 0.96 (0.32-1)  | 0.96 (0.92-1)  |
there was an increase in the surgery rate (6.6%) in concomitant dislocated GT fractures and anterior shoulder dislocation. Our study also showed that 5.8% of cases required additional surgery after reduction, especially in type III. Furthermore, there was no significant difference between the groups in terms of SST or EQ-5D-5L (utility score) with a rising point in type III. When compared to a study by Dussing et al., there was a decreasing range of shoulder motion with an acceptable functional outcome, either conservative or surgical treatment in combined anterior shoulder dislocation and GT fractures. Their study also showed a minimal risk of secondary displacement after treatment and a shallow re-dislocation rate.

In this study, most cases had minimal displacement (<3 mm) at 4-week post-reduction. This knowledge may explain the good SST and excellent utility index score. A retrospective study also found promising results (75%) after performing open reduction and internal fixation along with early rotator cuff repair in this injury for post-surgery outcomes. The higher functional outcomes in type III might relate to higher surgery rates in this study.

This study had several limitations. First, there were incomplete data or recall biases due to the retrospective nature of the study. Second, most patients in the study were elderly and more data on younger patients are needed to increase the understanding of this complex injury. The third limitation was measuring displacement from plain radiographs. We tried to reduce measurement bias by studying the pre- and post-reduction radiograph taken by the same protocol (true AP and lateral transcapular view) and using 2 orthopedic surgeons to measure displacement within a 2-week interval to calculate the intra- and inter-observer reliabilities to increase the validity and reliability of data. Fourth, observing the extension of the fracture to the articular surface of the humeral head might be limited in plain radiographs. In future studies, a computed tomography scan with three-dimensional reconstruction is recommended to differentiate the articular involvement between type II and type III. Finally, the total number of type III and surgical cases was low, which limited the statistical comparison between each injury type. Since there was a low rate of surgical treatment, a multi-center study or a future systematic review may help document the advantages of surgical treatment of this complex injury.

In conclusion, this new classification of combined GT fracture and anterior shoulder dislocation based on morphology and location of fracture extension had good-to-excellent intra- and inter-rater reliabilities with good ability in determining the type of injury. Three types of injury, small avulsion (type I), GT fractures without articular involvement (type II), and articular involvement (type III), were studied to determine fracture displacement after reduction and risk of surgery. Type III was associated with a higher risk of fracture displacements and surgery. A future prospective study with a new design is needed to answer the functional outcomes of each type of injury and to determine the differences between conservative and surgical treatment.

Ethics Committee Approval: This study was approved by the Siriraj Institutional Review Board, and was conducted in full compliance with international guidelines for human research protection, such as the Declaration of Helsinki, the Belmont Report, and the International Conference on Harmonization in Good Clinical Practice; COA no. Si 049/2556 (EC2).

Informed Consent: Informed consent was obtained from all participants who participated in this study.

Author Contributions: Concept – P.G., T.H., E.K.; Design – P.G., N.P., T.H., E.K.; Supervision – B.V., T.H., E.K.; Materials – P.G., E.K.; Data Collection and/or Processing – P.G., N.P.; Analysis and/or Interpretation – P.G., N.P., B.V., T.H., E.K.
Literature Review – P.G., N.P.; Writing – P.G., N.P., E.K.; Critical Review – B.V., T.H., E.K.

Declaration of Interests: The authors have no conflicts of interest to declare.

Funding: The authors declared that this study has received no financial support.

References

1. Launonen AP, Lepola V, Saranko A, Flinkkilä T, Laitinen M, Mattila VM. Epidemiology of proximal humerus fractures. Arch Osteoporos. 2015;10:209. [CrossRef]
2. Lind T, Krenner K, Jensen J. The epidemiology of fractures of the proximal humerus. Arch Orthop Trauma Surg. 1989;108(5):285-287. [CrossRef]
3. Gruson KI, Ruchelsman DE, Tejwani NC. Isolated tuberosity fractures of the proximal humeral: current concepts. Injury. 2008;39(3):284-298. [CrossRef]
4. George MS. Fractures of the greater tuberosity of the humerus. JAAOS. J Am Acad Orthop Surg. 2007;15(10):607-613. [CrossRef]
5. Bahrs C, Lingenfelter E, Fischer F, Walters EM, Schnabel M. Mechanism of injury and morphology of the greater tuberosity fracture. J Shoulder Elbow Surg. 2006;15(2):140-147. [CrossRef]
6. Dimakopoulos P, Panagopoulos A, Kasimatis G, Syggelos SA, Lambiris E. Anterior traumatic shoulder dislocation associated with displaced greater tuberosity fracture: the necessity of operative treatment. J Orthop Trauma. 2007;21(2):104-112. [CrossRef]
7. Neer CSI. The classic: displaced proximal humeral fractures: Part I. Classification and evaluation. Clin Orthop Relat Res. 2006;442:77-82. [CrossRef]
8. Meinberg KG, Agei J, Roberts CS, Karam MD, Kellam JF. Fracture and dislocation classification compendium-2018. J Orthop Trauma. 2018;32(suppl 1):S3-S170. [CrossRef]
9. Müller ME, Koch P, Nazarian S, Schatzker J. Principles of the classification of fractures. In: The Comprehensive Classification of Fractures of Long Bones. Berlin, Heidelberg: Springer; 1990:4-7.
10. Mutch J, Laflamme GY, Hagemeister N, Cikes A, Rouleau DM. A new morphological classification for greater tuberosity fractures of the proximal humerus: validation and clinical implications. Bone Joint J. 2014;96-B(8):646-651. [CrossRef]
11. Hébert-Davies J, Mutch J, Rouleau D, Laflamme GY. Delayed migration of greater tuberosity fractures associated with anterior shoulder dislocation. J Orthop Trauma. 2015;29(10):e396-e400. [CrossRef]
12. Lippitt S, Harryman D, Matsen F. A practical tool for evaluating function: the simple shoulder test. In: Matsen F, Hawkins R, eds. The Shoulder: A Balance of Mobility and Stability. Rosemont, IL: American Academy of Orthopaedic Surgeons; 1993:501-518.
13. Kangwannattanakul K, Parmontre P. Psychometric properties comparison between eq-5d-5l and eq-5d-3l in the general Thai population. Qual Life Res. 2020;29(12):3407-3417. [CrossRef]
14. Pattanaphesaj J, Thavorncharoensap M, Ramos-Góñi J, Tongsiiri S, Ingsrisawang L, Teerawattananon Y. The eq-5d-5l valuation study in Thailand. Expert Rev Pharmacoecon Outcomes Res. 2018;18(5):551-558. [CrossRef]
15. Koe TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med. 2016;15(2):155-163. [CrossRef]
16. Platzer P, Kutscha-Lissberg F, Lehr S, Vecsei V, Gaehbler C. The influence of displacement on shoulder function in patients with minimally displaced fractures of the greater tuberosity. Injury. 2005;36(10):1385-1389. [CrossRef]
17. Dai F, Xiang M, Yang JS, et al. Injury mechanism of acute anterior shoulder dislocation associated with glenoid and greater tuberosity fractures: a study based on fracture morphology. Orthop Surg. 2020;12(5):1421-1429. [CrossRef]
18. Bono CM, Renard R, Levine RC, Levy AS. Effect of displacement of fractures of the greater tuberosity on the mechanics of the shoulder. J Bone Joint Surg Br. 2001;83(7):1056-1062. [CrossRef]
19. Park TJ, Choi HY, Kim YH, Park MR, Shin JH, Kim SI. A new suggestion for the treatment of minimally displaced fractures of the greater tuberosity of the proximal humerus. Bull Hosp Jt Dis. 1997;56(3):171-176.
20. Rouleau DM, Mutch J, Laflamme GY. Surgical treatment of displaced greater tuberosity fractures of the humerus. J Am Acad Orthop Surg. 2016;24(1):46-56. [CrossRef]
21. Dussing F, Plachet F, Grossauer T, et al. Anterior shoulder dislocation and concomitant fracture of the greater tuberosity: clinical and radiological results. Obere Extrem. 2018;13(3):211-217. [CrossRef]