Avascular necrosis of humeral head after proximal humerus fracture: Comparison between classification systems in predicting necrosis risk

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Abstract. *Background and aim:* Avascular necrosis (AVN) of the humeral head is a relatively frequent complication after proximal humerus fractures (PHF). There are many factors related to the risk of developing AVN, with fracture complexity being one of the most relevant. Aim of the present study is to evaluate the correlation between different classification systems and the risk of post-operative AVN in patients treated with locking plate fixation for Neer 3 and 4-part PHFs. *Methods:* The study population included 44 patients (F:M 2:1, mean age 62) treated between December 2014 and April 2019. Fractures were classified according to Neer, Russo and Lego classifications and Hertel's criteria. AVN was established on postoperative radiographs after a minimum follow-up of 6 months. The odds ratio (OR) for AVN for each classification subtype was calculated. *Results:* The incidence of necrosis was 11%. Significant association with AVN was found for Neer 4 part (OR=8), Russo IVB (OR=4), Lego pattern 12 (OR=8) and in presence of 3 mayor Hertel's criteria (OR=15,5). *Conclusions:* There is a significant association between AVN and Neer 4 part, Russo type IVB and Lego pattern 12 fractures. AVN risk is also significantly higher in presence of 3 major Hertel's criteria. (www.actabiomedica.it)

Key words: proximal humerus fracture; avascular necrosis; complications; osteosynthesis; classification

Introduction

The prevalence of proximal humerus fractures (PHF) is between 4 and 10% in the general population. These are the third most frequent fractures in over 65, after proximal femur and distal radius fractures. In the female population they more commonly result from low energy trauma, while in the male gender there's a bimodal distribution, being mainly secondary to high energy trauma between 18 and 60 years old, while mainly secondary to low energy trauma after 65 years old (1-3).

An important aspect to consider in these fractures is the risk of vascular compromise, which may lead to avascular necrosis (AVN) of the humeral head.

The vascularization of the humeral head is guaranteed by branches of the axillary artery, the anterior (35%, ACHA) and the posterior (65%, PHCA) arteries (5,6). Regarding the vascularization of the articular capsule, the anterior capsular branches are associated to antero-medial fragments, while the posterior capsular branches are associated to postero-medial fragments (4).

In Neer 3 and 4 parts PHF, there is a great degree of variability in the reported incidence of AVN of the humeral head, ranging from 0 to 34% of cases (6,8-10).

Damage to the ACHA is found in up to 80% of complex PHF, while the PHCA is intact in 85% of the cases. Thus, protection of vascular structures is fundamental during surgery (6).

Regarding the classification of PHF, the AO classification and the Neer classification are the most commonly used (11). However, other classification systems have been introduced as an attempt to give more information about treatment and prognosis, especially regarding the risk of AVN.

In 2005 Hertel created a new classification (12), also known as the LEGO classification, conceived from the study of a series of 100 intracapsular fractures of the proximal humerus surgically treated between 1998 and 2001. The author identifies 12 groups, based on the number of fragments involved. He also defines accessory criteria, such as posteromedial metaphyseal extension of the head fracture and eventual rupture of the medial hinge, identifying them as reliable predictors of ischemia. In fact, in the work of Hertel et al. a correlation emerged between peculiar characteristics of fracture and AVN. Fracture of the anatomical neck of the humerus, medial metaphyseal extension of the humeral head inferior to 8 mm and interruption of the medial hinge, when combined, had a positive predictive value for AVN equal to 0.97. The authors postulated that if the anteromedial segment has an extension greater than 8 mm, and an articular segment displacement inferior to 5 mm compared to the shaft, the perfusion of the articular segment has a limited risk of being compromised (7).

The classification elaborated by Russo et al. in 2012 is based on the Neer and Codman (13) 4 part classification systems but gives major importance to the involvement of the calcar area, defined by the authors as the "missing fifth fragment". The classification is divided into 6 groups based on the type of involvement of the Calcar area (14).

At the moment, risk factors for AVN after PHF are not precisely established and no classification system can be surely used as a guide for choosing the right surgical treatment in these cases. There is still need to study different factors and different classifications in order to help surgeons in the choice between shoulder prosthesis and ostesynthesis, especially in complex fracture patterns. (15,16,17) Aim of the present study is to evaluate the correlation between different classification systems and the risk of post-operative AVN in patients treated with locking plate fixation for Neer 3 and 4-part PHFs.

Patients and methods

The study population included all adult patients who underwent open reduction internal fixation (ORIF) with angular stable plates for complex (Neer 3 and 4 part) PHF at the Orthopedics and Traumatology Department of the Cattinara Hospital (Trieste, Italy) between December 2014 and April 2019. Patients who did not reach at least 6 months of radiographic follow-up were excluded.

All fractures were classified based pre-operative X-ray and CT scan images according to Neer, Russo and LEGO classifications. Hertel's major and minor criteria for AVN were also registered.

At follow-up X-rays any sign of AVN was detected and cases of AVN classified according to Creuss classification (20, Table 1).

The correlation between risk of necrosis and fracture pattern was evaluated by calculating the Odds Ratio (OR) values.

Results

The final study population included 44 patients, of which 14 males (32%) and 30 females (68%), mean

Table 1. Creuss classification for humeral head avascular necrosis.

Stage	Description
Stage I	Normal appearance on plain radiographs, changes seen on MRI only
Stage II	Sclerosis and osteopenia on radiographs, humeral head sphericity preserved
Stage III	Crescent sign on radiographs, subchondral fractures
Stage IV	Flattening and progressive collapse of the humeral head with joint space narrowing
Stage V	Degenerative arthrosis of both the humeral head and glenoid
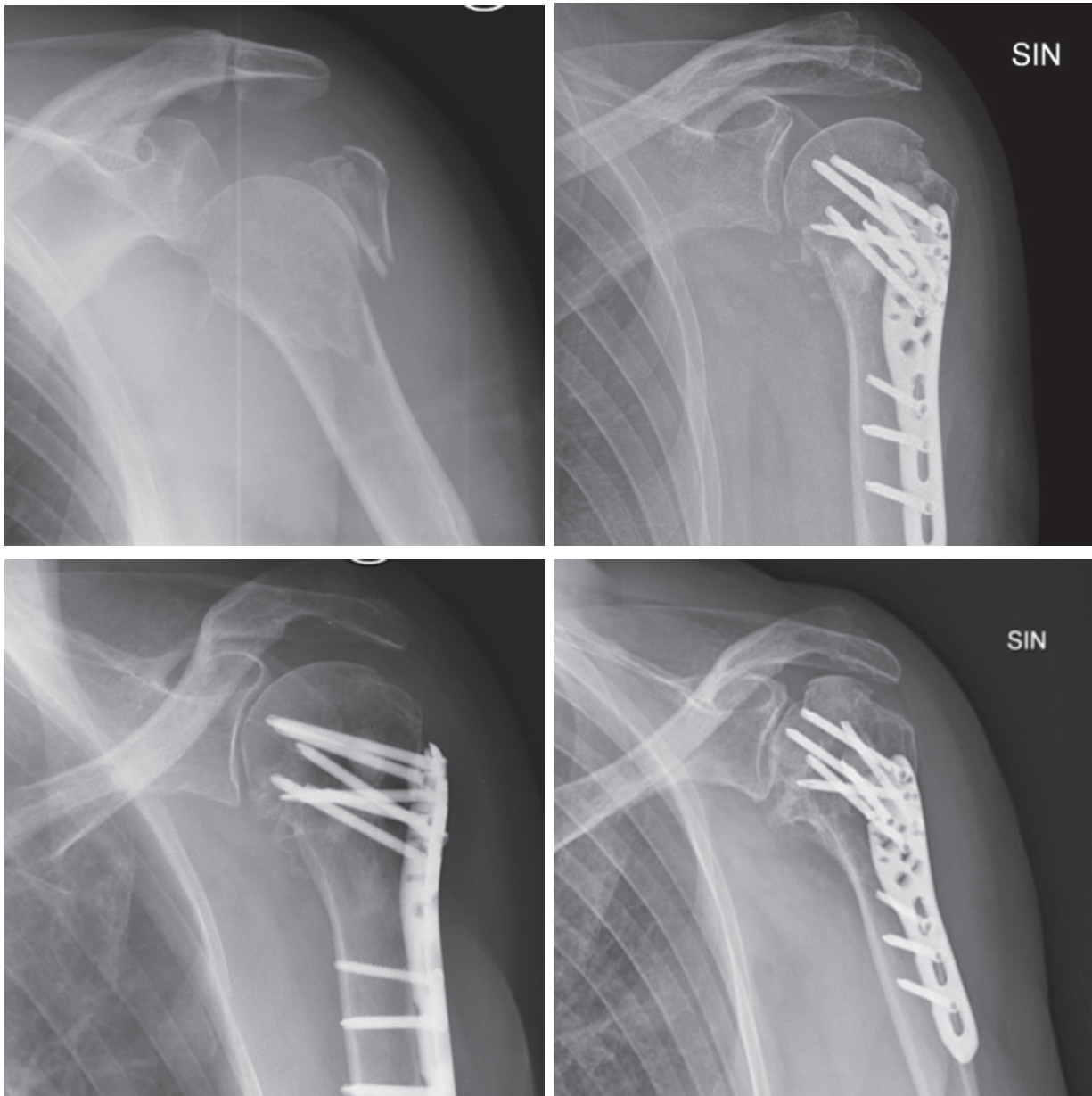
Figure 1. Clinical case of a 72 years old man treated for 4-part Neer PHF with locking plate fixation. From top -right to bottom-left: X-ray of left PHF at ER; first postoperative X-ray after ORIF; X-ray at 6 months follow-up showing early stage of AVN (Creuss stage II); X-ray taken at 18 months showing AVN of the humeral head (Creuss stage IV).

age 62 years (standard deviation 9.6 years). Most fractures occurred after low energy trauma (64%). Surgical treatment was accomplished after 5 days on average (standard deviation 3,7), with a delto-pectoral approach in most cases (75%).

Considering the Neer classification, 17 patients (39%) had a 4 parts fracture, 27 (61%) had a 3 parts fracture. Considering the Russo classification 2 patients had a IIA (12%), 4 patients a IIB (24%), 9 patients a IIC (53%) and 2 patients a IVB (12%). Considering

the LEGO classification 23 patients had a pattern 7 (52%), 1 patient a pattern 8 (2%), 1 patient a pattern 9 (2%), 1 patient a pattern 11 (2%) and 17 patients a pattern 12 (39%).

Considering the presence of Hertel's criteria, in 8 cases there were none (18%), in 11 cases 1 criterium (25%), in 13 cases 2 criteria (30%) and in 12 cases 3 criteria (27%). From the analysis of Hertel's minor criteria, no cases of head split or glenohumeral dislocation were found, while all patients presented with a 3-4 parts fracture according to inclusion criteria.

Mean radiographic follow-up was 12 months from the date of surgery (range 6-54 months, standard deviation 9 months).

At follow-up, AVN was found in 5 patients (11%); according to Creuss classification it was a stage III necrosis in 2 cases (40%) and stage IV in 3 cases (60%) (Figure 1).

The relationship between AVN and fracture patterns according to different classifications is shown in Figure 2 and Table 2.

The Odds Ratios (OR) for developing AVN according to different fracture patterns and evaualted criteria are reported in Table 3.
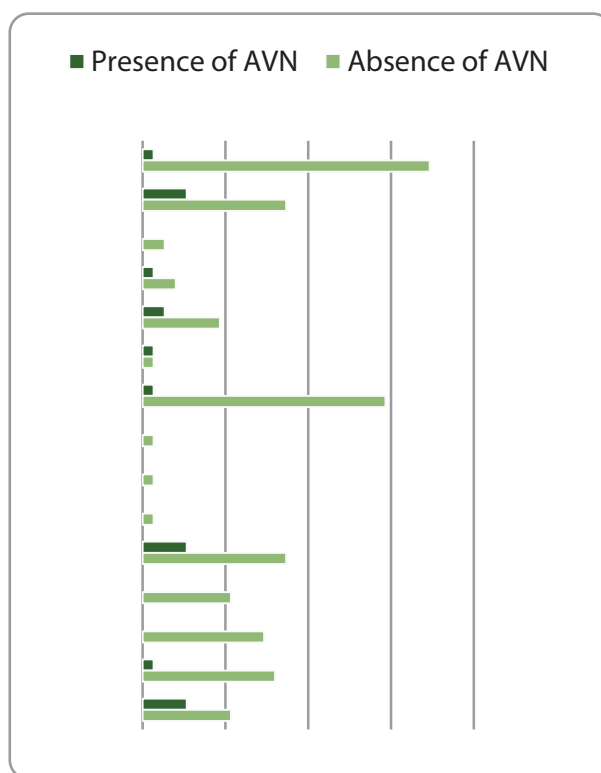

Figure 2. Presence and absence of AVN in PHF.

Table 2. AVN rates within the different classification subtype.

Classification subtype	CASES WITH AVN	RATES OF AVN
3 parts Neer	1 in 27	4%
4 parts Neer	4 in 17	24%
IIA Russo	0 in 2	0%
IIB Russo	1 in 4	25%
IIC Russo	2 in 9	22%
IVB Russo	1 in 2	50%
LEGO 7	1 in 23	4%
LEGO 8	0 in 1	0%
LEGO 9	0 in 1	0%
LEGO 11	0 in 1	0%
LEGO 12	4 in 17	24%
0 CRITERIA	0 in 8	0%
1 CRITERION	0 in 11	0%
2 CRITERIA	1 in 13	8%
3 CRITERIA	4 in 12	33%

Table 3. Fracture pattern and Odds Ratio for necrosis. A value of 1 indicates no correlation, a value greater than 1 indicates a positive association, a value less than 1 indicates a negative association. Strongest correlations of AVN stand with Neer 4 parts fracture, IVB Russo, LEGO 12 and in presence of 3 Hertel's criteria.

Fracture pattern	Odds Ratio
3 parts Neer	0,125
4 parts Neer	8
IIA Russo	0
IIB Russo	1,111
IIC Russo	0,857
IVB Russo	4
LEGO 7	0,173
LEGO 8	0
LEGO 9	0
LEGO 11	0
LEGO 12	8
0 CRITERIA	0
1 CRITERION	0
2 CRITERIA	0,562
3 CRITERIA	15,5

Conclusions

Humeral head AVN is a serious complication of PHF fixation, possibly leading to revision surgery and poor functional outcome. In literature, the risk of AVN has been correlated with various factors, including type of surgical approach, timing of surgery and quality of reduction. Nevertheless, fracture type seems to be the most relevant variable to consider. Moreover, length of follow-up may have a relevant role. Geiner et al. found that AVN incidence doubles when the period of follow-up is longer (12 months VS 45 months). They suggested that a minimum follow-up of 5 years should be mandatory, especially in cases with higher risk for necrosis. (26) Thus, the relatively brief minimum (6 months) and mean (12 months) follow-up in the present study might have led to an underestimation of actual AVN incidence. Nevertheless, the AVN rate found in the present study (11%) is in line with other literature reports, especially considering that all patients suffered from complex (Neer 3 and 4 part)

fractures. Clavert et al and Greiner et at report an AVN incidence of 16.4% and 15.6% respectively on series of 3-4 parts PHFs. The authors did not differentiate if necrosis occurred in the 3 or 4 part fractures. This limit is common to many literature studies, thus few data are available for comparing the incidence of AVN in 3 and 4 part fractures (18, 19, 21-25). Despite this limit, AVN is generally believed to occur more commonly in 4 part fractures. Data from the present study confirm this statement, with a significant association for AVN with 4 part fractures resulting in an OR of 8, to be compared with the OR of 0.125 for 3 part fractures.

In the original paper from Russo et al, the authors report an overall AVN incidence of 9% (6 out of 70 patients), not distinguishing between the subtypes that during follow-up incurred in this complicaton. (14) In the cases we considered, there was a significant association for AVN with IVB type (OR=4, 50% of cases), while in the other types this relationship did not exist (OR around 1 for IIB and below 1 in IIA e IIC). Nonetheless, AVN rate was 22% in IIC subtype and 25% in IIB subtype, thus the association may become significant with a higher number of events and might deserve further research.

Hertel et al report a strong correlation between AVN and LEGO classification patterns 12 (80%, 34 out of 46 patients) and 7 (33%, 10 out of 30 patients) (7). The same authors reported a 20% risk of developing AVN when all 3 of Hertel's major criteria were present. (7,18,19). These data are partially consistent to the results of the present study. As far as LEGO classification is concerned, the present study data did not demonstrate a significant association with LEGO pattern 7 while LEGO pattern 12 fractures were associated with a 24% AVN rate which resulted in an OR for AVN of 8. Regarding Hertel's criteria, the present study data confirmed the significance of the presence of 3 major criteria, with a much stronger correlation (OR=15,5, 33% rate) with respect to the original Hertel's paper.

LEGO pattern 12, Neer 4 part and Russo IVB fractures share the common feature of involving the lesser tuberosity and medial calcar area, which is also considered in Hertel's major criteria. These data suggest a relevant role of calcar area involvement in the development of AVN, both by a biological (blood supply

interruption) and a mechanical (maximized instability) point of view. Other authors had already reported on the importance of the calcar area analysis in predicting AVN development (21). In the authors opinion calcar area involvement should be the main focus in future research about the relationship between fracture pattern and AVN developement

The limits of the present study are the retrospective design and the relatively brief follow-up.

Moreover, the small number of events may have influenced the statistical power of data analysis, thus it could be necessary to analyze data from a bigger database with a higher number of events to reach more relevant results. Finally, other factors possibly associated with AVN have not been considered in the present paper that focuses on classification systems only.

In conclusion, the results of the present study confirm the significant association between complex fracture patterns, especially involving the lesser tuberosity and the calcar area, (Neer 4 parts, Lego pattern 12, Russo IV-B) with the risk of developing AVN. Hertel's major criteria also confirmed to be strong predictors of AVN.

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