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Incidence of secondary displacement after osteosynthesis of proximal humerus fractures: a retrospective study of 185 cases

A. DJEBARA, I. BOULNOIS, B. EL FATAYRI, P. MERTL, E. DAVID

Orthopaedic surgery department, CHU Amiens-Picardie, 80480, Salouel, France.

Correspondence at: Azeddine Djebara, Orthopaedic surgery department, CHU Amiens-Picardie, 80480, Salouel, France, Phone: 06.19.09.93.63, Fax: 03.22.08.97.22, Email: mo_eddine@hotmail.com

Proximal humerus fractures are the third most common fracture in patients over 65 years of age. There is no clear consensus regarding their treatment. The objective of this retrospective observational study was to calculate the incidence of secondary displacement after osteosynthesis of these fractures and to identify possible risk factors. 185 cases were reviewed and all osteosynthesized fractures between January 2008 and December 2016 were included. Data collected included age, sex, body mass index, alcohol and tobacco use, bone mineral density of the proximal humerus, fracture type, initial displacement, management time, type of treatment, surgeon's experience and expertise, and postoperative reduction quality. A radiographic follow-up was done at least 3 months following the fracture (until consolidation). The definition of secondary displacement was: varus/valgus displacement >10°, tuberosity translation >5 mm, articular effraction or material breakage. 53 secondary displacements were found, with an incidence of 28.6%. Seventy-two percent were diagnosed at the first follow-up visit, which occurred at an average of 29 days postoperatively. Among all factors studied, only two were statistically significant for secondary displacement: 1) low proximal humeral bone density (defined by a Tingart index <4) appears to be a risk factor, with a calculated relative risk of 2.71 (p = 0.04); and 2) the operator's specialization in the upper limb appears to be a protective factor, with a relative risk of 0.27 (p = 0.01).

A similar high incidence of complications after osteosynthesis of the proximal humerus is found in the literature, confirming the difficulty in managing these fractures. More attention should be given to patients with low bone density.

Keywords: proximal humeral fracture, complications, secondary displacement, osteosynthesis, risk factor.

INTRODUCTION

Proximal humerus fractures represent 5% of all fractures. Beyond 65 years of age, they become the third most frequent fracture[1]. In addition, their number is steadily increasing due to the overall aging of the population and osteoporosis[2]. This constitutes a major public health issue because of the loss of autonomy generated and the additional health care costs they imply[3].

Fifteen to 20% of these fractures require surgical treatment[4] if we refer to the operating criteria defined by Neer (angulation >45° or linear displacement >10 mm)[5]. However, there is no consensus on the surgical strategy to adopt in the event of a displaced fracture. Particular attention must be paid to the type of fracture, the number and displacement of the fragments, the risk factors for necrosis as well as the patient's age, functional need, and comorbidities. Taking these factors into account would refine the operative indication, limit complications, and thus would improve results.

Fixation in porotic bone is challenging, and constitutes a risk factor for secondary displacement, malunion and therefore leads to poor functional result[6]. For this reason, manufacturers have developed locking plates which provide better stability and reduce complications such as secondary displacement[7].

The aim of this work is to evaluate the incidence of secondary displacement (SD) after osteosynthesis of the proximal humerus, then to identify the risk factors for the occurrence of these SDs in order to select the patients eligible for conservative surgical treatment.

MATERIALS AND METHODS

This observational, single center, retrospective study was carried out in a French university hospital. All patients hospitalized for a proximal humerus fracture

from January 2008 to December 2016 and who had undergone osteosynthesis by plate, nails, screws, or osteosuture of the tuberosities were included.

The exclusion criteria were: pathological fractures, age under 18 years, patients with multiple fractures, diaphyseal extension of the fracture, non-conservative treatment, and incomplete records (lack of follow-up, follow-up <3 months, lack of initial X-rays).

Data collection was carried out by a single investigator. Epidemiological data included age, sex, alcohol and tobacco use, preoperative body mass index (BMI), ASA score, and time to surgery.

Fractures were classified according to Neer and AO classifications. Analyses were carried out on the initial displacement (cervico-diaphyseal angle, translation, retroversion of the humeral head on shoulder radiographs (anteroposterior view and Lamy profile), Hertel's criteria for risk of osteonecrosis[8], the presence of associated dislocation, and bone mineral density of the proximal epiphysis (Tingart index)[9]. Criteria for operative treatment were: valgus >45°, varus >10°, translation >10 mm, contact surface between the epiphysis and the shaft estimated at less than 50%, and offset and/or hyper-retroversion of the head.

Peroperative data included the type of osteosynthesis, number of screws in the humeral head, and experience and expertise of the surgeon. In the immediate postoperative period, data collected were: the quality of reduction (measurement of the cervico-diaphyseal angle on the anteroposterior radiograph, estimation of the posterior tilt on the Lamy profile image, position of the tuberosities), and the postoperative protocol (immobilization time and rehabilitation protocol).

Follow-up was heterogeneous. Left to the operator's discretion, the first follow-up consultation varied from D15 to D45. The last follow-up date varied from M3 to M24. From follow-up radiographs, we collected data on time to consolidation, the cervico-diaphyseal angle, the position of the tuberosities, material breakage, any intra-articular effraction of screws or osteonecrosis. Secondary displacement was considered to be any angular variation in the varus/valgus >10°, any displacement of the tuberosities >5 mm, any intra-articular intrusion, or breakdown of the material.

Quantitative variables are expressed as median or mean ± standard deviation according to the distribution method, and were compared using Student's *t*-test. The qualitative variables are expressed as numbers (percentage), and are compared with a Chi-square test.

Secondary displacement risk factors were identified using the binary logistic regression method with step-by-step selection. Variables with p <0.15 in the univariate analysis were included in the multivariate analysis. The threshold for statistical significance was set at p <0.05. The risk factors are presented in the

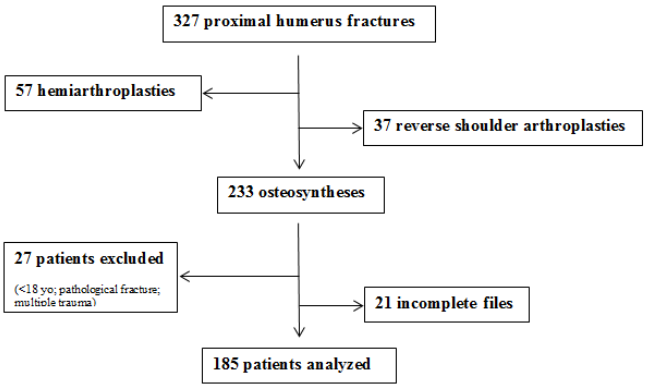

Figure 1 — Study flowchart.

Table 1. — Population data

Variable	
Age (years)	63 (20-9.5)
Sex, female (n)	129 (70.2)
Tobacco (n)	42 (22.3)
Alcohol (n)	33 (17.6)
ASA score 2-3 (n)	92 (48.9)
BMI (kg/m^2)	25.7 ± 5.96
Spur size (mm)	3 (0-30)
Bone density (Tingart index)	3.74 ± 0.71
Time to surgery (days)	3 (0-15)
NEER classification	
2	77 (40.9)
3	87 (46.3)
4	21 (12.8)
AO classification	
A1.2	13 (6.9)
A1.3	6 (3,2)
A2.2	4 (2.1)
A2.3	4 (2.1)
A3.1	11 (5.9)
A3.2	32 (17)
A3.3	7 (3.7)
B1.1	37 (19.7)
B2.1	18 (9.6)
B2.2	11 (5.9)
B2.3	11 (5.9)
B3.2	4 (2.1)
B3.3	1 (0.5)
C1.1	3 (1.6)
C1.2	2 (1.1)
C2.1	9 (4.8)
C2.2	3 (1.6)
C3.2	2 (1.1)
C3.3	7 (3.7)

(ASA = American Society of Anesthesiologists, BMI = Body Mass Index).

form of relative risk (RR) with their associated 95% confidence intervals (95% CI). The statistics were obtained with PASW version 22 software (SPSS Inc., Chicago Ill).

RESULTS

One hundred and eighty-five cases were included (Figure 1), of which 129 were female (70.2%). Mean age was 63 years old (20-95). Mean time to surgery was 3 days (0-15). Mean follow-up was 6.5 months (3-24). Epidemiological data are given in Table I.

Among fracture types, there were 58 fractures of the surgical neck (31%), 87 cephalo-tuberous fractures

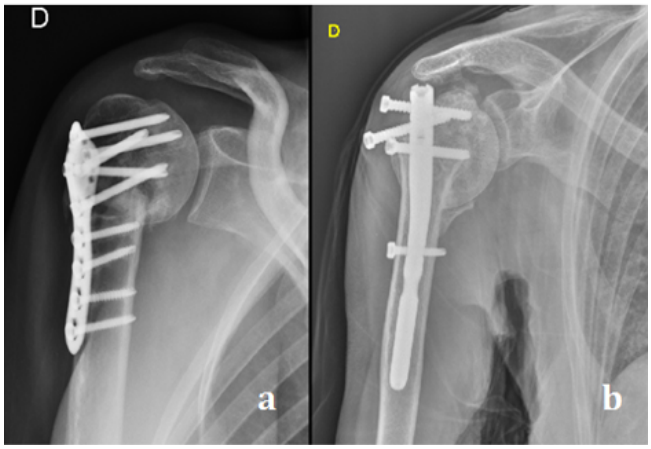

Figure 2 — Secondary displacement in the varus with (a) locking plate and with (b) centromedullary nails.

Table II. — Risk factors for secondary displacement

	Univariate analysis		Multivariate analysis	
Variables	**RR (95% CI)**	***p*-value**	**RR (95% CI)**	**p-value**
Age > 65 years	1.50 (0.79-2.85)	0,21	-	-
Sex, female	1.32 (0.67-2.62)	0.43	-	-
Tobacco	1.72 (0.82-3.64)	0.15	1.43 (0.49-4.21)	0.51
Alcohol	2.58 (1.16-5.73)	0.02	2.04 (0.66-6.24)	0.21
Obesity	0.99 (0.93-1.06)	0.86	-	-
ASA score	1.26 (0.73-2.18)	0.41	-	-
Fracture type	1.43 (1.02-2.01)	0.04	1.83 (0.76-4.39)	0,17
Preoperative CT-scan	1.77 (0.13-13.84)	0.59	-	-
NEER classification	5.32 (0.77-1.94)	0.38	-	-
AO classification	1.33 (0.02-6.34)	0.71	-	-
Medial hinge	1.24 (0.45-3.36)	0.68	-	-
Spur size	0.96 (0.91-1.01)	0.13	0.96 (0.89-1,02)	0,20
Bone density (Tingart index < 4)	1.75 (0.87-3.55)	0.12	2.71 (1,08-7,04)	0,04
Time to surgery	1.01 (0.93-1.11)	0.79	-	-
Treatment type	1.31 (0.97-1.29)	0.43	-	-
Surgeon's expertise	0.35 (0.16-0.76)	0.008	0.27 (0.09-0.73)	0,01
Initial displacement type	1.12 (0.76-1.65)	0.56	-	-
Dislocation	0.81 (0.25-2.66)	0.74	-	-
Initial lack of reduction: - Varus - Valgus	 2.21 (0.93-5.24) 1.22 (0.84-1.76)	 0.07 0.29	 1.81 (0,59-5.55) -	 0.30 -
Surgeon's experience	0.99 (0.52-1.89)	0.98	-	-
Number of screws in humeral head	0.83 (0.59-1.16)	0.28	-	-

(ASA = American Society of Anesthesiologists, RR = Relative risk).

Table III. — Risk factors for non-union

	Univariate analysis		Multivariate analysis	
Variable	**RR (95% CI)**	***p*-value**	**RR (95% CI)**	***p*-value**
Age > 65 years	1.04 (0.27-4.02)	0.95	-	-
Sex, female	1.44 (0.29-7.19)	0.66	-	-
Tobacco	2.37 (0.43-13.29)	0.33	-	-
Alcohol	0.59 (0.05-6.92)	0.67	-	-
Obesity	1.10 (0.98-1.24)	0.09	1.11 (0.99-1,23)	0.06
ASA score	1.03 (0.29-3.57)	0.96	-	-
Fracture type	1.14 (0.56-2.29)	0.72	-	-
NEER classification	5.32 (0.77-1.94)	0.38	-	-
AO classification	1.33 (0.02-6.34)	0.71	-	-
Medial hinge	1.24 (0.45-3.36)	0.68	-	-
Spur size	1.04 (0.< 95-1.04)	0.73	-	-
Bone density	0.92 (0.94-1.16)	0.41	-	-
Time to surgery	0.32 (0.02-4.23)	0.39	-	-
Degree of initial displacement	1.12 (0.76-1.65)	0.56	-	-
(ASA = American Society of Anesthesiologists, RR = Relative risk).				

with 3 fragments (CT3) (47%), 21 cephalo-tuberous fractures with 4 fragments (CT4) (12%), and 19 isolated trochiter fractures (10%). According to AO classification, the most frequent type was B1.1 (19.7%), which corresponds to CT3 fractures impacted in the valgus.

Regarding treatment, 105 fractures benefited from centromedullary nails, 60 from internal osteosynthesis with a locking plate, 15 from simple screw fixation, 2 from an isolated osteosuture, and 3 from reinsertion with anchors.

There were 53 secondary displacements recorded. The incidence was 28.6% (95% CI = 22.0-35.2). Of these 53 SDs, 19 required surgical revision, with an incidence of revision of 35.8% (95% CI = 27.6-43.9). Nine patients underwent arthroplasty (7 total reverse shoulder arthroplasties and 2 partial arthroplasties), 5 intra-articular screw removal, 4 complete material removal, and 1 nail revised by a locking plate with a bone autograft. Of the 53 SDs, there were 15 surgical necks (28%), 20 CT3 (38%), 13 CT4 (24%), and 5 trochiter (10%). SD involvement included 33 nails (31%), 14 osteosyntheses by plate (23%), 5 screw fixations (33%), and 1 reinsertion with anchors (33%) (Figure 2).

Thirty-eight of these 53 SDs were diagnosed during the first follow-up consultation (72%, 95% CI = 59.9-84.1). This first consultation took place on average on the 29th postoperative day (15-45).

Among the factors studied, only two had a statistically significant association with secondary displacement. First, bone density with a Tingart index <4 appears to be a risk factor for SD, with a relative risk in multivariate analysis of 2.71 (95% CI = 1.08-7.04; $p = 0.04$). Second, the surgeon's specialization in the upper limb appears to be a protective factor, with a relative risk in multivariate analysis of 0.27 (95% CI = 0.09-0.73; $p = 0.01$). The number of fragments appears to be a risk factor in univariate analysis, with a RR of 1.43 (95% CI = 1.02-2.01; $p = 0.04$). However, this was corrected by the multivariate analysis which did not find any statistically significant association, with an RR of 1.83 (95% CI = 0.76-4.39; $p = 0.17$). There is a statistical association between a lack of reduction in the varus and the occurrence of SD in univariate analysis (RR = 2.21, $p = 0.07$), which was corrected in multivariate analysis (RR = 1.81, $p = 0.30$). The results for the SD risk factors are summarized in Table II.

Nine cases of non-union were found, with an incidence of 4.9% (95% CI = 1.7-8). None of the factors analyzed had a statistically significant association with the occurrence of non-union. The results are presented in Table III.

Four cases of osteonecrosis were found, with an incidence of 2.2% (95% CI = 0.1-4.3). Medial comminution appears to be the only independent risk factor, with a relative risk in multivariate analysis of 2.79% (95% CI = 1.02-7.58; $p = 0.04$). Size of a possible metaphyseal spur, 4-fragment fractures, and associated dislocation, however, had no statistically significant association with the occurrence of osteonecrosis (Table IV).

Table IV. — Risk factors for osteonecrosis

	Univariate analysis		Multivariate analysis	
Variable	**RR (95% CI)**	***p*-value**	**RR (95% CI)**	***p*-value**
Medial comminution	2.79 (1.02-7.58)	0.04	2.79 (1.02-7.58)	0.04
Spur size	1.05 (0.85-1.15)	0.94	-	-
CT4 fracture	1.01 (0.34-3.03)	0.98	-	-
Dislocation	3.57 (0.35-36.56)	0.28	-	-
(CT = Cephalotuberosity, RR = Relative risk).				

DISCUSSION

We report in our study an incidence of 28.6% for secondary displacement after osteosynthesis of the proximal humerus. This high rate can be explained by our very broad definition of SD. Our results are in line with data in the literature from studies carried out on populations similar to ours in terms of age, sex, and fracture type. In his 2007 prospective study of 119 cases, Hirschmann *et al*. reports a revision rate of 22%, following secondary loss of reduction, intra-articular screw, or osteonecrosis[10]. In 2008, Owsley *et al*. reported, in their series of 53 osteosyntheses by plate, a secondary displacement rate of 36%[7]. In 2009, Brunner *et al*. found an incidence of 29% for SD among 158 cases of osteosynthesis using locking plates[11].

In 2010, Clavert *et al*. reported a series of 73 CT3/CT4 fractures treated with plates, with a rate of secondary displacements of 8%, to which was added 13% intra-articular screw and 16% osteonecrosis[12]. This high incidence of osteonecrosis is probably due to a longer follow-up (18 months minimum), and to the fact that they studied only fractures with three or four fragments with greater risk of osteonecrosis[8]. In contrast, in their 2007 study, Agudelo *et al*. found only 14% SD following 153 osteosyntheses by plate of the proximal humerus[13]. Similarly, Hardeman *et al*. found a failure rate of only 15.3% after osteosynthesis of 307 fractures treated by an experienced surgeon[14].

Of our 53 SDs, only 19 (35.8%) underwent revision surgery. Proximal humerus fractures mainly affect elderly patients with comorbidities, lower functional demand, and greater surgical risk compared to a young population[15]. Regarding the time of diagnosis of SD, 72% of them were diagnosed during the first follow-up consultation, on average on the 29th day after surgery. This result is in agreement with the study by Agudelo *et al*.[13] in which 73% of SDs were diagnosed before the 4th week. We believe that the first radiographic follow-up examination should take place between the 15th and the 21st postoperative day in order to diagnose a possible SD and avoid a delay in its management.

In our study, the only independent risk factor found for SD was low bone mineral density of the proximal humerus, defined by the Tingart index as below 4[9]. We did not find any studies in the literature using this criterion preoperatively. However, fixation in porotic bone may be difficult, and will therefore expose the fracture to an increased risk of secondary displacement. This index appears to us to be a more reliable and reproducible indicator than the patient's age in predicting failure. Stability of materials is improved by the use of multidirectional epiphyseal locked screws, which increase resistance to tearing of the screws[16]. Indeed, a failure rate of 55% is reported when using non-locking plates on porous bone in the management of fractures of the proximal humerus with 3 or 4 fragments[17].

The surgeon's specialization in the upper limb appears to be a protective factor, probably related to the quality of the fracture reduction. Indeed, in several studies the quality of reduction has been found to be an independent factor for secondary displacement[12,13,18,19]. However, it does not appear to be a risk factor in our study, despite a statistical trend in univariate analysis. The complexity of the fracture was not found to be an independent risk factor, unlike findings from other studies that highlight the initial fracture type as the primary prognostic factor. Poor results were shown for type C fractures in the study of Hardeman *et al*.[14] and for 4-fragment fractures as reported by Jobin *et al*.[20] and Boudard *et al*.[21]. In these three studies, however, no reference was made to the quality of reduction. We believe that, apart from the complexity of the fracture, it is the quality of reduction that primarily influences the occurrence of an SD.

The osteosynthesis type does not seem to influence the occurrence of SD in our study, regardless of the fracture type. Several articles comparing centro-medullary nail fixation and plates also found no difference in terms of SD[14,21]. Similarly, the number of screws in the humeral head does not appear to be a risk factor for Owsley *et al*. in their series of 53 locking plate osteosyntheses[7] or for Agudelo *et al*. in their series of 153 fractures treated

with plates or nails[13]. Epidemiological factors such as age, sex, alcoholism, smoking, and obesity do not appear to be risk factors for SD [13,22].

Finally, performing a preoperative shoulder CT-scan does not affect the risk of SD. However, a CT-scan may be useful in complex or articular fractures to more precisely analyse the number and the displacement of the fragments[23]. Preoperative planning provides optimal therapeutic management[24].

Two alternatives to osteosynthesis can be discussed: orthopaedic treatment and arthroplasty. The results of partial arthroplasty are generally satisfactory with regard to pain (60 to 90% of pain-free or minimally painful shoulder), but functionally disappointing, with poor range of motion[25]. In addition, in his review of the literature, Plausinis *et al*. found rates of SD and non-union of the tuberosities in partial arthroplasties of up to 23% and 17%, respectively[26]. Migration and non-union of the tuberosities cause the rotator cuff to be non-functional and are the main cause of failure.

Reverse total shoulder arthroplasty (RTSA) seems to obtain better results for function[27,28]. This leads to proposing, in the first intention, an RTSA in elderly patients, representing a population at risk for failure of partial arthroplasty[29]. Studies have shown the superiority of RTSA in terms of functional results compared to partial arthroplasty in first-line treatment of these fractures in the elderly[30,31]. In addition, some studies have found better functional results when the RTSA was used as first-line treatment compared to after osteosynthesis failures[32,33,34].

In their meta-analysis of 31 randomized clinical trials, Handoll *et al*. did not demonstrate any superiority in terms of quality of life of surgery compared to orthopaedic treatment for the management of displaced proximal humerus fractures in the elderly[35]. In contrast, Olerud *et al*. found superior results of surgery reflected in pain, functional scores, and range of motion, in a randomized clinical trial comparing internal osteosynthesis versus orthopaedic treatment in the management of displaced CT3 fractures[36]. Another randomized clinical trial by the same author comparing partial arthroplasty and orthopaedic treatment found better results with arthroplasty treatment in terms of pain and functional scores, but not for range of motion[37]. In their prospective study of 93 orthopedically treated patients, Foruria *et al*. were interested in the relationship between type of initial displacement and the results at one year for pain, function, and range of motion. It appears that the worst results were obtained for CT3/4 fractures impacted in the valgus. However, impacted varus fractures and isolated fractures of the major tubercle seem to show good results for pain and function[38].

The limits of this study are a selection bias induced by patients lost to follow-up, an information bias related to the irregular follow-up of patients as well as the inhomogeneous quality of the radiographs. However, the confounding biases were controlled by modelling in multivariate analyses of the confounding factors. Nevertheless, our cohort is relatively large compared to other studies, with a proportionally low number of patients lost to follow-up, reducing selection bias. In addition, a single investigator could reduce the information bias since they always follow the same evaluation methodology.

CONCLUSION

Management of fractures of the proximal end of the humerus remains challenging, with a high incidence of secondary displacement after osteosynthesis (28.6%) found in this work and confirmed by data reported in other studies. It is necessary to consider the characteristics related to the patient and their functional demand as well as the complexity of the fracture in order to provide the best therapeutic strategy.

The estimation of the bone mineral density of the proximal humerus using the Tingart index seems to us to be a reliable and reproducible indicator for predicting the occurrence of SD.

Orthopaedic treatment of these fractures in the elderly with low mineral density and low functional demand seems to us to be indicated. However, if the patient is active with a high functional demand, total reverse arthroplasty appears to be a good alternative after 70 years of age.

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List of abbreviations:

ASA : American Society of Anesthesiologists
BMI : Body Mass Index
CI : Confidence Intervals
CT : Cephalo-Tuberous
RR : Relative Risk
RTSA : Reverse total shoulder arthroplasty
SD : Secondary Displacement
SPSS : Statistical Package for the Social Sciences

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