

# Humeral shaft fractures treated with antegrade intramedullary nailing: What are the consequences for the rotator cuff?

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## Abstract

**Purpose** The purpose of this study was to investigate the clinical and sonographic impact on the rotator cuff (RC) of the use of the anterolateral approach for nailing.

**Methods** A retrospective cohort of 48 patients treated for humeral diaphyseal fractures at the University Hospital of Parma between 2007 and 2011 was analysed. Inclusion criteria were (1) acute humeral shaft fractures treated with T2-proximal humeral nail (PHN) and (2) a minimum follow-up of one year. Exclusion criteria were (1) history of proximal and metaphyseal humeral fractures, (2) pathological fractures or open fractures of the humerus, and (3) RC lesions.

Clinical assessment using the Constant score, simple shoulder test and through shoulder examination tests was carried out. The sonographic study investigated the integrity of the RC.

**Results** Mean score on Constant's scale was 78.21 points, with most patients achieving a good result (79 % obtained more than 65 points). One patient had a limited functional outcome (Constant's score of 49 points). The sonographic findings described for supraspinatus tendon were a partial ruptures of less than 30 mm in three patients and a complete tendon rupture in one case.

**Conclusions** The results of this study suggest that the use of the anterolateral approach for antegrade humeral nailing

ensures a good functional result with no significant clinical-sonographic impact on the rotator cuff and a satisfactory long term clinical outcome.

## Introduction

Fractures of the humeral shaft represent 1–3 % of all fractures seen in accident and emergency departments, with approximately 20 % of all humeral fractures, and it is the third most common fracture in individuals older than 65 years after hip fractures and distal radial fractures [1–3]. Most humeral shaft fractures are undisplaced or minimally displaced and can be managed non-operatively with satisfactory outcomes in more than 90 % of patients [1]. Different treatment options exist for such lesions; although conservative treatment has achieved satisfactory results in 96–98 % of cases [4, 5], indications for surgery have gradually been extended to less complex humeral fractures, such as spiral, long and transverse fractures [6]. The intramedullary nailing is an option for surgical treatment especially in patients with multiple injuries [7]. The choice of approach for intramedullary nailing (antegrade or retrograde) remains controversial, especially for the possible residual impairment of the shoulder and of the elbow, and depends on the type of fracture, the type of nail, and the surgeon's preference [8].

The disadvantage of antegrade nailing, which is usually indicated in proximal diaphyseal and metaphyseal fractures [1], is damage of the shoulder joint, of cartilage or the rotator cuff [8]. Clinical outcomes of the shoulder after antegrade nailing have been evaluated in a previous study [8] reporting a positive functional outcome.

A rotator cuff tear is not always associated with clinical symptoms. In some clinical and ultrasonographic studies on asymptomatic volunteers [9, 10], evidence of ultrasonographic rotator cuff tear in 23 % and 6 % of cases,

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respectively, with an increase of frequency with the age of patients was reported.

The objective of this study was to evaluate the clinical and functional outcome of patients treated with antegrade intramedullary nailing.

## Patients and methods

### Patients

From September 2006 to May 2011, 60 patients (33 males and 27 females with mean age of 52 years) underwent surgical treatment with the T2-proximal humeral nail (PHN) (Stryker®) for humeral fractures. Diagnosis of humeral fracture was made on the basis of clinical and radiological assessments (Fig. 1). For 12 subjects it was not possible to perform the follow-up evaluation.

Finally, we included 48 patients (26 males and 22 females), with mean age of  $51.37 \pm 18$  years (range, 16–75-years), that were clinically and ultrasonographically evaluated after an average of three years from surgery (from nine months to five years).

The charts of all patients were reviewed and data collected including trauma origin, treatment and complications.

At the time of the follow-up, all the patients were evaluated using the Constant score (CS), Constant score normalised for age and gender, and simple shoulder test score (SSTS), and through shoulder examination tests [11].

### Sonographic analysis

All patients included in this study underwent an ultrasound study (Figs. 2 and 3). An experienced musculoskeletal radiologist (G.C.) performed all the scans on a Philips iU22 Ultrasound System (Philips Medical Systems, Surrey, U.K.) using a broadband linear array transducer L12-5 50 mm following a standard shoulder ultrasound protocol. In each case, the presence or absence of a rotator cuff tear and the size of the cuff tear were recorded. The tendon injuries were classified as partial if there was a focal nonhomogenous area into the cuff substance, a defect limited to the articular or bursal side and structural alterations without discontinuity at dynamic scan. The sonographic criteria of full thickness tears are diffuse thinning tendons, a full thickness gap, partial or complete retraction of the cuff, diastasis edge breaking at rest or during dynamic scan [12].

### Statistical analysis and fracture classification

Data were analysed by use of IBM SPSS v.20.0.0 software (SPSS, Inc, Chicago, IL). Fractures (15 on the left side and 9 on the right side) were classified according to the AO fracture classification system.

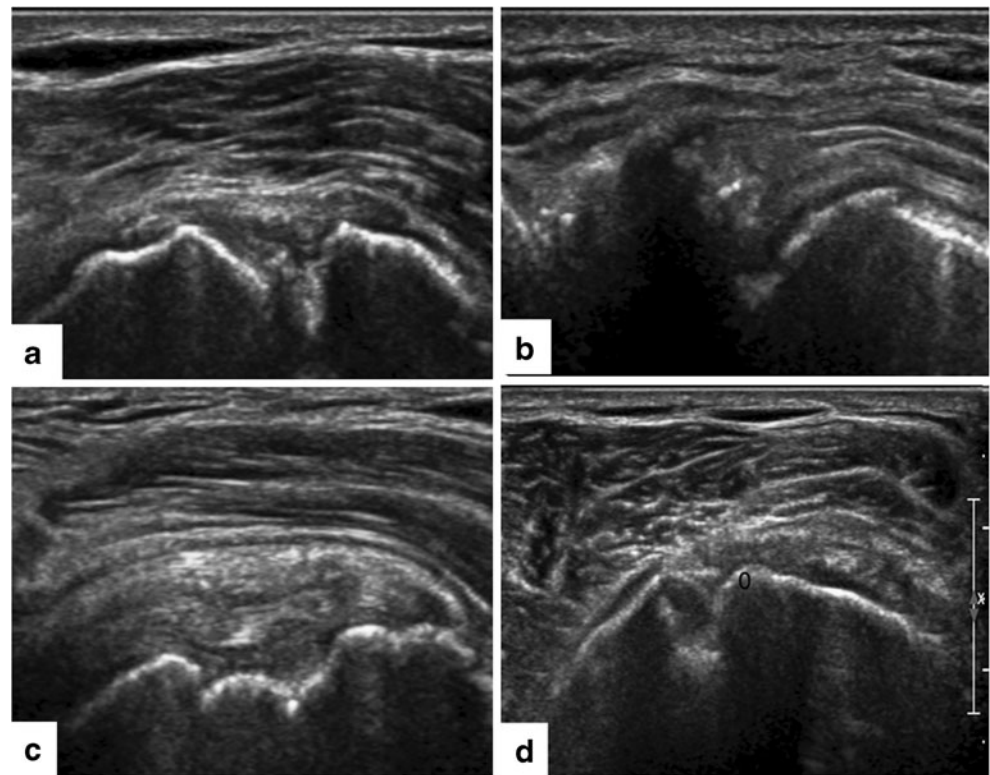
### Surgical technique and postoperative care

Surgery was performed with patients placed in a beach-chair position. A small incision was performed within the fibres of the deltoid muscle antero-lateral to the acromion. The deltoid

**Fig. 1** Radiographic appearance of a humeral shaft fracture (**a**) and post-operative imaging (**b**)



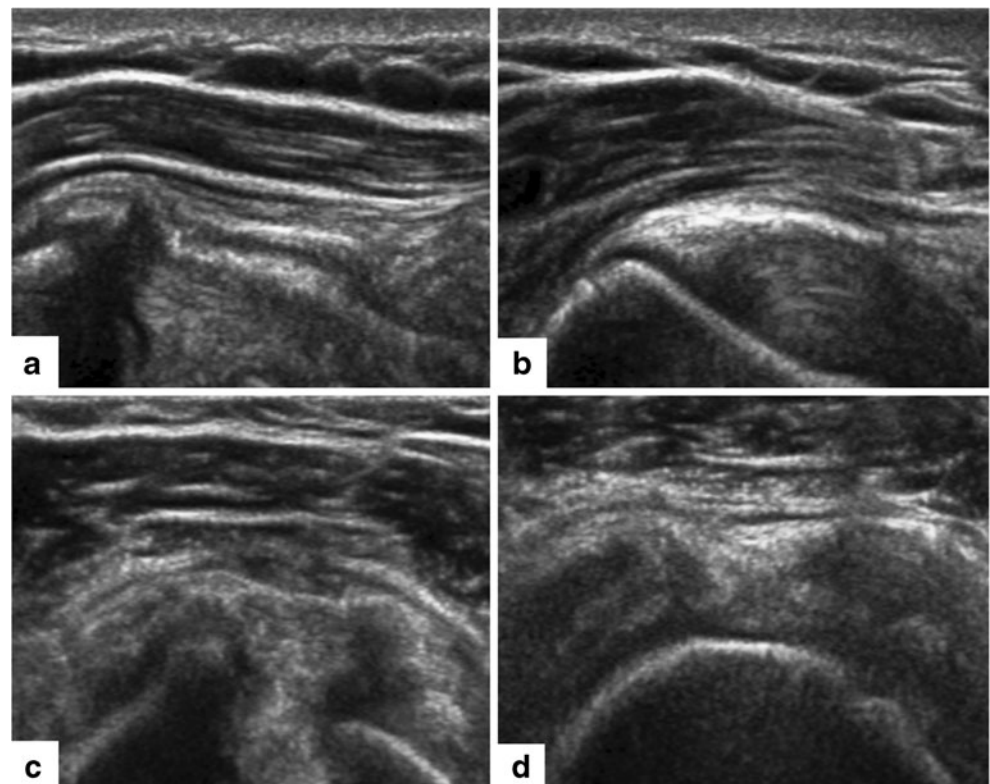
**Fig. 2** Ecographic appearance of supraspinatus tendon with full-thickness lesion and partial retraction of anterior rim in the long axis (A-B-C) and short axis (D). **a** Absence of visualisation of supraspinatus tendon in the anterior region near the surgical access to positioning of the intramedullary nail with elevation of the head of the humerus which is in contact with the acromion. **b** Appearance of the anterior region with shoulder abduction. **c** Posterior portion of the supraspinatus tendon without pathological alterations. **d** Absence of visualisation of the tendon under the deltoid in the anterior region and integrity of the tendon in the posterior region



was split to expose the subdeltoid bursa. The supraspinatus tendon was then incised in line with its fibres. The real rotation of the proximal fragment was checked (inversion

or reversion), to expose the entry point at the tip of the greater tuberosity. If the proximal fragment was inverted, the entry point was more anterior. If the proximal fragment

**Fig. 3** Ecographic appearance of supraspinatus tendon of a patient without a tear. **a Long axis:** Thickness and aspects of the tendon appear conserved in the surgically treated area. Some artifacts derived from the suture are visible. **b Long axis:** In the posterior region the tendon appear normal. **c-d Short axis:** The site of insertion of the intramedullary nail and on the medial region are visible; it is possible to see the surgical scar in the tendon with irregularity of the superior convexity, but without full-thickness tears of the tendon



**Table 1** Patient functional data

	Age	Side	Nail-screw asp	Extra-add	Extra-abd	Ant-elevat	Abduction
	66	L	NO	45°	35°	91–120°	91–120°
	74	L	NO	60°	90°	151–180°	151–180°
	75	L	NO	60°	60°	121–150°	121–150°
	66	L	NO	45°	35°	121–150°	121–150°
	38	L	NO	60°	90°	151–180°	151–180°
	74	L	NO	60°	60°	121–150°	151–180°
	66	L	NO	55°	90°	151–180°	151–180°
	58	L	NO	45°	60°	91–120°	121–150°
	63	L	Proximal screw	45°	90°	91–120°	91–120°
	56	R	NO	60°	90°	121–150°	91–120°
	48	R	NO	45°	45°	121–150°	91–120°
	63	L	NO	45°	90°	121–150°	121–150°
	57	R	NO	45°	60°	91–120°	61–90°
	23	R	NO	60°	90°	151–180°	151–180°
	35	R	Nail and screws	60°	90°	151–180°	121–150°
	51	L	NO	25°	80°	121–150°	91–120°
	39	L	Nail and screws	60°	90°	151–180°	121–150°
	60	L	Nail and screws	60°	80°	121–150°	121–150°
	61	R	NO	60°	90°	151–180°	121–150°
	16	R	NO	60°	90°	151–180°	151–180°
	57	L	NO	60°	60°	61–90°	91–120°
	31	R	NO	60°	90°	151–180°	151–180°
	29	L	NO	45°	45°	151–180°	121–150°
	66	L	NO	45°	35°	91–120°	91–120°
	74	L	NO	60°	90°	151–180°	151–180°
	63	L	NO	45°	90°	121–150°	121–150°
	66	L	NO	45°	35°	121–150°	121–150°
	60	L	Nail and screws	60°	80°	121–150°	121–150°
	75	L	NO	60°	60°	121–150°	121–150°
	38	L	NO	60°	90°	151–180°	151–180°
	74	L	NO	60°	60°	121–150°	151–180°
	66	L	NO	55°	90°	151–180°	151–180°
	58	L	NO	45°	60°	91–120°	121–150°
	63	L	Proximal screw	45°	90°	91–120°	91–120°
	57	L	NO	60°	60°	61–90°	91–120°
	48	R	NO	45°	45°	121–150°	91–120°
	56	R	NO	60°	90°	121–150°	91–120°
	57	R	NO	45°	60°	91–120°	61–90°
	23	R	NO	60°	90°	151–180°	151–180°
	35	R	Nail and screws	60°	90°	151–180°	121–150°
	51	L	NO	25°	80°	121–150°	91–120°
	39	L	Nail and screws	60°	90°	151–180°	121–150°
	35	R	Nail and screws	60°	90°	151–180°	151–180°
	16	R	NO	60°	90°	151–180°	151–180°
	61	R	NO	60°	90°	151–180°	121–150°
	31	R	NO	60°	90°	151–180°	151–180°
	29	L	NO	45°	45°	151–180°	121–150°
	35	R	Nail and screws	60°	90°	151–180°	151–180°

*Extra-add* external rotation with humerus in adduction position at 0°, *Extra-abd* external rotation with humerus in abduction position at 90°, *Ant-elevant* anterior elevation of the arm, *Nail screw asp* nail screw asportation



was in external rotation, the entry point was more lateral. After introduction of the guide wire, the nail—connected to the targeting device—was introduced into the medullary cavity. Guided multidirectional proximal and distal locking was then performed. The rotator cuff was carefully closed after nail insertion with non-adsorbable sutures.

Patients were immobilised with a sling for three weeks after the operation. Passive range of motion exercises of the shoulder assisted by a physiotherapist and active motion of the elbow was allowed soon after this, as early as tolerable, avoiding rotational exercises. Twenty-five days after surgery, radiographic examination was performed and all patients began active motion of the shoulder and muscular strengthening of the deltoid and the rotator cuff, when the radiograph showed callus formation.

## Results

All patients underwent surgical treatment within an average of 4.84 days (range, one to 14 days). The mean follow-up period was 32.54 months (range, 12–61 months). Ten patients underwent additional operations—eight complete implant removals and two proximal screw removals due to back-out. However, no patient required revision for loss of reduction.

The results of the clinical examinations are summarised in Table 1.

Thirty-four patients had no pain, four had mild pain and ten had moderate pain. None had severe pain. The mean absolute Constant score achieved was 78.21 points (range, 49–100). The functional outcome was excellent in 14 patients (score > 75 points), satisfactory in nine patients (score between 50 and 75) and poor in only one patient (score < 50 points). The Constant score normalised for age and gender showed 18 patients to have excellent results, six patients had satisfactory results and no poor results were documented. Although the mean Constant score was significantly higher in patients younger than 60 years old (mean CS of 76.50) ( $P=0.009$ ), the adjusted score was not significantly better in this group of patients (mean normalised CS of 79.21) ( $P=0.09$ ) (Table 2). As a conclusion, elderly patients (mean CS of 80.60, mean normalised CS of 89.80) in the study did not show differences when the scoring was weighted according to the age group.

Evaluation of the simple shoulder test revealed good subjective overall evaluation with a mean of 9.46 points (range, 2–12).

The sonographic results documented no tears in 44 patients. The supraspinatus tendon showed partial-thickness rotator cuff tears in three cases and a complete-thickness rotator cuff tear in only one case. The subscapularis, infraspinatus, and teres minor tendon always appeared normal on ultrasonographic analysis.

The mean age of the 20 patients without sonographic abnormalities was 62.3, and the mean age of subjects with

**Table 2** The difference in the clinical scores between patients older and younger than 60 years old

Test	Age	N	Mean	Standard deviation
Simple shoulder test	< 60	28	9.21	3.309
	> 60	20	9.80	2.700
Constant score	< 60	28	76.50	16.865
	> 60	20	80.60	12.167
Normalized constant score	< 60	28	79.21	14.418
	> 60	20	89.80	12.155

documented sonographic lesions was 49.6 ( $P=0.174$ ). In the three worst Constant scores (less than 60), we see that only one patient presented an ultrasound considered pathological, with a diminished tendon size. In the only one patient (number 4) in whom complete tear of the supraspinatus tendon (SST) was observed on the ultrasound, the functional result turned out to be good, with a Constant score of 73 points. Moreover, the other two patients with partial cuff tears of the supraspinatus tendon (SST) scored 94 and 81 points.

There was no statistically significant difference in Constant score between patients with or without ultrasonographic lesions ( $P=0.682$ ).

## Discussion

There is a high incidence of asymptomatic rotator cuff tears in the general population [13]. The clinical significance however, is not well understood because the natural history remains unclear. Some anatomical investigations on cadavers have demonstrated a spectrum of pathological changes in the rotator cuff from 5 % to 39 %, with an increased frequency in older individuals. Sher et al. [14] demonstrated a 28 % prevalence of full-thickness rotator cuff tears in individuals over 60 years old as compared with a 4 % prevalence in those below 60 years old. Moreover Milgrom et al. [15], in an ultrasound study, showed a 50 % prevalence of rotator cuff disease in those patients older than 70 years. Finally, Mall et al. [16], in a prospective study on 195 patients, found that 22.5 % of asymptomatic patients with rotator cuff tears become symptomatic over a two-year period, confirming that a sonographic lesion of rotator cuff must not be underestimated.

Selecting the best treatment option for a diaphyseal humeral fracture, the patient's characteristics, fracture type and bone quality must be taken into consideration [17]. Surgical management of humeral shaft fractures includes different approaches. Intramedullary nailing is currently the most widely used method among the different surgical techniques available (external fixation, plate and screw osteosynthesis, intramedullary osteosynthesis) [8], and it is indicated for most humeral fractures

localised between the surgical head and the distal diaphyseal–metaphyseal junction. The humeral nailing systems offer an option for either an antegrade or a retrograde approach to repair fractures of the humerus, combining limited tissue trauma and high primary stability, particularly in osteoporotic bone, ensuring early mobilisation and favourable clinical results [3]. The choice of the type of approach for intramedullary nailing remains controversial, especially for the possible residual impairment of the shoulder and of the elbow, and depends on the type of fracture, the type of nail, and on the surgeon's preference. Mückley et al. found that there was no significant difference between the antegrade and retrograde approaches regarding the total Constant score ( $P=0.124$ ) [18]. Antegrade intramedullary nailing is not an extra-articular approach, and its main disadvantage is that it crosses the rotator cuff and the articular cartilage of the humeral head. In literature there is no evidence which suggests a higher percentage of infection in patients treated with this technique when compared with patients treated with other surgical techniques.

The use of bent nails for fixation of diaphyseal fractures is debatable and there are studies showing that external insertion of the nail at the cuff footprint may be a iatrogenic condition [19].

Moreover, Cuny et al. reported that the Telegraph nail provides a reproducible and satisfactory outcome for surgical neck and valgus impacted fractures in older patients but the outcome was less satisfactory for unstable articular or dislocated fractures [20].

In a previously reported study a favourable long-term outcome has been documented, but no studies are reported in literature about the ultrasonographic outcome of rotator cuff tears after antegrade nailing for humeral shaft fracture. In this study we found that the favourable clinical outcome of these patients reflects a low percentage of ultrasonographic rotator cuff tears.

Ultrasound evaluation in the postoperative tendon structures is generally limited by the partial disruption of the fibrillar matrix and the formation of heterogeneous structure in areas of scarring, as potential mimic partial tears. Following bursectomy, secondary signs of full-thickness tears could also fail as the distension liquid from joint communication. A higher accuracy might be achieved for full-thickness lesions where the use of dynamic scan could show diastasis edge of tears [21].

Our findings suggests that there is no association between the previous status of the surgically treated cuff (partial tears, micro-tears, microvascular alterations, muscle atrophy, etc.) and the final functional outcome. We could see that age does not tend to lead to poorer Constant scores, so we believe it should be considered an indication when choosing the ideal approach.

Finally, to answer the initial question that prompted this study, we believe that ultrasonographic lesions of the shoulders and clinical impairment in patients after antegrade humeral nailing are not frequent.

## Conclusions

The results of this study suggest that the use of the anterolateral approach for antegrade humeral nailing provides an acceptable functional result on the operated shoulder. About 92 % of the patients in this study showed no significant clinical-sonographic impact.

A clinical-sonographic dissociation was documented in the three patients with rotator cuff tears who had a Constant score higher than 70.

**Conflict of Interest** The authors declare that they have no conflict of interest.

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