Four-part proximal humeral fractures: diagnosis with the ‘sunset’ sign on anteroposterior radiograph

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ABSTRACT

INTRODUCTION Four-part proximal humeral fractures require surgical intervention. However, they can be difficult to diagnose in radiological images. We aim to define a new, easily recognisable, radiological sign as a predictor of four-part fracture of the proximal humerus in a plain anteroposterior radiograph of the shoulder.

PATIENTS AND METHODS We describe our ‘sunset’ sign as ‘articular surface of humeral head pointing away from the glenoid and tilted upwards, in the presence of a displaced greater tuberosity fracture’. We postulate that a patient with proximal humerus fracture showing this sign has four-part fracture until proven otherwise. Between 2002 and 2006, 80 consecutive patients had surgical treatment of their proximal humeral fractures in our unit. Pre-operative radiographs and operative notes of 79 patients were evaluated independently by three blinded observers. The presence of ‘sunset’ sign was recorded. Findings were then correlated with the operative diagnoses to confirm whether they were four-part fractures or not. With 95% confidence interval, we calculated the sensitivity, specificity, positive and negative predictive values for our diagnostic sign.

RESULTS Of 79 patients, 30 displayed ‘sunset’ sign in their pre-operative radiograph. Of these, 28 had confirmed four-part fractures operatively. The positive predictive value of ‘sunset’ sign was 93%. The specificity and sensitivity were 95% and 78%, respectively. The sensitivity was affected by eight patients with four-part fractures with displaced articular head fragment which had dropped either medially or posteriorly.

CONCLUSIONS These results suggest that, in patients with proximal humeral fractures, the presence of ‘sunset’ sign in the anteroposterior radiograph is a reliable indicator of four-part fracture.

KEYWORDS

‘Sunset’ sign – Anteroposterior radiograph – Four-part fracture

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Planning of appropriate management of four-part proximal humeral fractures requires the treating surgeon to appreciate the common fracture patterns. In the proximal humerus, the fractured fragments often move in different directions dictated by their rotator cuff attachment. What makes this a challenge, is that on the plain radiographs the fragments often superimpose on top of each other making recognition of their displaced position difficult to determine.

We describe a new, simple, radiological sign, present in the plain anteroposterior radiograph of the shoulder indication to the displacement of the fracture. This diagnostic sign can be used by front-line staff in the accident and emergency department and surgeons of all levels of experience.

The articular surface of the humeral head relies on the greater and lesser tuberosities as lateral support to maintain its position to face the glenoid. When both the tuberosities are fractured and move away, as in a four-part fracture, the lateral

support is lost. The head then drops back and tilts up to face the subacromial space. In the anteroposterior radiography the articular fragment appears to be the setting sun among the clouds of the tuberosities. We call this the ‘sunset’ sign (Fig. 1). We hypothesise that the presence of the ‘sunset’ sign in an anteroposterior radiograph of the shoulder is due to a four-part proximal humeral fracture until proven otherwise.

Patients and Methods

Anteroposterior radiographs and operating notes of a consecutive series of 80 patients with proximal humerus fractures presented acutely to our institution and treated in our shoulder unit between 2002 and 2005 were collected by the first author who was not an observer in this study. Images available were the films viewed by the treating orthopaedic surgeon and were used for actual decision making in

Figure 1 (A) Diagrammatic representation of the 'sunset' sign. (B–D) Examples of radiographs displaying the 'sunset' sign.

patient management. One radiograph was not available; therefore, 79 were used for the statistical analysis.

Anteroposterior radiographs were reviewed by three observers, a shoulder fellow, a senior orthopaedic registrar and a senior house officer in orthopaedics. The observers had no *a priori* knowledge of the cases and were blinded to the identity of the patients and their diagnoses. In the first instance, observers received a brief lecture on the description of the 'sunset' sign with a PowerPoint presentation showing the tilt of the articular surface towards the sub-acromial space and three examples of radiographs displaying the 'sunset' sign. Subsequently, the three observers reviewed all 79 radiographs independently in random order and stated whether the sign was present or not. A second stage review of all radiographs in random fashion by the same three observers was also undertaken 2 months later to assess intra-observer variability.

The radiographs for which there was disagreement between observers as to whether the 'sunset' sign was present or not were discussed among the observers and a final consensus decision was made for the purpose of calculating the diagnostic accuracy. The first author then correlated findings of the study with operative diagnoses from the operating notes to confirm the type of the fracture.

Statistical analysis

With 95% confidence interval, the sensitivity, specificity, and positive and negative predictive values for our diagnostic sign were calculated. Non-weighted kappa coefficients were used to determine interobserver and intra-observer reliability. Kappa coefficients range from 1.0 (complete agreement) to 0.0 (chance agreement) to less than 0 (less agreement than would be expected by chance). We used the guidelines proposed by Landis and Koch¹ (Table 1) for interpretation of these values to categorise the kappa coefficients. Kappa ranges were identified as follows: values of less than 0.00 indicated poor reliability; 0.00–0.20, slight reliability; 0.21–0.40, fair reliability; 0.41–0.60, moderate reliability; 0.61–0.80 substantial reliability; 0.81–1.00, excellent or almost perfect agreement.^{1,2} A significance level of $P < 0.05$ was used.

Table 1 The measurement of observer agreement

Reliability score	
0.00–0.20	Slight
0.21–0.40	Fair
0.40–0.60	Moderate
0.61–0.80	Substantial
0.81–1.0	Excellent

Figure 2 Age distribution in blocks of ten years.

Results

There were 19 men and 60 women. The mean age of patients at the time of fracture was 65 years (range, 19–87 years; Fig. 2). The right proximal humerus was fractured side in 47 of cases and the left in 32. All were acute fractures. Of the 79 fractures studied, 18 were two-part fractures, 25 three-part fractures and 36 four-part fractures, as confirmed by the senior authors at surgery.

The 'sunset' sign was displayed in 30 out of 79 anteroposterior radiographs. Of these 30, 28 fractures were four-part fractures confirmed intra-operatively. The 'sunset' sign had a sensitivity of 0.78 and specificity of 0.95.

There were two false-positive and eight false-negative results. The positive and negative predictive value was 0.93 and 0.83, respectively (Table 2). Both false-positive cases were three-part fractures. Of the eight false-negative results, two had fracture dislocation where the head was dislocated (Fig. 3A), two had varus displacement (Fig. 3B) of the humeral head, three had posterior displacement of the humeral head and one was a head splitting four-part fracture.

Table 2 Statistical results

	Estimated value	95% confidence interval	
		Lower limit	Upper limit
Prevalence	0.45	0.34	0.57
Sensitivity	0.78	0.60	0.89
Specificity	0.95	0.83	0.99
Positive predictive value	0.93	0.76	0.99
Negative predictive value	0.83	0.70	0.92
Positive likelihood ratio	14.00	9.67	20.28
Negative likelihood ratio	0.20	0.10	0.37

Figure 3 Examples of false negatives: (A) fracture dislocation, (B) medial displacement.

Table 3 Intra-observer reliability

Observer	Kappa	Agreement	SE	95% CI	
				Lower limit	Upper limit
Observer 1	0.857	0.93	0.052	0.755	0.959
Observer 2	0.853	0.928	0.053	0.749	0.958
Observer 3	0.772	0.89	0.065	0.645	0.899

CI, Confidence interval

Intra-observer agreement for each of the three observers was calculated to assess the reliability of responses of observers at different time points (Table 3). K coefficients were 0.857, 0.853, and 0.772 for each observer respectively. The mean intra-observer correlation (k) was 0.827.

Interobserver coefficients were also calculated to assess the agreement between observer responses (Table 4). Interobserver coefficients were 0.827, 0.82, and 0.79 when responses of observer 1 against observer 2, observer 1 against observer 3 and observer 2 against observer 3 were compared, respectively. Mean interobserver coefficient was 0.812.

Discussion

Proximal humeral fractures are the third most frequent fracture in elderly patients, after hip and Colles' fracture.³⁻⁵ The largest proportion is caused by falls in a background of osteoporosis. A Finnish study showed that the overall incidence of proximal humeral fractures has increased 3-fold in the last three decades,⁴ which was attributed to the evermore ageing population.

Of all proximal humeral fractures, 80% are undisplaced and could be treated non-operatively with satisfactory results.^{6,7} However, the remaining 20% are often displaced with complex three-part and four-part fracture patterns which

Table 4 Interobserver agreement

Observer	Kappa	Agreement	SE	95% CI	
				Lower limit	Upper limit
Observer 1/2	0.827	0.915	0.04	0.748	0.906
Observer 1/3	0.82	0.91	0.04	0.741	0.899
Observer 2/3	0.79	0.895	0.043	0.705	0.875

CI, Confidence interval

Table 5 The value of Neer's classification

Author	Year	n	Kappa value
Sharder <i>et al.</i> ¹⁹	2005	113	0.45
Sallay <i>et al.</i> ¹⁶	1997	71	-0.03 to 0.56
Bernstein <i>et al.</i> ²⁰	1996	20	0.52
Siebenrock <i>et al.</i> ¹¹	1993	95	0.40
Sidor <i>et al.</i> ²	1993	50	0.52

would require some form of surgical intervention. Non-operative treatment in these cases often leads to malunion with stiffness and poor shoulder function.⁶

The management of four-part proximal humeral fractures is challenging. These fractures require special consideration as they may result in disruption of soft tissue attachments and blood supply. They should, therefore, be identified early. Radiological evaluation is the most important diagnostic tool for proximal humerus fractures. Poor quality or inadequate views can lead to errors in choice of treatment and prognostic outcome.

Various classification systems have been developed to understand the different fracture patterns. They assist in categorising the injury, prognosis, and planning of appropriate treatment. In 1934, Codman⁸ first described how the proximal humerus tends to fracture into four major segments along the epiphyseal line. These are the humeral shaft, the greater and the lesser tuberosities above and the articular fragment of the head on top. In 1970, Neer⁹ refined this classification by bringing in the concept of displacement. A fragment is only considered displaced if it has moved more than 1 cm from its neighbour and tilted more than 45°. This simple system has gained acceptance among orthopaedic surgeons internationally. Subsequently, the Association for the Study of Internal Fixation (AO-ASIF)¹⁰ has added an alpha-numeric universal long bone classification scheme which differentiates between articular and extra-articular fractures and it is based on the location of the fractures, the presence of impaction, translation or the surgical neck and dislocation. This can be applied to the shoulder and helps to standardise fracture pattern for the ease of comparison and communication.

Despite wide-spread use of the Neer classification, there has been much debate about the reproducibility and prognostic value of aforementioned classification systems. Several reports have reported poor reliability and moderate reproducibility when the Neer classification is tested among observers (Table 5).^{2,11-14} A number of studies have also addressed the influence of experience of observers.^{2,11,13,15,16} Kristiansen *et al.*¹⁵ concluded that the reliability of the Neer classification was highly dependent on the level of experience of the observer, but the overall

k-values remained unsatisfactory. Other studies have ruled out lack of experience as a factor contributing to low agreement.¹¹ In addition, the reproducible identification of four-part fractures poses even a greater problem. Brorson *et al.*¹⁴ reported mean kappa values for interobserver agreement on displaced four-part fractures ranging from 0.16 to 0.48 indicating slight-to-moderate agreement.

Studies which include computed tomography (CT) and 3-D CT for diagnostic purposes have reported a higher agreement on displaced four-part fractures, probably by assisting in identification of more complex fracture patterns. However, overall agreement on the Neer system with the use of advanced imaging modalities was not significantly improved.^{17,18} All studies emphasised the need for means to minimize variation in classification to improve clinical care.

Our aim was to describe a simple, radiological sign present in the plain anteroposterior radiograph of the shoulder. We have shown that the 'sunset' sign has a substantial intra-observer and interobserver agreement making it more reliable tool to identify four-part fracture. This sign is easy to see and teach and will help the front-line staff in both the accident and emergency and orthopaedic department to recognise pattern of four-part injury.

The 'sunset' sign is also present in the more recently described valgus-impacted four-part fracture by Neer, which is a borderline lateral displacement of the head with both tuberosities fractured and displaced enough to make room for the articular segment to be impacted.

Our results show that the 'sunset' sign has high specificity and positive predictive value. In other words, if the sign is present, the fracture should be considered to be a four-part fracture until proved otherwise. However, it should be remembered that the sign may not be displayed in a minority of four-part fractures where the head fragment is dislocated, split or displaced in either posterior or medial directions.

Conclusions

The newly described 'sunset' sign is an easily recognisable and a reliable radiological indicator of a four-part proximal humeral fracture which can be used by all grades of staff to assist diagnosis and management.

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