

# Complex fractures of the humeral shaft treated with antegrade locked intramedullary nail: clinical experience and long-term results

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**Summary.** *Background:* indications for surgical treatment of complex humeral shaft fractures are still controversial. The purpose of this study was to evaluate the outcomes of treating humeral shaft fractures using antegrade locked intramedullary nail, compared to the treatment with traditional more aggressive techniques such as plate and screws. *Methods:* between February 2008 and January 2011 38 patients were treated with antegrade locked intramedullary nail for humeral shaft fractures, divided according to the AO classification. 28 patients were clinically followed: disability, pain and functional recovery were evaluated using the Constant score and DASH score and the ROM of the shoulder was checked. *Results:* Bony union was obtained in 27 patients at a mean time of 2.7 months. One fracture ended in nonunion, healed after replacing the nail with a longer one. Patients achieved satisfactory shoulder function with a mean Constant score of 90.57 points and with a mean DASH score of 4.69 points. There were no other complications. *Conclusion:* the antegrade locked intramedullary nail represents a recommended option for the treatment of humeral shaft fractures, obtaining a steady synthesis, a short time of consolidation and a rapid functional recovery. ([www.actabiomedica.it](http://www.actabiomedica.it))

**Key words:** fracture, humeral shaft, intramedullary nail

## Introduction

The humeral shaft extends from the lower edge of the pectoralis major insertion to the supracondylar ridge of the distal humerus. The fracture which occurs in this space is called humeral shaft fracture, which is found in a proportion of about 3% of all the fractures (1). These fractures usually present with two incidence peaks: a peak below 50 years, with a clear predominance of males, and one above 70 years, with a predominance of females (2). The causes in younger patients are commonly represented by high-energy trauma (car accident or sports injury), while in older patients by lower energy trauma (such as an accidental fall), but they often associated with osteoporosis.

AO classification is based on simple criterions: it divides the humeral shaft fractures in 3 main groups: type A (simple fractures with two fragments), type B fractures (three fragments), type C (complex fractures with four or more fragments or comminuted) (3). Epidemiologically, type A fractures appear to be prevalent with 63% of cases, while type B and C are found respectively in 26.2% and 10.4% of cases (2-4).

From the biomechanical point of view, the morphology of the fracture is related to the intensity of trauma and to the site of the lesion. In the low-energy trauma, there is commonly a modest displacement of fracture fragments, especially in old patient with osteoporosis, while in the high-energy trauma there is a comminution of the fracture. The site of the lesion

determines a different morphology of the fracture according to the different stress exerted by muscles groups, and therefore we can find a the different secondary displacement as Fernandez-Esteve described in the functional classification of humeral shaft fractures (5).

There is a debate about the choice of treatment of humeral shaft fractures. It has been shown that an adequate conservative treatment allows a high rate of healing (24). However, the casts are not very tolerated and long periods of immobilization can lead to a stiffness of the shoulder and literature underlines the problems associated with nonoperative treatment, such as an increased frequency of nonunion. (6-7). Compared to the past when nonoperative treatment was considered the gold standard, now there is the belief that surgical treatment can offer superior advantages in terms of final outcomes and patient management, especially in those fractures characterized by a unacceptable orthopedic reduction, by the presence of a exposed or bifocal fracture, by the concomitant radial nerve palsy, or by general conditions, such as polytraumatic patient, which require a synthesis in a short time. Surgical treatment is characterized by a more efficient and accurate reduction and an immediate stability that helps to reduce pain. The purposes of the surgical treatment are the reduction with restoration of the length and the control of rotations (peri-humeral muscular structures can tolerate an anterior angle of 20°, varus of 30° and a shortening of 3 cm without the deterioration of the functionality and the morphology (8), while rotational defects, in particular the internal rotation, are less acceptable). Other purposes are the stabilization and early mobilization of neighboring joints.

The literature describes several surgical options of treatment: plates and screws (ORIF), external fixators, the antegrade and retrograde intramedullary nail fixation (CRIF). The use of locked intramedullary nails with advanced technology has allowed us to obtain better results compared to the past and now several publications highlight the good results in the treatment of these fractures with this method (1-9-10-11-12). This intervention, using a minimal surgical access, offers the advantages of the preservation of the site of fracture, and it maintains the vascularity and the biologic bone repair; however, it exposes the orthopedic

surgeons at a moderate load of radiations. The intramedullary nailing also has disadvantages represented by the juxta-articular fractures, particularly the distal ones, fractures in childhood and puberty, and fracture of the medullary canal with obstruction or concomitant infection (13-14).

## Objectives

The objectives of this study are to examine the advantages and disadvantages of surgical treatment of complex humeral shaft fractures with minimally invasive surgical technique based on the introduction of the antegrade locked intramedullary nail, compared to the treatment with traditional more aggressive techniques such as plates and screws.

## Materials and methods

In the period between February 2008 and January 2011 at the Orthopedic department of Polyclinic of Modena, 38 patients were treated with intramedullary nail Polarus for multifragmentary humeral shaft fracture. In two cases a mini-open access was associated for the stabilization of a fragment with screws.

According to the classification AO-ASIF, 34 cases of complex fractures were divided into 12-B type with three fragments (89%) and 4 cases in 12-C comminuted fractures type (11%). It 's been possible to control clinically and radiographically 28 patients, 9 males (32%) and 19 females (68%) with an average age of 67.75 years (Stand. Dev. 18,3), with a follow-up of 19 months (range 6-32 months) . 9 patients were not traceable and one patient died other causes. The right side was affected in 15 cases (54%), the left side in 13 cases (46%). The dominant side was involved in 19 cases (68%). The mechanism of injury was a trauma for an accidental fall to the ground in 25 cases (89%), a motorcycle crash in 2 cases (7%) and 1 case of traction injury (4%) (Table 1).

The exclusion criteria for our study were pathologic fractures, nonunions, fractures associated with radial nerve injury.

*Notes for the surgical technique*

All patients were treated with intramedullary nail Polarus Plus<sup>®</sup> Acumed with antegrade insertion (Fig. 1). The antegrade nailing requires particular attention in the surgical access.

The patient is positioned in a beach chair by performing an access of 3 cm in line with the antero-lateral fibers of the deltoid muscle. After the split of the deltoid, the surgeon has to lance the supraspinatus tendon, on the outside of the insertional area of the tendon and along the course of its fibers in order to

**Table 1.**

	Age	Gender	Mechanism of Injury	Classification	Side
1	20	M	MC	12-C2.2	LD
2	80	M	AF	12-B1.1	L
3	75	M	AF	12-B1.2	RD
4	82	F	AF	12-B1.1	RD
5	62	F	AF	12-B1.1	LD
6	84	F	AF	12-B1.2	RD
7	48	M	MC	12-B1.2	L
8	76	M	AF	12-C1.1	L
9	42	M	TI	12-B1.1	RD
10	85	F	AF	12-B1.2	RD
11	97	F	AF	12-B2.2	RD
12	46	F	AF	12-B1.1	LD
13	68	F	AF	12-B1.1	RD
14	61	F	AF	12-B1.1	RD
15	64	F	AF	12-B1.2	RD
16	54	F	AF	12-B3.1	L
17	82	F	AF	12-B1.1	L
18	33	M	AF	12-B2.2	RD
19	81	F	AF	12-B1.1	RD
20	70	F	AF	12-B1.2	L
21	40	F	AF	12-B2.2	L
22	70	M	AF	12-B2.2	RD
23	68	M	AF	12-B2.2	RD
24	77	F	AF	12-B2.2	RD
25	80	F	AF	12-C1.1	L
26	86	F	AF	12-B1.2	L
27	82	F	AF	12-B1.2	RD
28	84	F	AF	12-B1.2	RD
avarage	67,75	M = 32% F = 68%	AF= 89% MC= 7% TI= 4%	12B = 89% 12C = 11%	R = 54% L = 46% D = 68%

Stand. Dev. 18,30

*Mechanism of Injury: AF: Accidental Fall; MC: Motorcycle Crash; TI: Traction Injury**Side: L= Left; R= Right; D= Dominant*

reduce functional complications (17). The entry point is medial to the great tubercle. It's important to insert the antegrade nail at least at 4 mm below the articular surface to avoid the subacromial impingement, determined by the protrusion of the nail within the subacromial space. The nail, occupying a reduced intramedullary space, doesn't require the enlargement of the medullary canal, with the exception of the proximal part, that is performed with suitable introducers. A series of interchangeable masks allows an easy stabilization, and it is led both proximally at the level of the humeral head with 4 screws (two 5 mm screws and two 3.5 mm screws) and distally with a 3.5 mm screw, avoiding the use of freehand stabilization techniques, which ask a long time of execution. These characteristics allow good control of the rotations, which is essential in the treatment of fractures with several fragments.

## Rating

All patients were clinically reviewed with the use of the Constant score (0-100) and the Dash score (Disability Assessment for the Shoulder and Hand) and radiographically controlled with assessment at 1 month, 3 months and 6 months after surgery (Fig. 2). Clinically, we have checked the ROM of patients evaluating the degrees of abduction, flexion, external rotation and internal rotation of the shoulder.



**Figure 1.** Polarus Plus Acumed® intramedullary nail



**Figure 2.** Male, 20 years old, motorcycle crash, plurifragmentary fracture with a fragment in humeral shaft (12-C2.2), treated with Polarus Plus Acumed® nail and radiographical controlled at 0 – 3 – 6 months after surgery.

The upper limb disability was measured with the DASH questionnaire, which investigates both on the physical and social function, both on symptoms of upper limb, and it consists of a questionnaire of 30 questions, which allows to obtain a score between 0 and 100, where a high DASH score indicates severe disability. (18).

The Constant score is a scoring system that provides to evaluate all the clinical aspects related to the functional recovery. The evaluation scheme is divided into 4 parts, and it consider respectively: pain (15 points), the common daily activities (20 points), the excursions of motion (40 points) and strength (25 points), for a total maximum of 100 points for a normal shoulder. The score decreases if there are any functional impairments. A normal shoulder has a Constant score of 100 points (19).

## Results

At follow-up of 24 months (range 12-38 months) 28 patients were reviewed, and they were followed until complete healing. The fracture healing was obtained in 27 patients (96.4%) with a mean time of radiographic union of 2.7 months (min 1, max 5.2) after surgery. Only one case (3,6%) has evolved into nonunion, which required the replacement of the nail with a new longer nail and autologous bone graft with subsequent healing. Apart from this case, no other failures of fixation occurred and there were no cases of infection or peripheral-nerve-damage. Clinically, we found a Constant score of 90.57 points (stand. Dev. 12,09) and a DASH score of 4.69 (stand. Dev. 9,95).

Assessing the ROM of the operated shoulder, we got a mean abduction of 161.07° (stand. Dev. 31,21), an average flexion of 164.29° (stand. Dev. 29,93), an average external rotation of 77.14° (stand. Dev. 17,50) and an internal rotation in 18 patients up to D7 (Table 2).

In 93% of cases the patient reported a good or excellent subjective satisfaction. The full resumption of daily activities occurred after a mean of 2.8 months after surgery, professional and sports activities after 4.1 months.

Some patients reported moderate pain at rest, and two of these cases were completely resolved with the removal of the intramedullary nail.

## Conclusions

Currently there is no universally accepted surgical technique for the treatment of diaphyseal fractures of the humerus, and in the literature different methods of fixation show variable results. Our study has produced comparable results to those reported by similar studies in terms of average time of healing and complication rate. In particular, Biggi et al. examined 50 humeral shaft fractures treated with antegrade intramedullary nailing in 76% and with retrograde nailing in 24%, and they have achieved complete consolidation in 96% of cases in an average time of 3 months and a sore consolidation with nonunion in 4% . (16).

In the case of a fracture of the humeral diaphysis with a surgical indication, it isn't still recognized if it

is better to proceed with an intramedullary nail or a compression plate.

In our study, we evaluated the results of surgical treatment of minor impact for the resolution of this type of fracture, highlighting the advantages of a less invasive but equally effective for the healing of so complex fractures.

Antegrade intramedullary nailing has many advantages: it is simple to perform, it doesn't expose the site of fracture, it respects the biology of osteosynthesis, allowing an immediate primary stability and early functional recovery. The Polarus Plus nail well responds to these purposes for its features; the dedicated instruments make easier the distal stabilization, allowing good control of the rotations, the reduced intramedullary space also allows the possible use of metal screws for the synthesis of free fragments. This type of technique has resulted in complete healing in 97.4% of cases at 2 months postoperatively, the humeral axis was always correctly restored and there were no migration of free fragments.

This technique is indicated in all humeral fractures regardless of their morphology and extension, while it isn't indicated for distal juxta-articular fractures, for joints fractures, for fractures in childhood, and those severely displaced associated with radial nerve palsy, in which however it is advisable the direct nerve exploration and the plate osteosynthesis. The literature (11-20-21) indicates a valid option for the treatment of these lesions also open osteosynthesis with plate and screws with the aim of restoring the proper bone contact and control of free fragments. The plaque technique makes it possible the anatomical synthesis of fragments, it prevents the onset of the outbreak and hypertrophic ossification, and it allows the revision of the radial nerve, which is often affected in humeral shaft fractures. (22). However, this technique exposes patients to increased risk of nonunion, infection and iatrogenic nerve injury. In our study, we have virtually wiped out the potential complications that are observed in the use of more aggressive surgical procedures, such as infection, dehiscence of the wound, soft tissue damage, iatrogenic nerve injury of radial nerve. We recorded one case of pseudoarthrosis, equal to 3.6% of all treated cases, which represents a lower value than the data reported in the literature, of 6-8%, with the use of the plate (20) and

Table 2.

	Follow Up	Dash Score	Constant Score	ROM			
				Abduction	Flexion	Extrarotation	Intrarotation
1	32	0,0	100	180	180	90	D7
2	31	3,3	72	110	120	60	D12
3	31	2,5	90	180	180	90	D12
4	29	0,0	100	180	180	90	D7
5	25	0,0	98	180	180	90	D12
6	23	7,5	80	130	180	60	L5
7	21	35,8	70	160	180	60	L3
8	23	0,0	92	130	130	60	D12
9	22	0,0	80	120	130	70	L5
10	29	0,0	100	180	180	90	D7
11	28	0,0	83	150	150	60	D7
12	22	0,0	100	180	180	90	D7
13	23	37,5	58	80	80	30	L5
14	18	15,8	86	180	180	60	D7
15	17	0,0	100	180	180	90	D7
16	14	1,6	86	180	180	70	D7
17	18	5,0	68	80	80	40	D12
18	10	0,0	98	180	180	90	D7
19	19	0,0	100	180	180	90	D7
20	6	18,3	79	130	130	60	D12
21	6	0,0	100	180	180	90	D7
22	6	4,1	96	180	180	90	D7
23	19	0,0	100	180	180	90	D7
24	19	0,0	100	180	180	90	D7
25	14	0,0	100	180	180	90	D7
26	13	0,0	100	180	180	90	D7
27	7	0,0	100	180	180	90	D7
28	14	0,0	100	180	180	90	D7
Standard deviation	7,77	9,95	12,09	31,21	29,93	17,50	
Media	19,25	4,69	90,57	161,07	164,24	77,14	D7=64% D12=21% L3=4% L5=11%
Min	6	0	58	80	80	30	
max	32	37,5	100	180	180	90	

even lower than those reported in the literature, with the use of the intramedullary nail. (5%) (20)

In relation to criticism (20) to the use of antegrade intramedullary nails for the possible deleterious effects on the rotator cuff, in our series we recorded very satisfactory average values of the Constant score (90.57). This value can be compared with the results published by Jiang et al (23): with the use of a compression plate for complex humeral shaft fractures they have achieved a Constant score of 83.1 points (range 59-93 ) and averaged values of abduction 142° (range 70° -170°) and averaged flexion 164° (range 135° - 175°), lower than the values that we collect. We have had some cases of pain at rest, two of them were completely resolved with the removal of the nail, 4 more cases improved with the physiotherapy treatment. In one case (fig. 3), it was necessary to open the focus of fracture because, during the surgery, we couldn't reduce the diaphyseal fragments and we had to stabilize them with 7 screws to made synthesis with the nail. Probably, this case was border line for indica-

tion of treatment with intramedullary nail and the best choice for this fracture was the reduction and synthesis with plate and screws.

In conclusion, the plurifragmentary humeral shaft fractures can be treated in different ways. In our opinion antegrade locked intramedullary nailing represents a surgical alternative to open techniques to keep in consideration in the treatment of diaphyseal fractures with multiple fragments. In particular the use of locked intramedullary nail has allowed us to obtain stable synthesis, optimization of time of healing, recovery of the humeral axis, enabling even the combination of fixation with interfragmentary screws. The good results and the low number of complications justify our interest in this type of method.

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**Figure 3.** Male, 76 years old, accidental fall, 3 fragments fracture of the left proximal humeral shaft (12-C1.1) treated with Polarus Plus Acumed® nail and 7 interfragmentary screws. Clinical controlled at 12 after surgery with Constant score = 92 and Dash score = 1. Radiographical control before and after surgery.

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