

# Antegrade intramedullary nailing in proximal humeral fractures: results of 23 cases

Francesco Pogliacomì, Giovanni Malagutti, Paolo Schiavi, Margherita Menozzi, Alessandra Colacicco, Francesco Ceccarelli, Enrico Vaienti, Filippo Calderazzi

Orthopaedic Clinic, Department of Medicine and Surgery, University Hospital of Parma, Italy

**Summary.** *Introduction:* the metaepiphyseal fractures of the proximal humerus represent 5% of all fractures and mainly affect elderly patients. The type of treatment remains controversial. This retrospective study aimed to evaluate the clinic and radiographic results of 23 patients affected by two or three fragments fractures of the proximal humerus with or without metaphyseal extension treated with antegrade intramedullary nailing. *Materials and Methods:* all patients were clinically evaluated using the “Constant score” (CS) and individual satisfaction was assessed with a visual scale (VS). Moreover, the fracture’s healing process and the neck shaft angle (NSA) were assessed radiographically. *Results:* the mean follow-up was 72 months (24-120). Clinical evaluation and individual satisfaction were positive in most cases (mean CS 79,39 and VS 3,17). Worse results were observed in patients over 65 years. *Discussion:* among the different surgical options intramedullary nailing ensures good fracture stability and high consolidation rate. The entry point through the rotator cuff is of main importance as well as proximal nail positioning and choice of the locking screws length. In this study the functional results of the shoulder were worse in the elderly, who were supposed to have already a degenerated rotator cuff. *Conclusions:* antegrade intramedullary nailing should be considered a valid therapeutic option in this type of fractures. The surgical technique may influence functional results, as consequence of iatrogenic damage of the rotator cuff. ([www.actabiomedica.it](http://www.actabiomedica.it))

**Key words:** proximal humerus, fracture, nailing, trauma.

## Introduction

Fractures of the proximal humerus are very common, representing about 5% of all fractures-in adults (1).

Their incidence, which currently stands at a value of 105 per 100,000 people/year, is growing, especially in two types of patients: elderly women with osteoporosis, usually following an accidental fall with a low energy trauma, and young males, after a high energy trauma (2,3).

Several studies (4, 5) assessed that females have a double risk of being affected by proximal humerus fractures compared to males; these studies also report

that according to AO classification up to 90% these fractures are type A and B (extra-articular, unifocal or bifocal) and only 8% are type C (intra-articular) (6).

The type of treatment is decided after a clinical and radiographic evaluation. Most proximal humeral fractures are not displaced or minimally displaced, and conservative treatment is the most indicated, especially in low-demanding patients and in those who have a high surgical risk (7, 8).

Surgical approach is recommended in displaced fracture and in high-demanding patients. A variety of surgical techniques have been developed, including plating, percutaneous pinning, joint replacement, and humeral nailing (7, 9-11).

Open reduction and internal fixation (ORIF) is the most used method (7, 9-11). The direct exposure of the fracture site offers the advantage of directly manipulating the bone fragments and positioning the implant. This type of approach, however, can interfere with the healing process and increase the risk of humeral head osteonecrosis. Despite the advantage of direct visualization of the fracture site, ORIF requires a precise knowledge of the fracture geometry and of the deforming forces involved.

Intramedullary nailing (IMN) is particularly suitable for multi-fragmentary fractures of the surgical neck and meta-diaphysis, where the tuberosity and the humeral head remain in a single fragment.

IMN offers both biological and mechanical advantages. This surgical procedure is performed without opening the fracture site and it allows to respect the periosteal blood supply and to promote physiological bone healing processes. In addition, the position of the nail is closer to the humerus mechanical axis if compared to other fixation devices, which guarantees greater resistance. It also assures greater primary stability with less stress in flexion on locking screws, if compared to plates and screw systems, where especially in osteoporotic bone, the implant pull-out is still a possible complication.

The aim of this study was to evaluate clinical and radiological outcomes of 23 metaepiphyseal fractures of the proximal humerus treated with antegrade IMN.

## Materials and methods

All patients affected by proximal humerus fracture who were surgically treated in our department between January 2009 and December 2017 were analysed. One hundred and eleven patients (30 males and 81 females), aged between 18 and 98 (mean age: 61 years), were then analysed. In the study two or three fragments fractures with or without metaphyseal extension according to the Neer classification, and operated with antegrade nailing (T2 Proximal Short and Long Nail, Stryker), were included. All subjects treated conservatively or with another device and younger than 18 years of age were excluded.

According to the inclusion criteria and after the exclusion of those who were not contactable or deceased, data regarding the 23 remaining cases were collected from the clinical charts and surgery register.

This study was conducted in accordance with the principles of Declaration of Helsinki. All patients signed informed consent about the treatment they were subjected and the processing of their personal data.

For each patient gender, age at the time of surgery, follow-up time, dominance, type of trauma (low or high energy), type of nail, complications and revision surgery were recorded.

All the pre-operative, post-operative and follow-up radiological images were downloaded from the radiology digital archive and then studied. If the CT scan was available, also this exam was downloaded and examined.

All the fractures were classified according to Neer's and AO classifications.

All patients were operated on in the "beach-chair" position using X-ray imaging. The image intensifier placed at the patient's head allowed both AP and axillary views to be obtained, which enabled fracture reduction, nail insertion site and positioning to be checked, as well as length and progression of proximal locking screws. In all cases the ADI approach was used. The skin incision was about 2 cm anterior to the middle portion of the acromion. After the deltoid muscle fibres were split longitudinally and the clavicular fascia was sectioned, the underlying rotator cuff was exposed and cut parallel to the direction of its fibres, at about 1 cm medial to the greater tuberosity. The underlying nail insertion site is localised in a cartilaginous area of the humeral head which is well aligned with the humeral medullary canal (12). After surgery all subjects were immobilized for two weeks in a brace. Fourteen days after surgery a passive and assisted kinesiotherapy was allowed. Active movements started always 1 month following surgery.

At follow up, each patient was clinically evaluated and the range of motion was measured with a goniometer. The functional results were determined with the Constant Score test (13). Also, the personal satisfaction was evaluated with a visual scale from 1 to 4 (1=unsatisfied, 2=little satisfied, 3=satisfied, 4= very

satisfied). Finally, fracture healing and Neck Shaft Angle (NSA) were assessed on the last available x-ray.

NSA is defined as the intersect between a line along the humeral shaft axis and a line perpendicular to the anatomical neck. This angle measures the proximal humeral displacement on the coronal plane (14). Its value is approximately 135° (14,15) and is measured on true anterior-posterior (AP) radiographs.

A statistical analysis of the collected data was then performed using the SPSS 20.0 software (IBM Corp. Armonk, NY, USA). The Constant Scores between operated and healthy arms were compared with the T Test and the Wilcoxon-Mann-Whitney test; a second statistical analysis of the same parameters through the Pearson Correlation Index wanted to highlight how the Constant Score scores were related to the patient's age.

## Results

Twenty-three patients, 17 females (73.9%) and 6 males (26.1%) were recruited. The average patients'

age at the time of surgery was 66.04 years (range 25-86). Two fragment fracture was observed in 8 cases and three fragment type in 15. Metaphyseal extension was associated in 12 subjects. According to AO classification fractures were always of type A and B.

The non-dominant limb was involved in 12 cases (52.2%). In 20 cases (88%) the long variant of the nail was implanted whereas the short one was used in other 3 (12%). The mean follow-up was 72 months (range 24-129). Traumatic mechanism was of low energy in 16 subjects (15 female and 1 male) and of high energy in 7 (5 males and 2 females). The average Constant Score of the operated side was 79.39 (range 42-100), whereas the mean CS of the non-operated was 89.67 (range 58-100). The distribution of the CS scores is illustrated in Figure 1.

The mean satisfaction with the VS was 3.17.

All fractures healed. Nonunions and malunions were never observed. No device needed to be removed after fracture healing and only in 2 cases one of the proximal locking screws had to be removed because of pain. The average measured NSA was 133.08° (range 108° - 150°). In two cases (8%) the NSA was less than

	CONSTANT SCORE Operated side		CONSTANT SCORE Non-operated side	
	N° cases	%	N° cases	%
EXCELLENT (>70)	16	70	22	96
VERY GOOD (60-69)	3	13	0	0
GOOD (40-59)	4	17	1	4
FAIR (30-39)	0	0	0	0
POOR (<30)	0	0	0	0

Figure 1. Distribution of CS in both arms

A

	Average	N	Standard deviation	Average standard error
• CONSTANT SCORE OPERATED SIDE	79.391	23	18.0800	3.7699
• CONSTANT SCORE NON OPERATED SIDE	89.674	23	11.3444	2.3655

B

	Paired differences					t	gl	Sign.
	Average	Standard deviation	Average standard error	Difference confidence interval 95%				
				Inferior	Superior			
CONSTANT SCORE OPERATED SIDE - CONSTANT SCORE NON OPERATED SIDE	-10.2826	14.5866	3.0415	-16.5903	-3.9749	-3.381	22	.003

C

	N	Correlation	Sign.
• CONSTANT SCORE OPERATED SIDE	23	.592	.003
• CONSTANT SCORE NON OPERATED SIDE			

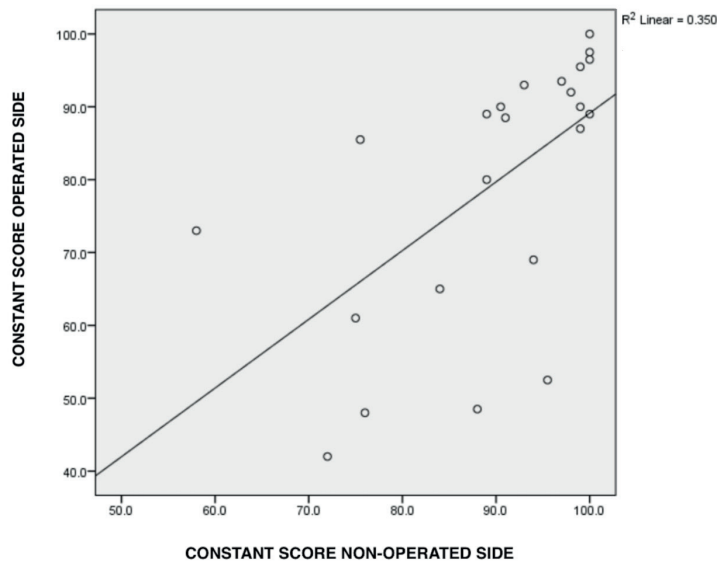


Figure 2. T test of CS without statistically significant differences

120° and this value correlated with unsatisfactory outcome.

The analysis by means of the “t Test” revealed a non-statistically significant difference between the values of the CS of the operated side and those of the non-operated one as shown in the figure 2.

The Wilcoxon-Mann-Whitney test, which allows the comparison between the two values (figure 3) showed a statistical significance difference. If the hypothesis was null, as in our case, the difference did not exist and the two groups were similar. Therefore, these

analyses showed that there was not a statistically significant decrease in the post-operative functionality of the operated limb.

The Pearson Correlation Index (figure 4), highlighted how the CS scores are related to patient’s age. Younger patients have higher Constant Score values, and therefore better functionality of the shoulder, both on the operated and non-operated side. On the other hand, aging (≥65 years) was associated to lower Constant Score values but also in these subjects the comparison of the values of the two arms (operated vs. non-operated) was similar.

NULL HYPOTHESIS	TEST	Sign.	Ris.
The median of differences between the OPERATED SIDE CONSTANT SCORE and NON OPERATED SIDE CONSTANT SCORE is 0	Wilcoxon-Mann-Whitney test	.002	Refuse the null hypothesis

Figure 3. Wilcoxon-Mann-Whitney test without differences of CS

		AGE'	CONSTANT SCORE OPERATED SIDE	CONSTANT SCORE NON OPERATED SIDE
AGE	Pearson Correlation	1	-.534**	-.609**
	Sig. (2-tailed)		.009	.002
	N	23	23	23
CONSTANT SCORE OPERATED SIDE	Pearson Correlation	-.534**	1	.592**
	Sig. (2-tailed)	.009		.003
	N	23	23	23
CONSTANT SCORE NON OPERATED SIDE	Pearson Correlation	-.609**	.592**	1
	Sig. (2-tailed)	.002	.003	
	N	23	23	23

\*\* . Correlation is significant at the 0,01 level (2-tailed)

Figure 4. Pearson Correlation Index with correlation between CS and age

## Discussion

Epidemiological studies show an exponential increase of proximal humerus fractures after the fifth decade due to the low quality of elderly patient's bone. In fact, the decrease of the trabecular density and the cortical weakening expose the elderly population to a higher risk of fracture even with low energy traumatic mechanism. In addition, female individuals were found to have a double risk, compared to male (16).

In this study, patients aged between 25 and 86 years were evaluated. Both women in the perimenopausal age and young men were included. The average age of the patients was 66 years. According to what literature reports, most of them (74%) were women as consequence of low energy traumas.

Despite the numerous available classifications, it is difficult to categorize all proximal humeral fractures, even with the help of CT imaging, and considering all patients' characteristics, it is also demanding to choose the best treatment.

Indeed, these fractures are challenging for several reasons, such as osteoporotic bone in the elderly, articular surface involvement, possible onset of AVN of the humeral head and reconstruction of collapsed fragments (17,18).

There are currently several treatment options and in literature there is no univocal consensus (18-21).

Rangan did not support the trend of increased surgery for patients with displaced 2-parts fractures of the proximal humerus. He stated that there is no significant difference between surgical treatment compared with nonsurgical among patients with displaced proximal humeral fractures involving the surgical neck (22).

However, most of the Authors did find that surgery improved the position of the fracture fragments (12,17). In fact, the dislocation of two or more fragments requires surgical stabilization since the interposition of soft tissues could induce an important joint dysfunction and a non-union of the fracture (23,24).

According to Neer classification, several Authors studied outcomes after surgery. Lekic (25) suggested that either ORIF or IMN for a two-parts fracture provides acceptable fixation and similar results in terms of shoulder range of motion. Although complication rates were low and there were no statistically significant

difference between the two groups, a trend toward increased complications in the IMN group was noted. Despite reoperation and complication rates remain high, Wong (26) concluded that IMN of acute, displaced two- and three parts fractures yields satisfactory clinical outcomes. Sobel (27) reported that in selected patients, IMN may present advantages over ORIF, as their implantation requires shorter surgical time and results in less fracture site pain reported by patients with 3-part fractures.

In conclusion, in literature it is described that IMN and ORIF yield similar functional long-term results in patients with proximal humeral fractures even though ORIF has better outcomes in 4-part fractures (13,22-27).

In this study, the most frequent fracture pattern was three-fragments fracture (n°15), followed by two-fragment fractures (n°8) and the 4 part ones were excluded.

Authors decided to treat them with an IMN of 3rd generation. Third generation nails were designed to improve some disadvantages of previous ones. In first-generation nails, the inability to ensure unstable fracture fragments and lack of rotational control often led to fixation failure; in second generation nails an inadequate security of the proximal interlocking screws was observed.

Third-generation nails evolved to solve the issue of proximal screw loosening and ultimate fixation failure. This led to the arrival of more secure locking mechanisms for proximal screw fixation in order to allow fixed angular stable constructs. The proximal bending offers insertion options laterally, just inside the greater tuberosity, or centrally, through the articular surface at the top of the humeral head. Strategic proximal locking holes enable locking of the lesser tuberosity, the greater tuberosity, and the humeral head. Threaded proximal locking holes allow increased holding strength in the nail, analogous to locking plate and screw fixation.

The purpose of nailing is to provide stability to a reduced fracture that allows early motion to rehabilitate the shoulder and to improve patient outcomes that may have otherwise been theoretically achieved with conservative management.

In literature, the most common complications of IMN is loss of reduction (24%) followed by fracture malunion (21%); in this study we detect no case of

malunion nor loss of reduction. Most of these complications developed 12 months after surgery, and average follow-up was 63 months. Another serious complication is osteonecrosis of humerus head (AVN) (higher in three-fragment fractures than in two-fragment fractures) (26); it has been reported to happen in 4% of IMN cases, whereas it occurs in about 10.8% of internal fixation and in 26% of cases treated with percutaneous fixation. In the present study no case presented this complication. This can be justified by the lower invasiveness of IMN insertion technique, although AVN radiological signs could appear after several years.

Authors wants to stress the importance of a precise surgical technique. Antegrade nailing is not extra-articular, and its main disadvantage is that it crosses the rotator cuff and the articular cartilage of the humeral head. For this reason the entry point is crucial and Authors always used the ADI approach in which the damage to the rotator cuff is more likely to heal, as it occurs in a well vascularised area, and the nail is inserted in a more medial position of the humeral head, localised in a cartilaginous area of relatively low biomechanical importance, which allows for a more linear access to the medullary canal (28).

Authors also wants to highlight two other surgical steps that they consider of main importance. Correct proximal nail positioning beneath the level of humeral head articular cartilage avoid subacromial impingement syndrome. Furthermore, the wrong length of the proximal locking screws can also cause problems to the deltoid muscle and lead to subacromial impingement syndrome at extreme degrees of abduction and extrarotation (12).

Authors assessed radiographically fractures healing, neck shaft angle and possible loosening of the implant. At final follow-up, despite the mean age of our patients, all fractures healed and no case needed total implant removal, in only two cases a locking screw was removed.

Clinical results of the present study on both sides were found to be similar. Statistical tests showed that there was no statistically significant decrease in the post-operative functionality of the fractured limb and treated with intramedullary nailing. However, functional results were worse in elderly patients ( $\geq 65$  years). This datum probably depends on the fact that these patients often

suffer of a pre-existing rotator cuff tear (29). Anyway, in these subjects the function of both arms at follow-up was comparable.

Literature reports a mean Constant Score (CS) value of 72.8 after intervention (13,25-27,30,31), whereas results of the present study were even better with a mean CS of 79.39 (range 42-100).

This mismatch could be due to the small number of recruited patients and this was an important limit of the study. Another limit was the heterogeneous sample with different ages, functional requests and comorbidity; moreover, we did not compare IMN to other techniques and we retrospectively analysed the data.

## Conclusion

Results observed confirm that antegrade intramedullary nailing is a valid surgical option for fractures with 2-3 fragments with or without metaphyseal extension of the proximal humerus. Functional outcomes depend on the correct entry point, proximal nail positioning and the length of the proximal locking screws. Patients older than 65 years of age have worse results in a possible context of degeneration of the rotator cuff.

**Conflict of interest:** Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

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Received: 10 April 2020

Accepted: 10 May 2020

Correspondence:

Giovanni Malagutti

Orthopaedic Clinic, Department of Medicine and Surgery,

University Hospital of Parma, Parma, Italy

Tel. 0039 05217028250

Email: fpogliacomì@yahoo.com