EVALUATION OF ANATOMICAL CHARACTERISTICS OF THE PROXIMAL HUMERAL FRACTURES BASED ON IMAGES OF PLAIN RADIOGRAPH AND COMPUTERIZED TOMOGRAPHY SCAN

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SUMMARY

Objectives: *To evaluate anatomical characteristics of the proximal humeral fractures (PHF) based on images of plain radiograph and computerized tomography (CT) scan with 3D image reconstruction.* ***Subjects and methods:*** *A prospective case series study on 101 patients treated with a close proximal humeral fracture at Nghe An Friendship General Hospital between April 2013 and July 2020. PHF were classified by Neer classification based on images of plain radiograph and CT scan with 3D image reconstruction.* ***Results:*** *Patients' median age was 59.68 ± 18.51 years, the youngest 18 years and the oldest 96 years. Based on images of plain radiograph, 101 patients were classified by Neer classification into six groups: Number of patients from group I to group VI included 5, 1, 37, 47, 6 and 5 patients respectively. Based on images of CT scans with 3D image reconstruction, 101 patients were classified by Neer classification, anatomic lesion characteristics also have full six groups including 5,1,30, 47, 13 and 5 patients respectively. The percentages of agreement of group III, group IV and group V between plain radiographs and CT-scans with 3D image reconstruction according to Neer classification were 81.08%, 87.23% and 100% respectively. The Kappa coefficient was 0.806.* ***Conclusion:*** *Fracture of humerus proximal occurs to all of ages. Anatomic lesions on conventional radiographs and CT-scans were found in all 6 groups according to Neer's classification; Group II anatomical neck fractures were rarely encountered; 4.95% in group I, group IV accounted for the highest rate (46.54%). The percentages of agreement according to Neer classification between images of plain radiograph and CT-scan are substantial.*

**Keywords: Proximal humeral fractures; Computerized tomography (CT) scans; Plain radiograph; Anatomical features.*

INTRODUCTION

A proximal humerus fracture (PHF) is a break of the upper part of the humerus which includes the head, anatomical neck, greater tubercle and lesser tubercle. PHF accounts for 4% - 5% of bone fractures. The incidence of PHF is 70 per 100,000 inhabitants per year [1]. PHF are often complex and comminuted fractures with displacement.

Previously, the Neer classification of PHF (1970) based on images of plain radiograph, provided surgeons a useful framework for clinical assessment and

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selection of appropriate treatment [1]. Nowadays, the CT-scan method, especially CT-scan with 3D image reconstruction, has been shown to be more accurate than radiograph in evaluating PHF before surgery and more helpful in surgical incision and instrument selections. Inter-rater reliability of Neer classification of PHF based on images of plain radiograph and CT-scan needs to be studied [2], [3].

At Nghe An Friendship General Hospital, we have performed plain radiograph and 3D CT-scan for all patients with PHF pre-operation to evaluate the injury grade and to choose an appropriate treatment.

In this study, we aimed: *To evaluate anatomical characteristics of the PHF based on images of plain radiograph and CT-scan with 3D image reconstruction.*

SUBJECTS AND METHODS

1. Subjects

We prospectively recruited 101 patients with a PHF treated at Nghe An Friendship General Hospital from April 2013 to July 2020, including 52 males and 49 females, aged from 18 to 96 years. All patients were performed plain radiograph and 3D CT-scan of shoulder joint.

** Selection criteria:*

- Patient with PHF aged ≥ 18 years.

- All documents consisting of X-ray films (anterior-posterior and lateral views) and CT-scan films (in Axial, Coronal, and Sagittal planes) with 3D image reconstruction of the shoulder joint, were available.

** Exclusion criteria:*

- Pathologic fractures.

- Once used to suffer from PHF.

2. Methods

A prospective case series study.

- The shoulder joint was imaged in two positions: An anterior-posterior view and a lateral view, using a digital X-ray machine.

- Another graph, the CT examinations were performed in axial, coronal, and sagittal planes with 3D image reconstruction of the shoulder joint, with a PHILIPS - Gemini LXL (32 slices).

** Radiology classification:*

- PHF patients were classified according to Neer classification (1970) [1, 4].

- Ph.D. student and an experienced specialist in radiology independently reviewed all cases. The plain radiograph images were analyzed together with CT-scan images in each case:

+ Classification of PHF using Neer classification based on plain radiograph images.

+ Classification of PHF using Neer classification based on CT-scan images.

+ The results of classification based on images of plain radiograph and CT-scan were compared to assess the degree of agreement between two methods of diagnostic imaging. The Cohen's kappa coefficient was calculated between two classification.

3. Data analysis: All data were analysed by SPSS 20.0 software. Cohen's kappa coefficient was calculated. Statistical significance was determined with $p < 0.05$.

RESULTS

1. Patients characteristics

** Age and sex:*

The average age was 59.68 ± 18.51 (the youngest 18 years and the oldest 96 years). The average age of male and

female patients was 52.46 ± 18.25 (18 - 89 years), 67.25 ± 15.60 (31- 96 years), respectively.

There were 47 patients aged 18 to 60, accounting for 46.53%, and 54 patients were over sixty years or older, accounting for 53.47%.

** Causes of fractures:*

Traffic accidents: 50 cases (49.50%); work accidents: 4 cases (3.96%). Daylife accidents: 46 cases (45.55%). Sport accidents: 1 case (0.99%).

2. Injury characteristics

There were 55 patients with proximal fractures of right humerus and 46 patients with left humerus.

** Evaluation of anatomical characteristics of PHF based on plain radiograph images:*

Table 1: Neer classification of PHF based on plain radiograph images (n = 101).

Groups	Injuried bone part			Total (n, %)
	2 parts	3 parts	4 parts	
I (non-displacement)	3	2	0	5 (4.95)
II (antomia neck)	1	0	0	1 (0.99)
III (sugeron neck)	37	0	0	37 (36.64)
IV (greater tuberosyty)	0	42	5	47 (46.54)
V (lesser tuberosity)	0	2	4	6 (5.93)
VI (dislocation)	0	4	1	5 (4.95)
Total (n, %)	41 (40.59)	50 (9.51)	10 (9.9)	101 (100.00)

It can be seen from table 1, fractures were divided into six groups according to Neer classification. Group I (nondisplacement) included 5 patients, group II (fractures of antomical neck) only one patient, group III (fracture of surgical neck) 37 patients, group IV (greater tuberosity): 47 patients (46.54%), group V (lesser tuberosity) 6 patients (47.54%), of whom 4 cases had to suffer from 4 injuried parts and 2 cases with 3 injuried parts; and group VI (dislocation) included 5 patients (4.95%).

** Evaluation of characteristics of PHF based on CT-scan images with 3D image reconstruction:*

Table 2: Neer classification of PHF based on CT-scan images (n = 101).

Groups	Injuried bone part			n	%
	2 parts	3 parts	4 parts		
I (non displacement)	2	3	0	5	4.95
II (anatomical neck)	1	0	0	1	0.99
III (surgical neck)	30	0	0	30	29.70
IV (greater tuberosyty)	0	38	9	47	46.54
V (Lesser tuberosity)	0	5	8	13	12.87
VI (Dislocation)	0	4	1	5	4.95
Total (n, %)	33 (32.67)	50 (49.51)	18 (17.82)	101	100.00

Similarly, according to Neer classification of PHF based on CT-scan images, fractures were divided into six groups. Group I (non-displacement) included 5 patients, group II (fractures of antomical neck) only one patient, group III (fracture of surgical neck) 30 patients (29.70%), group IV (greater tuberosity) 47 patients (46.54%), group V (lesser tuberosity) 13 patients (12.87%), and group VI (dislocation) included 5 patients (4.95%).

3. Comparison of agreement between method of plain radiograph and CT-scan

Table 3: Comparison of the number of injuried bone parts on plain radiograph images and CT-scan images (n = 101).

Radiograph iamges		**CT scan images**			**% of agreement**	**Kappa coefficient**
Injuried Bone part	Number of cases	2 parts	3 parts	4 parts		
2 parts	41	33	8	0	80.48	**0.738**
3 parts	50	0	42	8	80.00	
4 parts	10	0	0	10	100.00	
Total	101	33 (32.67)	50 (49.50)	18 (17.82)		

Based on plain radiograph images, there were 41 cases identified with 2-parts fractures, but based on CT-scan images only 33 cases were 2-parts fractures and 8 cases were 3-part fractures. Thus, accorrding to fracture part, the percentage of agreement between plain radiograph and CT scan was 80.48%.

Based on plain radiograph images, there were 50 cases identified with 3-part fractures, but based on CT, there were 42 cases 3-parts fractures and 8 cases were 4-parts fractures. Thus, according to fracture group, the percentage of agreement between plain radiographs and CT scan was 80.00%.

Based on CT-scan images, there were 18 cases identified with 4 part-fractures whereas on plain radiographs 4-part fracture was present in 10 cases and 3-part fracture in 8 cases.

CT-scan showed to be more accurate than plain radiographs in evaluating the number of injuried bone parts.

Table 4: Comparison of Neer classification based on plain radiograph and CT-scan (n = 101).

Radiograph images		**CT-scan images**						**% of agreement**	**Kappa coefficient**
Group	Number of cases	I	II	III	IV	V	VI		
I	5	5	0	0	0	0	0	100	
II	1	0	1	0	0	0	0	100	
III	37	0	0	30	6	1	0	81,08	**0.806**

IV	47	0	0	0	41	6	0	87,23	
V	6	0	0	0	0	6	0	46.15	
VI	5	0	0	0	0	0	5	100	
Total (n, %)	101	5 (4.95)	1 (0.99)	30 (29.70)	47 (46.55)	13 (12.87)	5 (4.95)	**100**	

Based on plain radiograph images, group III had 37 patients (36.63%) whereas there were only 30 cases groups III, 6 cases group IV and 01 case group V on CT-scan.

and 7 cases group IV on CT-scan.

Based on plain radiographs, group IV included 47 patients (46.53%) as compared to 41 cases in group IV and 6 cases in group V based on CT-scan.

Based on plain radiograph images, group V had 6 patients (5.94%) and also in group V on CT-scan. But only 13 patients in group V (12.87%) on CT-scan including 6 cases in group V and 7 cases in other groups (group IV 6 cases and group III: 1 case) on plain radiograph images.

but only 13 patients in group V (12.87%) including 6 cases in group V and 7 cases in other groups (group IV 6 cases and group III: 1 case).

Hence, if the patients are classified into group V on plain radiograph images, they are also classified into group V based on CT-scan images. The percentages of agreement of group III, group IV, groups V according to Neer classification between plain radiograph images and CT-scan images were 81.08%, 87.23% and 46.15% respectively.

DISCUSSION

1. The role of plain radiograph and CT-scan in diagnosis of PHF.

Plain radiograph is an important method in the diagnosis of fractures in general and PHF in particular. Theoretically, there are three standard X-ray views of the shoulder to diagnose PHF including a true anterior-posterior view, a lateral view, and an axillary view [5, 6].

Plain radiograph images of the shoulder joint in three positions show signs of fracture in the shoulder region: Fracture of the surgical neck, humeral head, the glenoid fossa, the acromion, the coracoid process of the scapula… Particularly for PHF, bone facture can be detected at surgical neck, anatomical neck, greater tuberosity, lesser tuberosity with different degrees of displacement or dislocation of the head, the number of displaced parts… by plain radiograph images [5].

In practice, we only performed plain radiograph of the shoulder joint in two standard X-ray views including the true anterior-posterior view and the lateral (Neers or outlet) view. It was not possible to perform plain radiograph in an axillary view of the shoulder because patients could not put their arm up to 90º. Therefore, based on plain radiograph, fracture of the surgical neck and the

anatomical neck can be identified with certainty but fracture of a greater tuberosity and lesser tuberosity sometimes can not be identified. When doctors are not sure or suspect the fractures of a greater tuberosity or lesser tuberosity, it was necessary to perform CT-scan [3, 7].

2. Comparison of anatomical characteristics of PHF based on images of plain radiograph and CT scan

After surveying the plain radiograph images and CT-scan images of 101 PHF patients treated in our hospital, the results showed that there were 50 cases with 3-part fratures (49.51%) based on plain radiograph images. There were 41 cases (40.59%) with 2-part fracture and 10 cases (9.9%) with 4 part-fractures. The number of PHF with ractures of surgical neck, greater tuberosity and lesser tuberosity were 90%, 47% and 13% respectively.

The study by Christian Bahrs et al [8] showed that among 44 patients with PHF, the ratio between 2, 3-and 4-part fractures on CT with 3D reconstruction were 12/22, 7/22 and 3/22 respectively. According to the authors, whether it is plain radiograph or CT-scans, the rate of PHF with 2 and 3 parts was the highest [8].

Based on plain radiograph, 101 patients were classified by Neer classification into six groups: group I, group II, group III, group IV, and group V and group VI included 5,1,37, 47, 6 and 5 patients respectively. In our study, the number of patients with group I was very small, including 3 cases of 2-part fracture and 2 other patients with 3-part fracture. There were 5 PHF patients with dislocation joint.

In our study, there were cases classified by Neer classification into group I and group II because these groups include PHF without displacement or less displacement treated conservatively or not hospitalized.

Based on CT-scans with 3D reconstruction, there were 33 cases of 2-part fracture (32.67%) and 50 cases of 3-part fracture (49.51%) in which 38 cases were identified with fracture at greater tuberosity, 5 cases with lesser tuberosity fracture and 5 cases of dislocation joint. There were 18 cases identified with 4-part fracture (17.82%). Based on plain radiographs, there were 41 cases identified with 2 injuried parts including 37 cases with fractures of surgical neck, one case of anatomical neck fractures and 3 cases of non-displacement fractures of surgical neck. There were 18 cases of 4-part fracture, more than that based on plain radiograph.

Comparison of the number of injuried parts on plain radiograph and that on CT-scans showed that the percentages of agreement of PHF with 2, 3 and 4 injuried parts were 80.48%, 80.00% and 100% respectively.

Comparison of Neer classification based on plain radiograph and on CT-scan with 3D image reconstruction showed that the percentages of agreement of group III, group IV and group V were 81.08%, 87.23% and 46.15% respectively.

In our study, the percentages of agreement of group III and group IV were high (> 80%). The studies by Castagno AA [2] and Shrader MW [5] showed that CT-scan with 3D image reconstruction were more valuable than radiograph in identifying the numbers of injuried parts.

CONCLUSION

Based on plain radiograph and CT-scan images, all cases were identified as PHF with 2, 3- or 4-part fracture. The ratio of PHF with 2- and 3-part fractures was the highest.

Based on plain radiograph and CT-scan iamges, 101 patients were classified by Neer classification including six groups: group I, II, III, IV, V and group V. The ratio of group IV was highest.

The percentages of agreement of group III, group IV and group V according to Neer classification on plain radiograph iamges and CT-scan iamges with 3D image reconstruction were 81.08%, 87.23% and 46.15% respectively.

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