



## Risk factors and complications in surgical management of proximal humeral fractures: a retrospective analysis of 132 cases

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**Proximal humeral fractures (PHF), ranking as the third most common osteoporotic fractures, pose a significant challenge in management. With a rising incidence in an aging population, controversy surrounds surgical versus nonoperative treatments, particularly for displaced 3- and 4-part fractures in older patients. Locking plates (LP) and proximal intramedullary nails (PHN) are primary choices for surgical intervention, but both methods entail complications. This retrospective study of 132 patients undergoing surgery for PHF (LP or PHN) aims to identify risk factors for postoperative complications. Results reveal a 31% complication rate, including secondary loss of reduction (17%) and intra-articular screw penetration (13%). Alcohol abuse emerges as the sole patient characteristic linked to complications. Non-anatomical surgical reduction, calcar comminution, and humeral shaft displacement over 10 mm also contribute to increased risks. LP and PHN show comparable complication rates, aligning with existing literature. The study underscores the pivotal role of achieving anatomical surgical reduction in minimizing complications. Surgical technique, fracture pattern, and patient characteristics significantly influence outcomes. Notably, alcohol abuse surfaces as a critical risk factor. The findings emphasize the importance of a nuanced approach to PHF management, tailoring interventions based on fracture characteristics and patient factors. Future research should explore these aspects, particularly in younger patient populations, to enrich our understanding of surgical outcomes in diverse age groups.**

**Keywords:** proximal humeral fracture, surgery, Locked plate, proximal humeral nail, alcohol abuse, loss of reduction, post-operative complications.

### INTRODUCTION

Proximal humeral fractures (PHF) stand as the third most prevalent osteoporotic fractures, following distal radius and femoral neck fractures. Predominantly affecting women (75%) and individuals over 60 years old (70%), their incidence is steadily rising due to the aging population<sup>1</sup>. Currently they constitute 5% of fractures in the appendicular skeleton<sup>2</sup>. According to the Neer classification, 90% of PHFs result from low-energy trauma, with half being non- or minimally-displaced<sup>3</sup>.

Nonoperative treatment is commonly employed for fractures with a head-shaft displacement of less than 50% and those without associated glenohumeral dislocation, yielding favorable outcomes. In a multicenter randomized clinical trial comparing surgical interventions (head fixation or replacement) to nonoperative treatment for displaced humerus fractures

involving the surgical neck in patients with a mean age of 66 years, no significant differences in functional outcomes were observed over a 2-year follow-up<sup>4</sup>. The most successful outcomes in nonoperative treatment are noted in fractures occurring in elderly patients. Jawa et al currently recommend nonoperative treatment for almost all fractures (excluding dislocations) in patients older than sixty<sup>5</sup>. A 2010 Cochrane review encompassing 23 randomized trials conducted by Handoll et al, found insufficient evidence to favor surgical over nonoperative treatment<sup>6</sup>. Approximately 80% of PHFs are managed nonoperatively with positive outcomes, while the remaining 20% necessitate surgery, either through osteosynthesis or prosthesis, due to increased complexity, displacement, or the requirement for enhanced shoulder function<sup>7</sup>. Locking plates (LP) and proximal intramedullary nails (PHN) are the primary choices for osteosynthesis, with locking plates being more commonly preferred. Controversy persists over

the choice between surgical and conservative management of PHFs, particularly for displaced 3- and 4-part fractures in older patients. In a randomized controlled trial by Fjalestad et al, involving 55 patients aged 60 and older with 3- and 4-part fractures, no significant difference in functional outcomes was noted after 1 year between surgical and conservative treatments<sup>8</sup>. Olerud et al reported improved range of motion (ROM) with surgical treatment for displaced 3-part fractures in patients with an average age of 74, although 30% of patients required additional surgeries to address complications<sup>9</sup>.

Surgical treatments, whether using LP or PHN, are not without complications. For LP, complication rates range from 21.4% to 49%, with major issues including secondary varus displacement, intra-articular screw cut-out, humeral head avascular necrosis, varus malunion, hematoma, and infection<sup>10</sup>. Despite this, complication rates are decreasing, potentially attributed to the increased use of reverse shoulder arthroplasty for complex cases, improvements in surgical techniques, and individualized indications for each case. Intra-medullary nails are predominantly employed for 2-part fractures and sparingly for 3-part fractures, with complications related to the entry point and reduction quality before nail insertion<sup>11-12</sup>.

This study aims to enhance surgical outcomes by identifying risk factors for surgical complications and aiding in therapeutic decision-making.

## PATIENTS AND METHODS

In a cohort of 132 patients, medical records were retrospectively analyzed from January 2016 to December 2018. This monocentric study was conducted in a general hospital with all patients having undergone surgical treatment for PHF, either by LP or by PHN. Patients with a proximal metaphyseal fracture, an isolated greater tuberosity fracture and a combined proximal humeral fracture and diaphyseal humeral fracture were excluded. A total of 32 patients were excluded. All included patients were aged 18 years or older and were followed for minimum six weeks after surgery.

Surgical criteria encompassed a varus-valgus pattern with a head angulation exceeding 45°, head-shaft displacement exceeding half of the diameter, complex fracture pattern, fracture-dislocation, head-split pattern and unstable fractures.

Patients' characteristics considered as risk factors were collected: smoking status, alcohol abuse, cardiovascular events (including arterial hypertension), presence of type II diabetes, corticoid medication

and BMI. Alcohol abuse was defined as daily intake exceeding 2 units, according to the recommendations of "La Santé Publique de France", where 1 unit equals 10 grams of alcohol. A minimal corticoid medication of 4 mg equivalent was considered a risk factor.

Preoperative radiography determined fracture morphology, capturing the neck-shaft angle (NSA) in degrees, greater tuberosity displacement in millimeters, and humeral shaft displacement between the head (medial cortex) and shaft medial cortex. Humeral shaft displacement was evaluated between the head (medial cortex) and shaft medial cortex. We considered a humeral shaft displacement more than 10 mm and a greater tuberosity displacement superior to 5 mm as a risk factor.

Fractures were categorized according to Neer and Hertel classifications, with Neer 1-part fractures excluded based on our surgical inclusion criteria. The time between trauma and surgery was recorded in days.

Calcar damage was classified into 3 groups: integrity of the medial hinge, postero-medial metaphyseal head extension more than 8 mm and comminution of the calcar.

Proximal humeral osteoporosis was defined by pathologic proximal humeral bone mass indices: cortical index (CI) < 0,23<sup>13</sup>; deltoid tuberosity index (DTI) < 1,4<sup>14</sup>; medial cortical ratio (MCR) < 0,16<sup>15</sup>. The presence of osteoporosis was considered when 2 out of 3 indices were pathological.

Surgical treatment involved open fixation using LP (Phylos Synthes®) or intramedullary nailing (T2 Stryker®). LP procedures employed a deltopectoral or transdeltoid lateral approach, with the presence of a calcar support screw and tuberosity osteosuture noted. For PHN, the number of proximal screws was recorded.

Complications were analyzed radiographically with check-ups at day 1 after the surgery, 2 weeks and 6 weeks postoperative.

Surgical reduction quality at 2-weeks was classified as anatomical, suboptimal and mediocre.

Six complications were studied: intra-articular screw penetration, secondary loss of reduction, delay of consolidation, avascular osteonecrosis, early implant removal (before 1 year postoperative) and second surgery (implant removal and replaced either by osteosynthesis or by prosthesis). Intra-articular screw penetration included both primary and secondary instances. Delayed union was defined as a lack of callus sign at 6 weeks postoperative.

A bivariate analysis using the chi-square test was performed to analyze the probability of having complications. To analyze risk factors for surgical

complications, we used multivariate logistic regression with Sigmaplot 13.0 software, considering results significant when the p-value was  $<0,05$ .

## RESULTS

In this retrospective study, a total of 132 patients were enrolled, comprising 94 women (72%) and 38 men (28%). The mean age was 67 years old, ranging from 20 to 94 years. A significant majority of patients (63%) were aged over 65 years. Regarding body mass index (BMI), 39% of patients had a BMI greater than 25 kg/m<sup>2</sup>. BMI records were lacking for 17 patients due to incomplete data, introducing a potential source of bias. Alcohol abuse was observed in 29% of patients, while 26% were daily smokers. Diabetes, treated with oral medications or insulin, was present in 12% of patients (Table I).

Based on Neer classification, 42,5% patients had 2-part fractures and 42,5% patients had 3-part fractures. Fracture-dislocations were observed in 3% of the patients. The mean NSA was 140,5° with a range of 48 to 200°. Varus displacement (NSA  $< 125^\circ$ ) was noted in 25% of the patients. The mean humeral shaft and greater tuberosity displacements were 6,7 mm and 1,7 mm respectively. For 94 patients (71%), the greater tuberosity was not displaced. Comminution of the calcar was observed in 17% of patients, and 42% had a proximal humeral osteoporotic fracture (Table II).

Among the 132 patients, 58 underwent treatment with LP (44%) while 74 were treated with PHN (56%).

LP was more commonly used for Neer 3-part fractures (63%), while PHN was predominantly employed for 2-part fractures (73%). The average time from trauma to surgery was 5 days. The LP approach involved deltopectoral in 50% and transdeltoid in the other half. A tuberosity osteosuture was performed for 69% of LP patients and 62% had a calcar screw. For PHN, half of patients had 2 proximal screws and the other half had 3 proximal screws. Surgical quality reduction was classified as anatomical for 60%, suboptimal for 27% and mediocre for 13% (Table III).

Of the 132 patients, 41 (31%) developed one or more complications with secondary loss of reduction in 17% and intra-articular screw penetration in 13% of cases. Women accounted for 26 of the 41 patients with complications, while men constituted the remaining 15. The most common complication for men was the secondary loss of reduction (60%) while for women, it was early implant removal (56%) (Table IV).

Among the 41 patients with complications, 23 were treated with PHN (17%) and 18 patients with LP (14%). The most frequent complications in the LP group were intra-articular screw penetration (10 patients), while in the PHN group, secondary loss of reduction was more prevalent (15 patients) (Table V).

Upon bivariate analysis of patient characteristics, pathologic alcohol consumption appeared to increase the risk of complications. Regarding fracture morphology, calcar comminution and humeral shaft displacement exceeding 10 mm were associated with a higher risk of complications. Surgical technique also played a

**Table 1.** — Demographic data of the study cohort

VARIABLES	N	%	Moy	Min/max	Standard deviation	Median	Complications %
<b>Patients</b>	132						31
Age			67	20;94	14	69	
>65 ans	83	63					20,5
>80 ans	28	21					9
Gender							
Male	38	28					11
Female	94	72					20
BMI (kg/m <sup>2</sup> )			25	0;47	5	24	
<25	64	49					16
[25;30]	29	22					7
>30	22	17					6
Active smokers	34	26					11
Alcohol abuse	38	29					14
CV ATCD	76	58					28
Diabetic II	16	12					5
Daily corticoids medication	12	9					6

**Table II.** — Fracture's characteristics

VARIABLES	N= 132	%	Moy	Min/max	Standard deviation	Median	Complications %
<b>Neer classification</b>							
<i>2-part fracture</i>	56	42,5					
<i>3-part fracture</i>	56	42,5					
<i>4-part fracture</i>	16	12					
<i>Fracture-dislocation</i>	4	3					
<b>Hertel classification</b>							
<i>Type 1</i>	56	42,5					
<i>Type 7</i>	47	36					
<i>Type 9</i>	9	7					
<i>Type 12</i>	14	12					
<b>NSA</b>			<b>140,5</b>	48;200		145	
<125	33	25					10
>125	99	75					21
<b>Humeral shaft displacement (mm)</b>			<b>6,7</b>	0;36	9	0	
<b>Greater tuberosity displacement</b>			<b>1,7</b>	0;22	3,5	0	
<i>0 mm</i>	94	71					31
<i>[1;5] mm</i>	20	15					1,5
<i>[6; 10]mm</i>	15	12					1,5
<i>&gt;10 mm</i>	3	2					2
<b>Calcar damage</b>							
<i>Medial hinge integrity</i>	62	47					13
<i>Metaphyseal extension &gt;8 mm</i>	48	36					10
<i>Comminution</i>	22	17					8
<b>Osteoporotic</b>							
<i>Yes</i>	55	42					14
<i>No</i>	77	58					17

role with a higher incidence of complications when the quality of surgical reduction was not anatomical. All these results were statistically significant with a p-value < 0,05 (Table VI).

The quality of surgical reduction significantly influenced postoperative outcomes. The risk for intra-articular screw penetration increased sixfold (OR= 6,136; p <0,001) and the risk for secondary loss of reduction increased twelvefold (OR= 11,660; p <0,001) with a non-anatomical reduction. These complications were also more frequent with alcohol abuse: with the risk multiplied by 12 for screw penetration (OR= 12,268; p= 0,004) and by 10 for the secondary loss of reduction (OR=10,411; p=0,018). The risk for

avascular osteonecrosis appeared higher with calcar comminution but was not statistically significant (OR= 33,003; p=0,098). Early implant removal (OR=2,635; p=0,017) and second surgery (OR= 5,787; p=0,006) were more likely when the surgical reduction was not anatomical. Implant removal was also more frequent in younger patients (OR= 0,950; p=0,045) and in the nail group (OR= 325,893; p=0,07) (Table VII).

## DISCUSSION

PHF treatment remains a subject of controversy and debate, particularly when considering surgical versus nonoperative approaches, especially in the context

**Table III.** — Surgical characteristics

VARIABLES	N = 132	%	Complications % (132 patients)
<b>LP</b>	58	44	14
<i>2-part fracture</i>	2	4	
<i>3-part fracture</i>	37	63	
<i>4-part fracture</i>	15	26	
<i>Fracture-dislocation</i>	4	7	
<b>PHN</b>	74	56	17
<i>2-part fracture</i>	54	73	
<i>3-part fracture</i>	19	26	
<i>4-part fracture</i>	1	1	
<i>Fracture-dislocation</i>	0		
<b>LP - osteosuture</b>			
<i>Yes</i>	40	69	10
<i>No</i>	18	31	21
<b>LP – calcar screw</b>			
<i>Yes</i>	36	62	6
<i>No</i>	22	38	7,5
<b>LP - approach</b>			
<i>DP</i>	29	50	5
<i>TD</i>	29	50	8
<b>PHN – proximal screw</b>			
<i>2 screws</i>	38	51	11
<i>3 screws</i>	35	47	7
<i>4 screws</i>	1	1	0
<b>Quality of surgical reduction</b>			
<i>Anatomical</i>	79	60	7,5
<i>Suboptimal</i>	36	27	11
<i>Mediocre</i>	17	13	12

of displaced 3- and 4-part fractures in older patients. Additionally, the surgical interventions, whether utilizing LP or PHN are not without complications.

In our monocentric study with a cohort of 132 patients, we observed a total postoperative complications rate of 31% (41 patients), comprising 26 women and 15 men. Within this, 23 patients belonged to the PHN group and 18 patients to the LP group. The most prevalent complication was secondary loss of reduction (17%), followed by the intra-articular screw penetration (13%).

A metanalysis conducted by Sun et al in 2018 compared the outcomes and complications of both LP and PHN treatments for displaced proximal humeral fractures<sup>16</sup>. The study found no statistically significant difference in terms of outcomes and complications between the two approaches. Specifically, the rates of complications were 30,4% for LP and 29,1% for PHN, with intra-articular screw penetration being the most common complication. Other studies, including those by Plath et al and Zhu et al, reported similar outcomes and complications between LP and PHN treatments for different fracture patterns<sup>11,17</sup>.

Analyzing complications in the LP group (58 patients), we found a total complication rate of 31%, similar to literature<sup>10,16,20,21</sup>. Intra-articular screw penetration occurred in 17%, consistent with reported rates between 8% and 14%<sup>19,20,21</sup>. Articular screw penetration is obviously correlated with the peroperative surgical reduction and the secondary loss of reduction. Secondary loss of reduction, a varus collapse often attributed to rotator cuff force, was observed in 12%, matching the literature's reported range of 12 to 17%<sup>10,21</sup>.

Our study emphasizes the significance of anatomical surgical reduction in minimizing complications. The quality of reduction influenced complications, with statistically higher risks of secondary loss of reduction and intra-articular screw penetration observed in cases where the surgical reduction was not anatomical. Achieving optimal peroperative reduction is crucial for favorable postoperative outcomes, as highlighted by Konrad et al.<sup>22</sup>.

Locking plates, such as the Phyllos (Synthes®), are known for their rigidity and angular stability<sup>23</sup>. The importance of restoring calcar support in valgus rather than varus angulation to enhance fixation stability was emphasized several times<sup>24,25,26</sup>. The stability of the calcar support can be improved with a locking screw in the inferomedial region of the proximal humerus (a calcar screw). With a fixation of a head into valgus, the plate acts as a strut and forces are compressive, with calcar buttressing. But for a head into varus, a plate will act as tension band force and in osteoporotic fracture the screw will pull-out because of this tension band mechanism<sup>25</sup>. According to Solberg et al, risk of complications is more correlated to the fracture pattern, either in varus or in valgus, than to the Neer classification<sup>27</sup>. In a LP fixation, it is also important to improve the fixation of the tuberosity with an osteosuture to oppose the rotator cuff force, to decrease the tuberosity fixation failure and to improve earlier mobilization. Tuberosity osteosuture is mainly relevant for the 3- and 4- part multifragmentary fracture as explained by Sinatra et al.<sup>28</sup>.

**Table IV.** — Complications by sex

Type of complications	All N	All %	Men N	Men % (N=15)	Women N	Women % (N=26)
Intra-articular screw penetration	17	13	6	40	11	42
Secondary loss of reduction	22	17	9	60	13	50
Delay of consolidation	4	3	1	7	3	12
Avascular osteonecrosis	6	4,5	1	7	5	19
Early implant removal	18	14	3	20	15	56
Second surgery	15	11	5	33	10	38
<b>Total of cohort (N=132)</b>	<b>41</b>	<b>31</b>	<b>15</b>	<b>11</b>	<b>26</b>	<b>20</b>

**Table V.** — Complications by type of osteosynthesis

Type of complications	All N	All %	LP	LP % (N=58)	PHN	PHN % (N=74)
Intra-articular screw penetration	17	13	10	17	7	9
Secondary loss of reduction	22	17	7	12	15	20
Delay of consolidation	4	3	3	5	1	1
Avascular osteonecrosis	6	4,5	4	7	2	3
Early implant removal	18	14	6	10	12	16
Second surgery	15	11	7	12	8	11
<b>Total of cohort (N=132)</b>	<b>41</b>	<b>31</b>	<b>18</b>	<b>14</b>	<b>23</b>	<b>17</b>
<b>Among LP/PHN group</b>				<b>31</b>		<b>31</b>

**Table VI.** — Results of bivariate analysis

VARIABLES	X <sup>2</sup>	p value	
<b>Patients' characteristics</b>			
Smoking	3,646	0,05-0,10	NS
Female	1,764	0,20-0,30	NS
Osteoporosis	0,535	0,50-0,90	NS
Age > 65 years old	0,226	0,50-0,90	NS
Alcohol abuse	<b>6,628</b>	<b>&lt;0,01</b>	<b>S</b>
<b>Fracture morphology</b>			
Calcar comminution	<b>4,42</b>	<b>&lt;0,05</b>	<b>S</b>
Humeral shaft displacement > 10 mm	<b>15,42</b>	<b>&lt;0,001</b>	<b>S</b>
Varus fracture (NSA < 125°)	1,43	0,20-0,30	NS
Trochiter displacement > 5 mm	0,042	0,50-0,90	NS
Trochiter comminution	1,47	0,20-0,30	NS
Complex PHF <sup>1</sup>	0,04	0,50-0,90	NS
<b>Surgical technique</b>			
Calcar screw	1,29	0,20-0,30	NS
Tuberosity osteosuture	0,75	0,30-0,50	NS
Number of proximal screw for nail	1,21	0,20-0,30	NS
Quality of surgical reduction: suboptimal and mediocre	<b>31,47</b>	<b>&lt;0,001</b>	<b>S</b>
Delay > 10 days after trauma	2,91	0,05-0,10	NS
Complex PHF including: 3- and 4-part fractures and fracture-dislocation.			

In the PHN group (74 patients), we also observed a total complication rate of 31%, with 20% experiencing secondary loss of reduction. This aligns with findings from Wong et al. where secondary loss of reduction and intra-articular screw penetration were reported at rates of 10% and 9% respectively<sup>29</sup>. Complications in PHN fixation are often attributed to surgical mal-reduction, secondary loss of fixation and pseudarthrosis<sup>30</sup>.

The proximal humeral nail (T2, Stryker®) is a third-generation short straight nail with proximal locking screws. The major problem with intramedullary nailing is the entry point and the fracture's malreduction<sup>11</sup>. The use of a straight nail avoids cuff tears, given that it is inserted through the muscular portion of the cuff rather than the tendinous portion and minimizes the risk of fracture displacement. The proximal screws must be locking and should have tuberosity fixation to restore tuberosity's anatomical position. To avoid the distal tangle effect, distal screw must be slightly divergent. It is also important to insert the nail after the surgical reduction. The nail does not aid in fracture reduction.

According to Wong et al, the rates of complications and second surgery with nail fixation are correlated with Neer classification and are higher with the 4-part patterns. Like plate fixation, surgical reduction influences the rate of complications<sup>29</sup>.

**Table VII.** — Results of multiple logistic regression for 6 types of complications

Independent variables	Coefficient ± SE	Odds ratio [LC-UC]	p value
<b>Intra-articular screw penetration</b>			
Alcohol abuse	2,5 ± 0,87	12,2 [2,23-67,24]	0,004
Surgical reduction	1,8 ± 0,53	6,1 [2,15-17,48]	<0,001
<b>Secondary loss of reduction</b>			
Alcohol abuse	2,34 ± 0,99	10,4 [1,48-73,13]	0,018
Surgical reduction	2,5 ± 0,60	11,6 [3,60-37,68]	<0,001
<b>Delay of consolidation</b>			
None			
<b>Avascular osteonecrosis</b>			
Calcar comminution	3,5 ± 2,1	33,00 [0,52-2077,77]	0,098
<b>Early implant removal</b>			
Age	-0,05 ± 0,03	0,95 [0,90-1,00]	0,045
Nail	5,8 ± 2,13	325,9 [4,98-21342,54]	0,007
Surgical reduction	0,97 ± 0,41	2,6 [1,18-5,86]	0,017
<b>Second surgery</b>			
Surgical reduction	1,76 ± 0,64	5,8 [1,65-20,26]	0,006
SE: standard error. LC: 5% lower confidence. UC: 95% upper confidence			

Our retrospective study identified four potential risk factors for postoperative complications: non-anatomical surgical reduction, calcar comminution, humeral shaft displacement exceeding 10 mm and alcohol abuse. Notably, alcohol abuse emerged as the sole patient characteristic identified as a complication risk factor in our study. Osteoporosis was not identified as a risk factor in our study unlike that of Klug et al.<sup>31</sup>.

Despite significant findings, our study had limitations, including its retrospective and observational nature, the analysis of complications solely through postoperative radiography by a single evaluator, a relatively short six-week follow-up and surgeries performed by different surgeons with varying experience levels.

## CONCLUSIONS

Our study identifies four potential risk factors for postoperative complications following proximal humerus fracture (PHF) surgery. It is crucial to consider the fracture pattern in surgical decision-making, particularly calcar comminution and humeral shaft displacement. We reaffirm the significance of achieving an anatomical surgical reduction to mitigate the risk of postoperative complications. Among the patient characteristics observed, alcohol abuse is

the only factor identified as a risk for complications. This underscores the importance of evaluating and addressing this specific risk factor in the preoperative assessment and management of PHF patients.

Considering the implications of our findings, it would be valuable to conduct a prospective study focusing on younger patients with proximal humeral fractures treated surgically. Such a study could provide additional insights into complication rates in this demographic, contributing to a more comprehensive understanding of surgical outcomes across different age groups.

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