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## Displaced 3- and 4-part proximal humeral fractures: Evaluation and management with an intramedullary nail within 48 h, in the emergency department

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### ABSTRACT

**Objective:** The aim of our study is to investigate if a locking intramedullary nail could be useful in the treatment of fractures of the humeral head in 3 and 4-fragments operated within 48 h from the trauma.

**Methods:** From 01/02/2011 to 31/05/2013, we performed 21 cases of humeral fractures treated with the Polarus intramedullary nail (Acumed). We considered parameters such as age, sex, time of radiological healing and functional outcome, which were assessed by Constant Shoulder Score, UCLA Shoulder Score, Oxford Shoulder Score and Dash Score. Study design: Cohort prospective study.

**Results:** Clinical and radiographic follow-up of patients was performed at 1, 2, 3, 6, 12, and 24 months after surgery. Evidence of radiographic bone healing occurred at an average of 2.42 months post-surgery (range: 1–6 months, median 2). There were no cases of avascular necrosis of the humeral head or failure of the synthesis. The functional outcome was excellent in 6 out of 21 cases (Constant score >86%); good in 11 out of 21 cases (Constant score 71–85); satisfactory in 3 out of 21 cases (Constant score 56–70); only in one case we recorded poor outcome (Constant score = 55).

**Conclusions:** The nail utilized is provided with locking and multiplanar proximal screws and could be applied through a mini-invasive anterolateral approach. This enables the reduction of the fracture fragments, while preserving vascularization of the scapulo-humeral joint. Our results confirm that the indication of endomedullary nail could be extended to the treatment of complex proximal humeral fractures with 3 and 4 fragments (level of evidence IV).

## 1. Introduction

Proximal humeral fractures account for 4%–5% of all fractures, involving mainly the elderly population (>60 years), particularly women. Many authors have estimated an exponential increase of these fractures in the next few years, which would have a considerable impact on social services and health budgets, as they severely limit patients' independence in daily life<sup>[1]</sup>.

Three- and four-part fractures of the proximal humerus, according to the Neer classification, represent a considerable fraction of all humeral fractures and have a significant impact on patients' lives and the economy of the health care system. At the present time, treatment of this type of fracture is a topic of debate.

Various authors have shown that a significant number of these fractures can be treated conservatively, especially in elderly patients<sup>[2,3]</sup>. However, conservative treatment poses several disadvantages such as lack of application, displaced fractures, prolonged immobilization, significant pain, and functional limitation<sup>[1]</sup>.

In the case of unacceptable deformity, where greater stability is required to reduce the fracture displacement and to allow early mobilization, surgery is needed. However, at the present time, there is not a standard osteosynthesis technique as data in the literature are inconsistent<sup>[4,5]</sup>.

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Surgical intervention with open reduction and internal fixation with locking plate is the main recommended option for complex fractures of the proximal humerus, with generally good or satisfactory results in the literature<sup>6,7</sup>. This treatment also presents some disadvantages due to large surgical exposure with risk of iatrogenic avascular necrosis (AVN), axillary nerve damage, risk of secondary dislocation and inaccuracy of execution<sup>8</sup>.

Hemiarthroplasty represents another surgical option which is a complex operation with disappointing results, therefore it is reserved for cases with massive comminution, severe joint involvement, or for patients with AVN after conservative treatment<sup>9–11</sup>.

A viable option for humeral head fracture treatment, particularly fractures without articular fragmentation and with 1 or 2 fragments of tuberosities is intramedullary (IM) proximal nailing. Treatment of 2-part fractures of the proximal humerus with an IM nail is widely established in scientific literature to be effective with a low rate of complication<sup>11–61</sup>. The hypothesis of this study is that converting a 3- and 4-part fracture into a 2-part fracture may allow the use of the IM proximal nail in even more complex fracture patterns.

We performed a prospective study to evaluate the efficacy and safety of the treatment for 3- and 4-part fractures of proximal humerus with a locking IM nail combined with a limited open reduction, the MacKenzie anterolateral approach.

## 2. Materials and methods

### 2.1. Patients

Patients with 3- or 4-part fractures of the proximal humerus were prospectively enrolled in the study during February 2011–May 2013 at the University Department of Orthopaedics and Traumatology, Hospital of Siena. The study was approved by the local ethics committee. Informed consent was obtained from all individual participants included in the study. The inclusion criteria were 3- and 4-part fractures of the neck of the humerus treated with IM nail, skeletally mature patients, fractures treated within 48 h of injury, and minimum follow-up of 24 months from the surgery. Exclusion criteria were not all those present in the inclusion criteria.

The participants were treated surgically using the Polarus TM nail (Acumed, Hillsboro, OR, USA). Patients who did not carry out periodic checks, had pathological fractures, or who had severe articular involvement that required treatment with hemiarthroplasty in first instance, were excluded from the study. All patients were treated within 48 h from the trauma.

We focused on 21 cases in 19 patients, including 2 with bilateral fractures of the humerus. They were 17 women and 2 men, with a mean age of 71.7 (range 36–91, median 71).

Fractures were classified according to the Neer classification by preoperative X-ray or CT scan. We discovered 10 cases of 4-part fractures (47.6%), 10 cases of 3-part fractures (47.6%) and 1 case of fracture-dislocation in 3 fragments (4.76%). The clinical and radiographic follow-up of patients was assessed at 1, 2, 3, 6, 12 and 24 months post-operation. Radiographs included posteroanterior and laterolateral views in order to evaluate the bony union and any complications. Healing was achieved upon obliteration of the fracture in 3 out of 4 corticals neurons in the

X-ray projections and was associated with active shoulder motion without pain as single capabilities allowed.

At 1 year and 2 year follow-up, we assessed functional outcomes through the use of Constant score. The Constant score was an outcome measure that allowed assessment of pain, range of motion and daily living activities. In order to limit the possible weakness of the Constant score, all patients were subjected to the Oxford shoulder score and University of California at Los Angeles (UCLA) shoulder score. The Oxford shoulder score ranged from 40 to 48, and indicated satisfactory joint function. UCLA results <27 were fair to poor, and results >27 were good to excellent. Finally, a global assessment of patients' disabilities was performed by means of the disability of arm, shoulder, and hand (DASH) outcome measure questionnaire, a 30-item self-reported questionnaire designed to measure physical function and symptoms in patients with any or several musculoskeletal disorders of the upper limb. Results ranged from 0 (no disability) to 100 (complete disability)<sup>12</sup>.

### 2.2. Device and surgical technique

Surgical interventions were performed by the same surgical team, under general anesthesia, with the patient positioned in beach chair. Intraoperative fluoroscopy was available for each patient.

In all cases, an anterolateral approach (MacKenzie approach) to proximal humerus was performed. A 3–5 cm longitudinal incision was made from the anterolateral side of the acromion, distally in line with the humerus. Deltoid fibers were split along the median raphe, separating fibers from the anterior third to the middle third.

The rotator cuff was incised for about 1 cm parallel to the course of its fibers. In this way, the tuberosities' fragments were exposed and synthesized with the help of non-adsorbable sutures or temporary Kirschner wires in order to convert a 3- and 4-part fracture into a 2-part fracture. Then, we proceeded to the synthesis with the IM device.

Polarus was a cannulated IM humeral rod that featured a tapered profile with a patented spiral array of proximal screws. About 5.3 mm cancellous locking screws allowed optimal fixation of tuberosities' fragments as they engaged multiplanar and threaded holes, locking smoothly on the nail (Figure 1).

In a second step, we proceeded to the synthesis of the surgical neck fractured by positioning distal low profile screws. Screw placement was guided by dedicating instruments and performing under X-ray control. To reduce the risk of damage, anatomical structures such as the axillary nerve were identified and protected. At the end of the bone synthesis, a careful rotator cuff suture was performed. Postoperatively, the patient's arm was protected in a sling at a neutral position. From the first week post-surgery, we recommended active and passive kinesis of the elbow. Cautious and passive kinesis of shoulder and Codman pendulum were recommended for 15–21 days after surgery. Finally, we prescribed active kinesis according to radiographic findings.

### 2.3. Ethical standards

All procedures performed in this study were in accordance with the ethical standards of the institutional research ethics committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.



**Figure 1.** The Polarus cannulated intramedullary humeral rod. Multiplanar fixation acted as a scaffold, restoring the proper anatomic alignment of the humerus.

### 3. Results

A total of 21 cases were available for the final review in 19 patients (2 cases of bilateral fracture). The cases included 17 women and 2 men, and 10 cases of 4-part fractures (47.6%), 10 cases of 3-part fractures (47.6%) and 1 case of fracture-dislocation in 3 fragments (4.76%). The three-part fracture-dislocation was included in the 3-part fracture group.

The average age of the patients was 71.7 (range 36–91, median 71). Patients with a 3-part fracture had a mean age of 73 (range 36–91, median 72) and patients with a 4-part fracture had a mean age of 70.1 (range 59–85, median 70).

The clinical and radiographic follow-up of patients was assessed at 1, 2, 3, 6, 12, and 24 months post-operation. Radiographs included posteroanterior and laterolateral views in order to evaluate the bony union and any complications. Radiographic bone healing was reached at an average of 2.42 months (range 1–6, median 2) with an insignificant difference between 3-part fractures (average bone healing at 2.2 months, range 1–6, median 2) and 4-part fractures (average bone healing 2.6 months, range 1–5, median 2.5) (Figure 2).

There were no cases of AVN. In 2 cases, one loosened screw (backed out screw) caused considerable pain. They were removed (one at 6 weeks and the other at 8 weeks) under local anesthesia without affecting the fracture healing. One case involved a delay of union. It was an 80 year old woman with a 3-part fracture-dislocation, in which healing was completed at the 6th postoperative month with excellent functional outcome (Constant score 94% at 1 year).

The results of Constant score, Oxford shoulder score, UCLA shoulder score and DASH questionnaire were summarized in Table 1. Functional outcome was excellent in 6 out of 21 cases (Constant score >86%), good in 11 out of 21 cases (Constant score 71–85), satisfactory in 3 out of 21 cases, (Constant score 56–70), and only one case recorded poor outcome (Constant score = 55) (Table 2).

### 4. Discussion

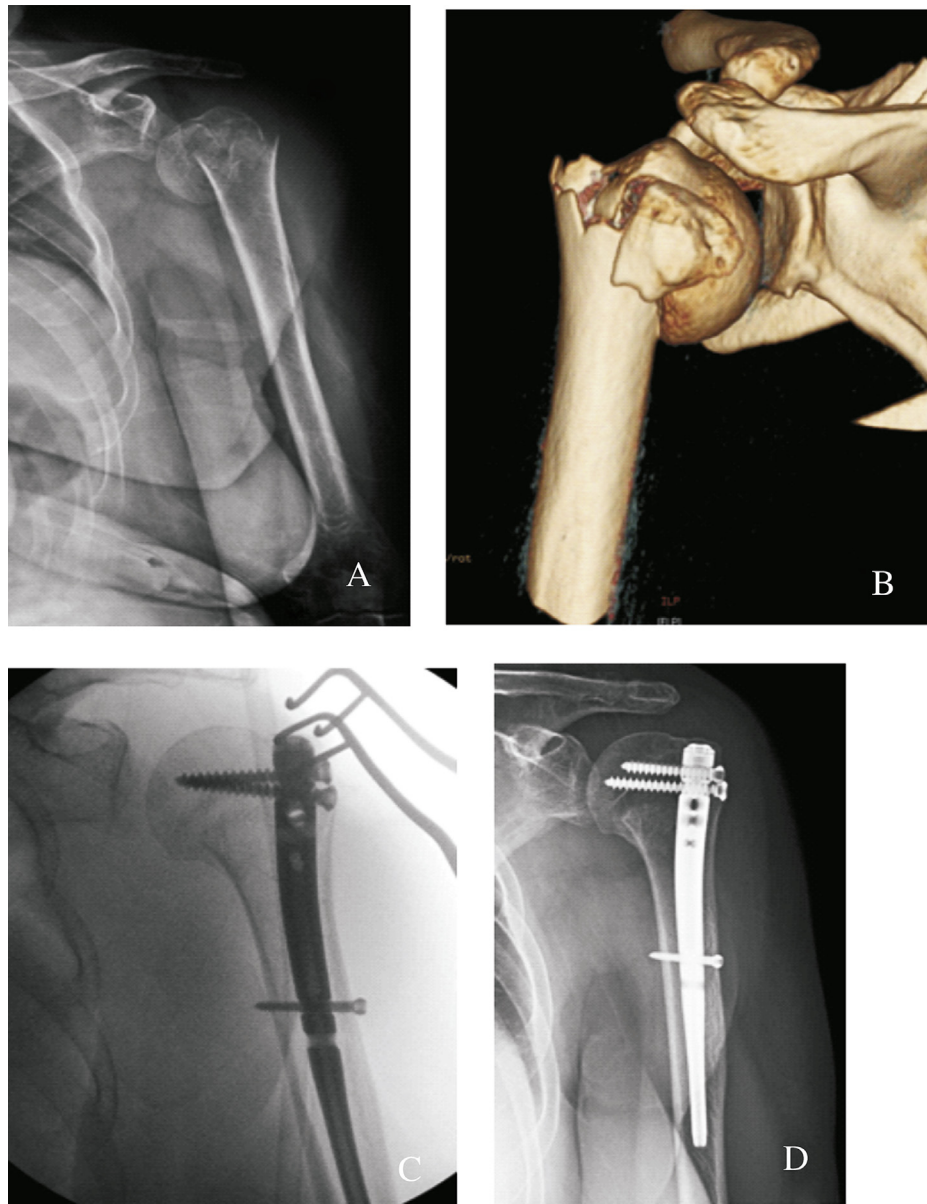
The incidence of proximal humeral fractures treated surgically has quadrupled from the 1980s until today<sup>[13]</sup>. Several surgical options are currently available, but no surgical technique has proven to be superior than others or uncomplicated. Therefore, there is a lack of adequate data for an evidence-based decision about the ideal treatment<sup>[14]</sup>. Misra *et al.* reported in their review the importance to treat these patients with 48 h for good outcomes<sup>[15]</sup>.

Three- and four-part humeral fractures are also worthy of a separate assessment in consideration of the severity of the fracture and risk of complications. Aaron *et al.* reported displacement of the humeral tuberosities above head as in 3- or 4-part fracture or 2-part fracture in varus often yields a poor functional outcome even if healing occurs nonsurgically<sup>[1]</sup>.

The main goal of surgical treatment is to achieve an anatomic reduction of the fracture and a stable synthesis in order to guarantee an early fracture healing, minimizing pain and optimizing the rehabilitation<sup>[16]</sup>.

Conservative treatment is reserved for a high percentage of fractures of the proximal humerus<sup>[17]</sup>. Canbora *et al.* showed satisfactory results in 42 patients with complex fractures of the proximal humerus treated conservatively<sup>[18]</sup>, with comparable results obtained by Kim *et al.*<sup>[2]</sup> and by Gupta<sup>[3]</sup>. These scientific studies have several limitations, mainly due to lack of uniformity in assessment of functional outcome. However, the authors agree in reserving the conservative treatment only in selected cases, as it is frequently associated with functional impairment, rigidity and pain<sup>[4,9]</sup>.

The results of treatment with stability plate (open reduction with internal fixation) are satisfactory, but they are countered with a considerable rate of complications. The intra-articular migration of the screws (screw joint perforation 13%–23%) and osteonecrosis (3%–16%) that involve surgical revision rate of 13%–26% are of particular concern<sup>[1]</sup>. Additionally, there is a



**Figure 2.** Woman, 59 years old, with humeral 4-part fractures.

A: Preoperative X-ray; B: CT scan, tridimensional reconstruction and anterolateral view; C: The same case after intramedullary nailing; D: X-ray at 2 years of follow-up.

**Table 1**

Results at 2 years follow-up.

Outcome measures	All fractures			3-Part fractures			4-Part fractures		
	Mean	Median	Range	Mean	Median	Range	Mean	Median	Range
Constant score	78.7	80.0	55.0–94.0	80.0	82.0	69.0–91.0	77.4	78.5	55.0–98.0
Oxford shoulder score	44.3	44.0	34.0–48.0	44.9	45.0	40.0–48.0	43.7	44.0	42.0–48.0
UCLA	30.2	30.0	20.0–35.0	30.8	32.0	28.0–35.0	29.5	29.0	20.0–34.0
DASH	8.1	7.5	0.0–20.5	8.2	7.5	0.8–15.8	8.1	7.5	0.0–20.5

risk of damage to soft tissues and devascularization, which results in considerable postoperative pain and stiffness<sup>[19]</sup>.

The treatment of complex proximal humeral fractures with hemiarthroplasty showed mostly disappointing results because significant pain relief is associated with a far less predictable functional outcome<sup>[11,19]</sup>. Hemiarthroplasty still requires osteosynthesis of the tuberosities where they are fractured and

should be reserved for selected cases with higher AVN risk or with massive articular comminution.

The use of IM nailing in the treatment of proximal humeral fractures received success in recent years due to improved techniques and surgical instruments as well as improved reliability of new surgical implants. Osteosynthesis with a nail allows recognition of the advantages of a limited invasiveness,

**Table 2**

Functional outcomes at 2 years follow-up.

Functional outcomes	Constant score	Number of patients	Percentage of patients
Excellent	>86	6	28.6
Good	71–85	11	52.4
Satisfactory	56–70	3	14.3
Poor	55	1	4.7

including reduction of complications and pain and the possibility of an early mobilization due to a stable synthesis.

In our case, the stable osteosynthesis is made possible by the characteristics of the Polarus nail (5.3 mm proximal cancellous screws were fixed to the thread of the nail ensuring a stable synthesis of tuberosity fragments). The multiplanarity of the screws ensures several configurations of synthesis depending on fracture type. Moreover, there is the possibility of applying the nail through the anterolateral deltoid approach (MacKenzie approach), which is a minimally invasive approach. It is thus possible to reduce fragments of tuberosities, which are eventually synthesized with sutures, without affecting the vascularization of the scapulo-humeral joint.

Our series showed that in 95.2% of cases (20 out of 21 cases) of 3- and 4-part fractures treated with IM nail, the Constant score ranges from satisfactory to excellent results at 2 years after surgery. Constant score ranges from good to excellent in 17 out of 21 cases (80.95% of cases). These excellent results are confirmed by other outcome measures. The mean Oxford shoulder score was 44.3 (satisfactory results for values >40) and the mean UCLA shoulder score was 30.2 (good to excellent for values >27).

Finally, we considered the functional outcome in terms of disability of fractured patient, assessed with DASH score, which showed an excellent average result of 8.11% (full disability for values near 100%).

There are no widely significant differences between the subgroup of 3-part fractures and the subgroup of 4-part fractures, though patients with 4-part fractures have slightly lower results.

In scientific literature, there are several works that analyze the results of the IM nailing applied to humeral fractures. Adedapo and Ikpeme demonstrated good results in 23 patients with complex humeral fractures<sup>[4]</sup>. Georgousis *et al.* demonstrated 83% of good to excellent results in 2- and 3-part fractures both young and old people<sup>[20,21]</sup>. According to Sosef *et al.*, IM nail is of value for (displaced) 2-, 3- and even 4-part proximal humeral fractures and enables early postoperative mobilization with a limited amount of pain<sup>[9]</sup>. Our results are in line with the literature, but we wish to remark that patient selection and appropriate fracture evaluation are key to achieve better outcomes in complex humeral fractures.

Possible complications related to proximal humerus IM nailing, such as fractures of the tuberosity associated to the entry point, varus malalignment and lack of proximal fixation, are potentially reducible due to the current development of IM devices. A straight design that allows for a more medial entry point has been proposed. The more medial entry point reduces the risk of iatrogenic fractures of the tuberosity more than the curved nails. The incision of the rotator cuff could be done in a more vascularized area that heals easily, thus reducing the risk of painful shoulder after intervention<sup>[22]</sup>. Moreover, the alternative

locking mechanism may reduce the risk of migration of the screws, providing better proximal stability.

Randomized comparative studies of the two different designs would be important to assess the advantages reported.

The IM nailing, associated with a less-invasive approach, provides optimal fracture stability and reduced surgical aggressiveness and risk of devascularization. Therefore, it guarantees optimal outcomes. The results presented confirm the possibility to extend the indication of IM nail to the treatment of complex proximal humeral fractures that do not present important comminution or a major articular involvement.

### Conflict of interest statement

The authors report no conflict of interest.

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