International Orthopaedics (2019) 43:1429–1434
https://doi.org/10.1007/s00264-019-04294-1

ORIGINAL PAPER

Inferior displacement of greater tuberosity fracture suggests an occult humeral neck fracture: a retrospective single-centre study

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Received: 19 August 2018 / Accepted: 6 January 2019 / Published online: 21 January 2019

Abstract

Purpose To radiographically characterize the relationship between inferior displacement of great tuberosity (GT) fracture and associated occult or minor displaced humeral neck fracture.

Methods Thirty patients with inferior displacement of the GT on the initial anterior-posterior (AP) view X-ray were included in this study. Twenty-four patients received further computed tomography (CT) scans. One patient with negative CT scans underwent MRI. Radiographic indexes included the cervico-diaphyseal angle, the distance of the inferior displacement of the GT fracture, the apex-tuberosity distance, and the direction of the GT shift on the 3D-CT scan. The measurement reliability was analyzed by calculating intra-class correlation (ICC) coefficients. The relationships between the parameters were revealed using Pearson correlation analysis.

Results In the 30 cases, humeral neck fractures were detected by AP view X-ray (6 cases), CT (23 cases), and MRI (1 case). The mean cervico-diaphyseal angle was 146.7° ± 8.9°. The mean inferior displacement of the GT fracture was 13.4 ± 5.9 mm. The mean apex-tuberosity distance was 11.8 ± 2.8 mm. Posterior/inferior displacement of the GT fractures was observed in 24 patients via CT scan. All the evaluated parameters presented correlations among methods, indicating intra-rater and inter-rater reliability. The Pearson correlation analysis revealed that inferior displacement of GT fracture was correlated with the cervico-diaphyseal angle ($P < 0.05$).

Conclusion The inferior displacement of GT fracture on AP view X-ray is a useful diagnostic clue for the early recognition of occult humeral neck fracture and may indicate the need for further CT/MRI examination.

Keywords Greater tuberosity · Shoulder · Humeral neck · Fracture · Radiography

Introduction

Isolated fractures of the greater tuberosity (GT) account for approximately 20% of all proximal humeral fractures [1, 2]. Once the GT is fractured, inferior displacement with or without superior/posterior shifting of the GT fragment can be observed in some patients [3–5]. The fact is that such a fracture pattern has been reported by many authors [6–8]. For example, Bahrs et al. [3] found a 25% rate of inferior displacement of GT fractures on anterior-posterior (AP) view in 103 patients, while Mutch JA [8] and Verdano MA [6] also reported inferior displacement of GT fractures. However, little is known so far regarding the exact clinical significance of the inferior displacement of GT fracture.

An occult fracture is one that does not appear well on an X-ray, therefore requires other imaging tests. Occult humeral neck fractures are more likely to happen when the fracture segments are non- or minimally displaced under relatively

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small external force. An occult humeral neck fracture is hardly detected by AP view X-ray in the emergency department since it is difficult to obtain a standardized shoulder X-ray series due to great pain.

Interestingly, in our clinical practice, we noted that GT fractures which were initially diagnosed as isolated ones and with inferior displacement of GT fragment on the AP view were always combined with a humeral neck fracture upon further CT test. Thus, the aim of this study was to explore the clinical significance of inferior displacement of GT fracture and to clarify whether it could be a diagnostic clue for diagnosing occult humeral neck fracture.

Materials and methods

Population selection

We retrospectively reviewed 432 patients with a diagnosis of GT fracture between January 2009 and December 2016. Among these cases, 30 who met the following criteria were included in our study: (1) inferior displacement of GT fracture (i.e., the inferior/lateral cortical margin of the GT overlapped with the upper/lateral cortical margin of the proximal humerus shaft on the AP view X-ray); (2) normal humeral head and GT alignment on the initial AP view X-ray; (3) fracture lines that included the humeral neck and the GT; and (4) AP shoulder radiographs, CT, and MRI images obtained within five days of the injury.

Meanwhile, cases were excluded when they fell into criteria as follows: (1) younger than 18 years old or a lack of epiphysis closure; (2) a history of old proximal humerus fracture; (3) GT fracture combined with ipsilateral shoulder girdle fracture; (4) obviously displaced humeral neck fracture (displacement distance larger than 1 cm); and (5) isolated tuberosity fracture, splitting of the humeral head, incomplete imaging, or CT or MRI scan obtained five days after the initial radiograph.

Radiographical measurements

Upon AP view X-ray image, we measured (Fig. 1a) (1) the fracture location; (2) the apex-tuberosity distance [9], exactly the distance between line A and line B; (3) the distance of the inferior displacement of the GT, specifically the length of the overlap between the upper edge of humeral metaphyseal (line C) and the lower edge of GT (line D); and (4) the cervico-diaphyseal angle by Walch's method [10] (Fig. 1b, range $132.4 \pm 4.7°$). Also, with CT images, we identified (1) the direction of the GT displacement and (2) the presence of a humeral neck fracture. We performed all measurement on a platform, namely the picture-archiving and communication system (Impax; Agfa, Greenville, SC, USA), in which radiographic images of all patients were saved.

Four skilled observers (one senior shoulder surgeon, two senior orthopedic surgeons, and one experienced radiologist) performed all radiographic measurements independently, for each image was measured three times at a four week interval. In a pilot sample, images from 16 patients were randomly selected to test the reliability of measurement, which is determined by intra-class correlation (ICC) analysis according to Landis and Koch [11]. In particular, the level of agreement was assessed as follows: $1.00 \geq \text{ICCs} \geq 0.81$ = very good; $0.80 \geq \text{ICCs} \geq 0.61$ = good; $0.60 \geq \text{ICCs} \geq 0.41$ = moderate; $0.40 \geq \text{ICCs} \geq 0.21$ = low; and $\text{ICCs} \leq 0.2$ = poor.

Statistical analysis

All statistical analyses were conducted using SAS software (Version 6.12; Cary, NC, USA). The results of all measurements are shown in the form of M ± SD and Gaussian distribution of the data set was evaluated using Shapiro-Wilk method. Furthermore, the relation between the distance of GT inferior displacement and either the apex-tuberosity distance or the cervico-diaphyseal angle was investigated via Pearson correlation analysis. $P < 0.05$ was considered to be statistically significant.

Results

A total of 30 patients (21 males and 9 females) were included with their mean age at 57 years old (range from 15 to 82 years old). Generally, the majority of the fractures were low energy: for eight resulted from bicycle accident; ten due to falling from standing height; four injured in a traffic accident; six because of sports accident; and two from assault.

In terms of the measurements on AP view X-ray images, the inter- and intra-observer reliabilities of measurements were assessed. As shown in Table 1, the measurements of all three parameters showed good intra-observer agreement in cervico-diaphyseal angle measurement (ICC = 0.76), very good agreement for measuring inferior displacement of GT and apex-tuberosity distance, with ICC values were 0.913 and 0.823, respectively. Similarly, the measurements of such three parameters showed good and very good inter-observer reliability as their ICC values were 0.795, 0.915, and 0.824, respectively (Table 1).

Additionally, among 30 cases, only six (20%) obviously exhibited slight displacement of the humeral neck on their AP view X-ray, yet humeral neck fractures of 23 patients could apparently be revealed on CT images (Fig. 2) and in one patient, the humeral neck fracture is only visible with MRI examination (Fig. 3).

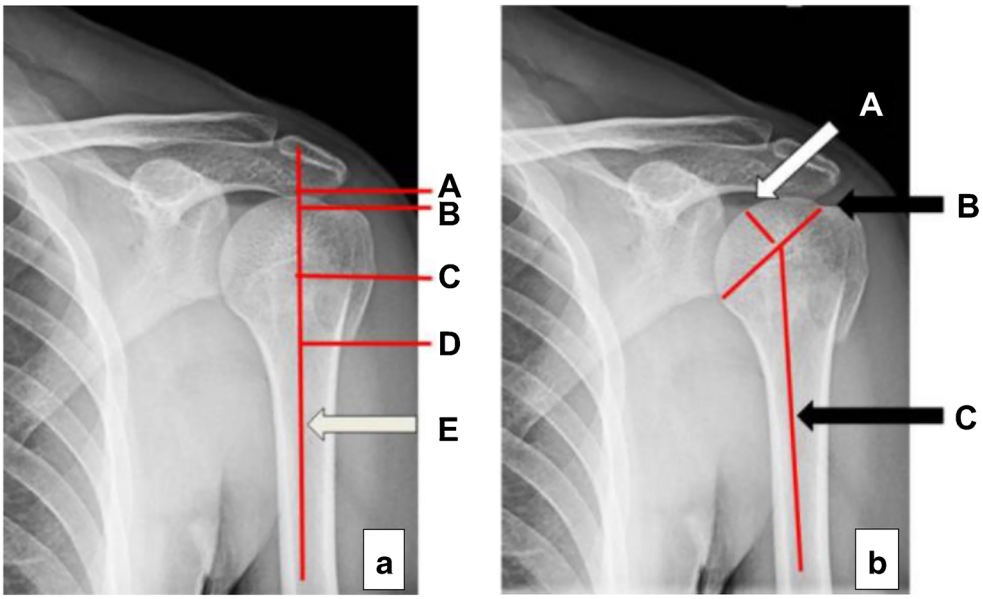

Fig. 1 The measurement on AP view X-ray image. **a** The ratio method in the AP view. Line E indicates the center axis of the humeral shaft, and all measurements are obtained parallel to this axis; line A is a vertical to line E along the apex of humeral head; line B is along the apex of humeral GT and also vertical to line E; line C, vertical to line E, is drawn across the apex of humeral lateral shaft at the fracture site; line D stands for the inferiormost point of humeral GT. AB measures apex-tuberosity distance; CD stands for the inferior displacement of GT. **b** Cervico-diaphyseal angle (Walch). Line A which is vertical to the humeral neck line at its middle point goes to the apogee of the humeral head; line B presents the humeral neck; line C is the centerline of humeral shaft; cervico-diaphyseal angle describes the angle between lines A and C

Meanwhile, the inferior displacement of GT fracture could be observed in 24 cases by CT scan. The mean inferior displacement of GT was 13.4 ± 5.9 mm, the mean apex-tuberosity distance was 11.8 ± 2.8 mm, and the mean cervico-diaphyseal angle was 146.7° ± 8.9°.

Moreover, the Pearson correlation analysis demonstrated a positive correlation between the inferior displacement distance of GT and the cervico-diaphyseal angle ($r = 0.6914$, $P < 0.001$; Fig. 4a), whereas no correlation was detected between the inferior GT displacement and the apex-tuberosity distance ($r = 0.1964$, $P = 0.3854$; Fig. 4b).

Discussion

The most important finding of the present study is we detected occult humeral neck fractures in the majority of inferiorly displaced GT fractures (24 out of 30 patients) by CT and MRI, while in only six cases, minor displacement of humeral neck presented on the primary AP view X-ray images. More importantly, our study suggests that inferior GT displacement on AP view X-ray is a diagnostic clue for early recognition of occult/minor displaced humeral neck fracture and may indicate the need for further CT/MRI examination.

In clinic, it is always difficult to detect the slight displacement of humeral neck fractures on a routine X-ray image of shoulder for the following reasons: (1) there is a lack of shoulder series radiographs: radiographic evaluation requires radiographs of the shoulder in three planes (standard anterior-posterior radiographs in internal or external rotation, an axillary view, and a scapulolateral view) [12–14] and (2) due to the pain of the injured shoulder, it is difficult to obtain a standard three-plane X-ray in the emergency room. (3) There is a

Table 1 Intra- and inter-observer reliabilities

	Intra-observer reliability			Inter-observer reliability		
	ICC	Confidence interval	*P* value*	ICC	Confidence interval	*P* value*
Cervico-diaphyseal angle	0.676	0.588–0.754	< 0.001	0.795	0.720–0.858	< 0.001
Inferior displacement of GT	0.913	0.880–0.940	< 0.001	0.915	0.880–0.943	< 0.001
Apex-tuberosity distance	0.823	0.760–0.874	< 0.001	0.824	0.757–0.879	< 0.001

*Significance level at $P < 0.05$

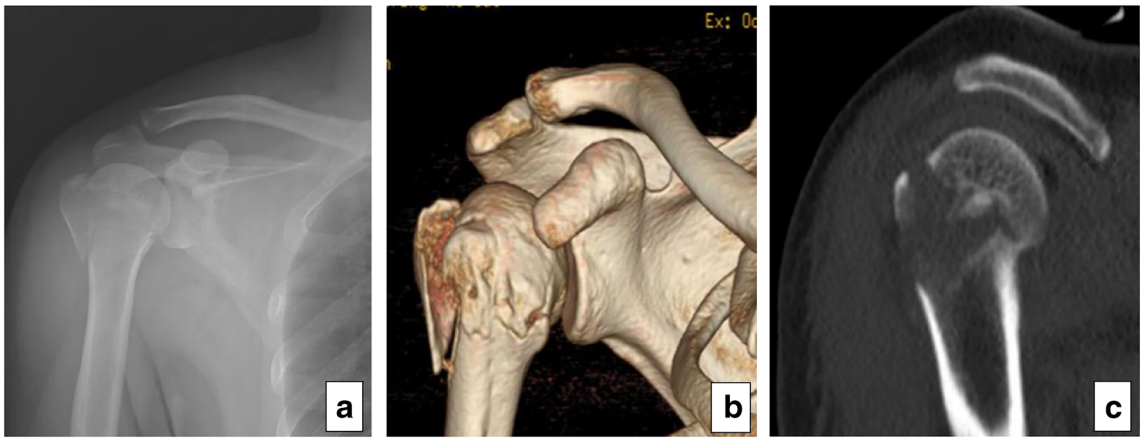

Fig. 2 Inferior displacement sign. **a** Inferior displacement sign on AP view X-ray image, while the humeral neck fracture was not obvious. **b** 3D-CT reconstruction shows the GT fragment had posterior/inferior displacement. **c** Coronal CT scan reveals the humeral neck fracture which is unseen on the X-ray image

lack of clinical experience with such injuries, especially among younger doctors and during emergencies.

Remarkably, based on our measurements of AP view X-ray images which were demonstrated to be reliable using ICC analysis (Table 1), we identified the correlation between the distance of GT inferior displacement and the cervico-diaphyseal angle ($r = 0.6914$, $P < 0.001$; Fig. 4a). In the meanwhile, no correlation between the distance of GT inferior displacement and the apex-tuberosity distance was detected ($r = 0.1964$, $P = 0.3854$; Fig. 4b). And CT scans demonstrated that the shift direction of the GT fragments was posterior/inferior. Furthermore, compared with Barhs' and others' studies which just reported the inferior GT displacement in the minimally displaced humeral neck fracture, our findings collectively suggest posterior/inferior GT displacement combined with a slightly displaced humeral neck fracture presents a manifestation of compression fracture of the proximal humerus, resulting in the change of cervico-diaphyseal angle.

More specifically, the mean cervico-diaphyseal angle in our series was 146.7° ± 8.9°, which is greater than the normal range (132.4° ± 4.7°). Such a difference may be attributable to different injury mechanisms behind. A valgus and compression mechanism may be involved, considering the shift direction of the GT fragment and the increasing cervico-diaphyseal angle. According to the valgus and compression mechanism [3, 15, 16], the humeral head and the glenoid sustain an impact via an axial force that is transmitted to the anatomical neck of the humerus, and the humeral head valgus is pushed outside of the support wall, resulting in GT fracture and shifting. This action creates a space where is large enough for the humeral head to slant outward. When the external force is relatively small, the fracture of the humeral neck is only slightly

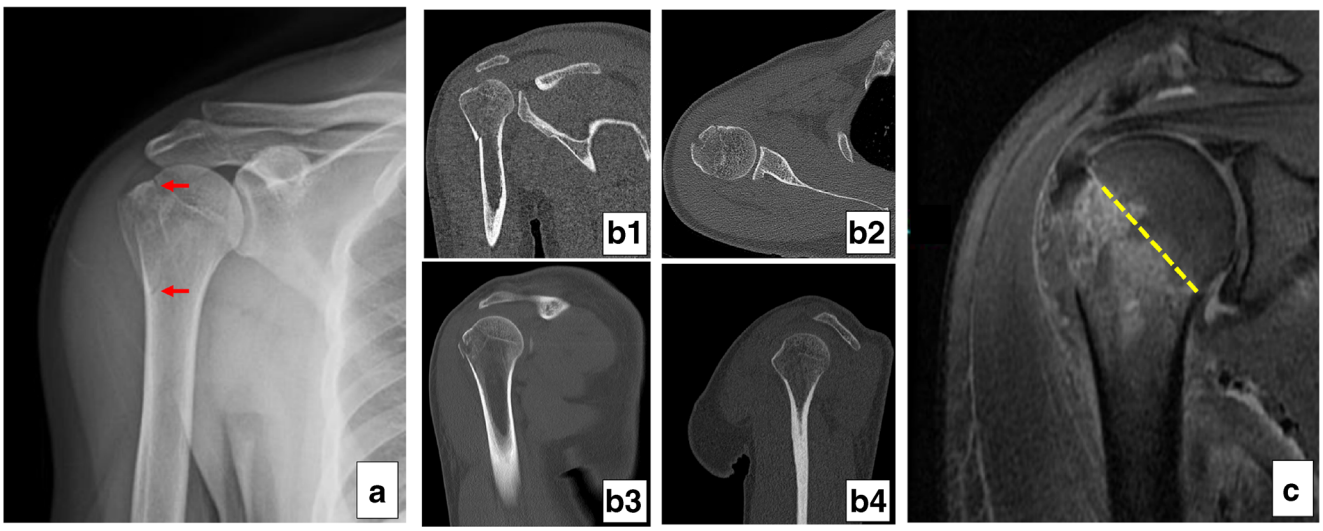

Fig. 3 Case with GT fracture and humeral neck fracture by various radiographic modalities. **a** GT fracture on AP view X-ray, arrows in red indicate the fractures line but the humeral neck fracture was occult. **b** Humeral neck fracture not visible by CT scan on axial plane (b1), transversal plane (b2), coronal plane (b3), and sagittal plane (b4), while GT fracture could be observed on axial (b1), transversal (b2), and coronal plane (b3). **c** Humeral neck fracture revealed under MRI, as the high-intensity signal indicates the fracture site (yellow dashed line)

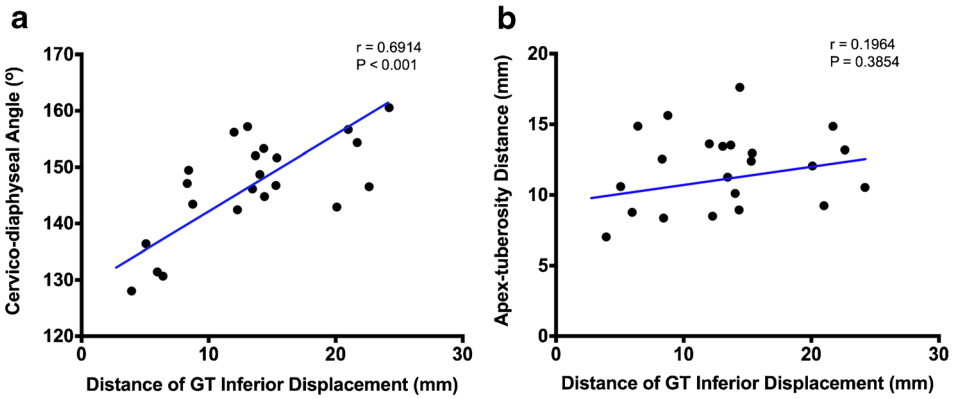

Fig. 4 The Pearson correlation analysis. **a** The positive correlation between the inferior GT displacement and the cervico-diaphyseal angle, whereas **b** no significant correlation was detected between the inferior GT displacement and the apex-tuberosity distance

displaced. If the external force is severe, the humeral neck fracture may be readily visible.

Moreover, under this injury mechanism, the shifting of the GT fragments is always posterior/inferior, as seen on CT images, which differ from isolated GT fractures. Particularly, for isolated GT fractures, the displacement of GT fracture should always be superior or posterior according to the widely accepted injury mechanisms such as avulsion force from the rotator cuff and shearing force against the glenoid rim [17, 18]. Based on the understanding of different injury mechanisms, we therefore speculate that a humeral neck fractures may be a prerequisite for the secondary GT fracture and its displacement.

Our finding is greatly clinic relevant. In particular, with the Pearson correlation analysis, we found that the inferior displacement of greater tuberosity did not correlate to apex-tuberosity distance, but correlated to the cervico-diaphyseal angle (Fig. 4). Moreover, larger cervico-diaphyseal angle is a manifestation of valgus or compression of the proximal humeral fracture. Inclusively, attention must be paid when the inferior displacement of greater tuberosity is significant on the AP view X-ray while the humeral neck fracture is not obvious. This suggests that further CT/MRI examination may be necessitated when inferior displacement appears in GT fracture, to avoid missing the diagnosis of an occult humeral neck fracture.

Accurate diagnosis leads to precise treatment. Firstly, for clinical classification, GT fractures with a slight or non-displaced humeral neck fracture should be classified as two-part fracture, according to Neer's classification of proximal humeral fractures [19]. Then, in 2002, valgus and compression fractures of the proximal humerus were revised in Neer's classification [20], and Robinson further classified this type of fracture as stage I (GT fractures associated with slight/non-displaced humeral neck fracture) [21]. More importantly, GT fracture with and without humeral neck fracture require varied treatments. It is generally accepted that minimally displaced (≤ 5 mm) fractures of the GT should be treated conservatively [22]. The involved extremity may be placed in a sling or bandage for approximately three weeks, following with intensive rehabilitation [23, 24]. However, upon the identification of a non-displaced humeral neck fracture, the patient should be given an external shoulder brace for an additional two to three weeks, and rehabilitation exercises should be delayed [22, 25, 26]. If conservative treatment fails, it is of utmost importance to correct the valgus of the humeral neck and then reduce the GT fracture by surgery. Internal fixation can be performed using screws, a proximal humerus locking plate, or a proximal humerus locking intramedullary nail [27–29].

There are some limitations in our study. At first, the sample size was not sufficiently large to allow progression analysis of displacement in every fracture pattern. Second, due to pain of injury, it was difficult to obtain a standardized trauma X-ray series in the emergency department.

Conclusion

In conclusion, slightly displaced humeral neck fracture is easily missed in clinical settings when GT fracture appears, and inferior displacement of the GT may provide a useful diagnostic clue for early recognition of occult humeral neck fracture. The better understanding of this association may be important for optimal stabilization and for prescribing an active post-operative physical therapy regimen.

Compliance with ethical standards

Ethics approval and consent to participate Given the retrospective nature of this study, written consent was not obtained. However, all patient records were anonymized prior to the analysis. Related data were obtained from the hospital's electronic and written medical records. The study was reviewed by and obtained approval from the Institutional Review Board of Shanghai General Hospital.

Conflict of interest The authors declare that they have no competing interests.

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