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Research Article

Failure of Proximal Humeral Fractures Osteosynthesis - Radiological Evaluation of Predictive Factors

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Abstract

The surgical treatment of proximal humeral fractures (PHF) remains a source of debate and research. Open reduction and internal fixation (ORIF) has become more popular with the advent of locking plates. However, it is associated with a significant rate of failure. The purpose of this study is to describe several radiological factors that can be predictive of failure in PHF osteosynthesis. A revision of all records of PHF treated with ORIF between January 2005 and December 2017 was performed and specific variables were measured in pre, post and two months radiographs. A total of 91 shoulders were analyzed. Osteosynthesis failure (dismantling) was observed in 42% of patients and it was associated with comminuted fractures (p=0.001). The use of locked plates (p=0.001) and calcar reconstruction (p=0.001) were related to a lower risk for dismantling. Cut-out was observed in 20% of patients and it was associated with tip to the apex distance (p=0.004). Higher cervicodiaphyseal angles were related to lower risk for dismantling and cut-out. Four radiological factors of PHF can be used to predict the final radiological outcome of PHF osteosynthesis: comminuted fracture pattern, the use of locked plates, calcar reconstruction, tip to the apex distance and the cervicodiaphyseal angles.

***Keywords:** Open reduction and internal fixation; proximal humeral fractures; radiological factors; osteosynthesis failure; cut-out; plate fixation.*

Introduction

Proximal humeral fractures (PHF) are the third most common fractures in elderly patients and its incidence is increasing, especially due to osteoporotic bone – they account for 6% of all adult fractures and 45% of humerus fractures. (1-3) In younger patients, proximal humeral fractures usually occur as a consequence of high-energy trauma, such as traffic or sporting accidents. In the elderly, due to osteoporotic bone, PHF are usually caused by a low energy mechanism - the most common cause is a fall onto the outstretched arm from a standing position. (4, 5) The Neer classification is the most frequently used. 80% are non-displaced fractures and can be treated conservatively. However, 20% are displaced. (3-5) There is no consensus regarding optimal surgical treatment. Options are numerous, including closed reduction and percutaneous fixation, open reduction and internal fixation (ORIF) and arthroplasty. (6) ORIF has become more popular with the advent of locking plates. However, there remain a significant number of complications from this technique, including varus deformity, nonunion or malunion, cutout, avascular necrosis of the humeral head, plate impingement - which are associated with poor functional and clinical outcomes. As so, it is important to find ways to anticipate and prevent these complications. (7) The purpose of this study is to describe several radiological factors that can be predictive of failure in PHF osteosynthesis.

Materials and Methods

A revision of all records of proximal humeral fractures treated in a Level I Trauma Center with Open Reduction and Internal Fixation (ORIF) between January 2005 and December 2017 was performed. This study was submitted and approved by the Center's Ethical Committee. All records from patients older than 18 years were reviewed.

Exclusion criteria consisted of patients younger than 18 years old; pathological fractures; fractures treated after more than 2 weeks from initial trauma; patients where intramedullary nailing was used; patients whose post operative radiographs available were made more than 2 weeks after surgery; and patients with incomplete data and/or lost follow-up. Medical records provided information about the patients (gender and age), timing of surgery and timing of the first radiograph post-surgery. The authors analyzed pre-operative radiographs (X-ray) and, when available, Computed Tomography (CT), to evaluate the fracture type based on Neer's criteria and the presence of fracture comminution. In the post operative radiographs, the authors evaluated: type of plate used; number of head screws; calcar reconstruction; the distance from the tip of the longest head screw to the subchondral bone (tip to apex distance – Fig. 1); the distance from the highest shaft screw to the calcar (calcar-screw distance – Fig. 2); and cervicodiaphyseal angle measurement (1st angle – Fig. 3). Two months' post operative radiographs were also analyzed for: cervicodiaphyseal angle measurement (2nd angle – Fig. 3), cutout (defined as intra-articular penetration of head screws) and dismantling (failure of osteosynthesis). Statistical analysis was performed using SPSS 24,0®. A p-value < 0,05 was considered statistically significant. Normal distribution of variables was achieved using histogram evaluation and complemented, when needed, with normality tests (Kolmogorov-Smirnov test). For normally distributed variables, a student t-test was performed for comparative analysis. When normality was not observed, a Mann-Whitney U test was preferred. For discrete x discrete analysis, a chi-square test was used; when chi-square assumptions were not met, a Fisher's exact test was preferred.

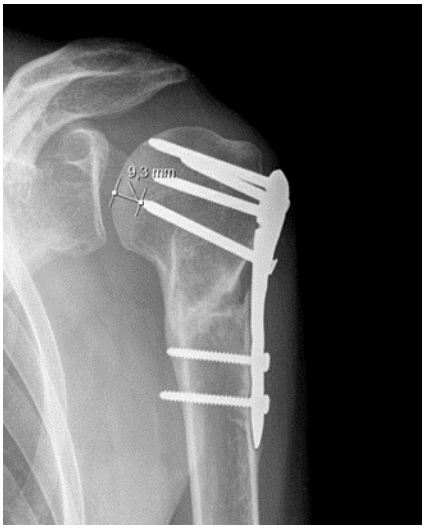

Figure 1- *Tip to apex distance.*

Figure 2- *Calcar-screw distance.*

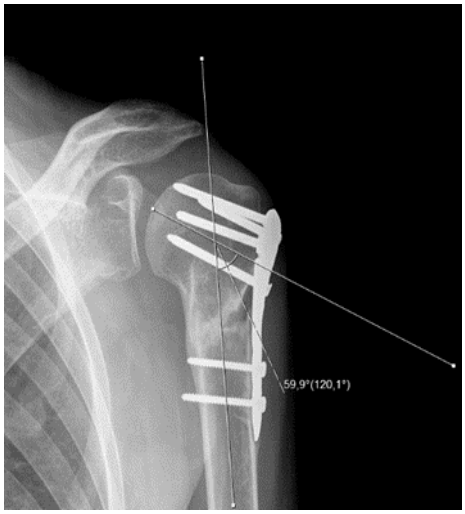

Figure 3- *1st and 2nd angles.*

Results & Discussions

A total of 91 patients with PHF, mean age (SD) of 60 (14) years old, were included in our study. The majority (58%) were female. Table 1 shows our sample's descriptives. Regarding Neer's PHF classification, in our sample, 19% had a two-part fracture, 60% a three-part fracture and 21% a four-part fracture. The vast majority of patients (75%) had a comminuted fracture. Concerning osteosynthesis, locked plates were used in 84% of patients; the number of screws to the humeral head are presented in Table 1. Calcar reconstruction was only achieved in 23% of patients.

Table 2 shows the descriptives of the calcar-head and screw-bone distance as well as the angles in the first and last radiographs. Osteosynthesis failure was observed in 42% of patients and cut-out in 20% of patients. A comminuted fracture pattern was significantly associated with higher risk of osteosynthesis failure (p=0.001), but no higher risk for material cut-out (p=0.739). Also, when calcar reconstruction was achieved, a significantly lower risk for osteosynthesis failure was observed (p=0.001), but no lower risk for cut out (p=0.471). The use of a locked plate was, as well, related to a significantly lower risk for ORIF failure (p=0.001) but no decreased risk for material cut-out (p=0.493). Still regarding osteosynthesis success, none of the indexes presented in table 2 significantly increased the risk failure. On the other hand, when considering osteosynthesis cut-out, the tip to apex distance presented a significant association (p=0.004)), with higher distances being associated with significant lower risk for cut-out. Relating to the first x-ray angles, no statistically significant differences were observed. However, in our sample, higher angles were both related to lower risk for osteosynthesis failure and material cut-out. The last x-ray angle was significantly associated with the risk for osteosynthesis failure, with higher angles being associated with lower risk for osteosynthesis failure (p=0.041). As for the association with material cut-out, no significant differences were observed, but a tendency towards association was observed between higher angles and lower risk for cut-out. In our study, the use of a locked plate was related to a lower risk for ORIF failure. In fact, this type of fixation presents more advantages compared to nonlocking plates: they allow introduction of multidirectional proximal screws, have a better reliability in osteoporotic bones and provide early and stable fixation which allows early mobilization. (8-10)

However, ORIF is associated with several complications resulting in an unsatisfactory functional outcome. (2) Osteosynthesis failure was observed in 42% of the patients. In other studies, dismantling occurs in 2.7% to 13.7% of the cases. (10 -13) Cohen et all. described two measures to avoid dismantling: to obtain anatomical reduction before the introduction of the plate and consider the placement of the screws, in central, inferior and posterior regions of the humeral head, which are the regions with higher trabecular bone density. (14)

75% of the fractures were comminuted. This fracture pattern was significantly associated with higher risk of osteosynthesis failure. Medial comminution is correlated with a higher risk of material releasing, fixation failure and fracture displacement. (3, 13-16) Calcar reconstruction was only achieved in 23% of patients. When calcar reconstruction was achieved, a significantly lower risk for osteosynthesis failure was observed. This is supported by Saul et all. – the loss of surgical fixation/dismantling – depends on anatomic reduction, particularly of the medial cortical support (calcar). (3) Actually, the reconstruction of the calcar is essential to prevent varus collapse. Moreover, different techniques have been described to increase support of the calcar, such as the use of a long oblique inferomedial screw or strut allografts. (17) Concerning cut-out, it was observed in 20% of the patients, as noted in numerous studies (0% - 23%). (11, 18) Owsley et all. detected this complication in 23% of their patients, especially in patients older than sixty years old. (18) Cut-out is the most frequent cause of surgery revision: the screws can injure the humerus and glenoid cartilage which leads to terrible functional outcomes. (8, 13)

Table I - Descriptives		
Age [a]		60 (14))
Gender [b]	Male	38 (42)
	Female	53 (58)
Side [b]	Right	38 (42)
	Left	53 (58)
Neer's classification [b]	Two-part	17 (19)
	Three-part	55 (60)
	Four-part	19 (21)
Comminution [b]	Yes	68 (75)
	No	23 (25)
Locked plate [b]	Yes	76 (84)
	No	15 (17)
Calcar reconstruction [b]	Yes	21 (23)
	No	70 (77)
Osteosynthesis failure [b]	Yes	18 (29)
	No	73 (80)
Material cut-out [b]	Yes	38 (42)
	No	53 (58)

Table II - Index		
Calcar-head index [a]		6,10 (0; 24,6)
Screw-bone index [b]		4,35 (4,36)
Cervicodiaphyseal angle	First x-ray angle [b]	136,34 (11,13)
	Last x-ray angle [b]	130,98 (12,19)

a- mean (SD)

b - n (%)

Higher cervicodiaphyseal angles seem to be related to lower risk for osteosynthesis failure and material cut-out. This fact is supported by AKSU et all, in a study where cut-out was seen in 60% of the patients with varus inclination (less than 120 degrees of the inclination angle) and in all the patients with varus displacement (100%) (postoperative increases in the varus angle). A varus inclination angle usually progresses to a varus displacement angle during the post-operative period which leads to screw penetration. (8) Agudelo et al. detected an association between a varus inclination angle and loss of reduction – it is considered a major risk factor for poor results. According to Gerber et al., the cervicodiaphyseal angle is essential to obtain a good functional outcome. Consequently, surgeons should pay attention to maintaining the angle in normal range during ORIF. (8, 11)

Still regarding cut-out, the tip to apex distance presented a significant association to this complication – when the distance increases, the incidence of cut-out decreases. To avoid cut-out, the surgeon can increase the working length of the screws but avoid the contact between the screw thread and the subchondral bone. On the other side, he shouldn't increase this distance considerably because this can reduce the construct stability. (10)

There are some limitations to this study: this is a retrospective, non-randomized study; and there is the possibility of surgeon-to-surgeon technique variability. Also, it was difficult to compare the obtained results with other studies, since there are insufficient studies about the measured variables. Thus, more studies are important in this area.

Conclusion

PHFs are complex lesions with difficult management problems, representing a challenge for the orthopaedic surgeon. ORIF represents a good option in selected patients. Several complications related to ORIF of the proximal humerus have been described so it is important to find ways to anticipate and prevent these complications. This study identified several radiological factors of PHF that can be used to predict the final radiological outcome of PHF osteosynthesis: comminuted fracture pattern, the use of locked plates, calcar reconstruction, tip to the apex distance and the cervicodiaphyseal angles.

Conflict of Interest

The authors declare no conflict of interest.

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