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Surgical treatment of proximal humerus fractures with intramedullary nail

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Summary

Introduction. Proximal humerus fracture is the most common fracture of the shoulder girdle, accounting for approximately 4-7% of all fractures. The aim of this study is to provide surgeons safe and effective surgical solutions, minimizing the risk of complications.
Materials and methods. We retrospectively analyzed all 3-fragment proximal humerus fractures, treated between January 2017 and December 2018 with the Diphos® short intramedullary nail (Lima Corporate®, San Daniele del Friuli, Italy). 33 patients, 19 men (57.6%) and 14 women (42.4%), were included; average age was 68.4 years (min. 63 - max. 78, SD 3.67).
Results. Hospitalization was 6.27 ± 2.87 days (3.6 days before undergo surgery, 2.7 days after). Mean surgical time was 27.36 ± 8.49 minutes. On average, patients healed after 78.36 days. We registered 10 complications: 4 malunion (12.1%), 2 screw-cut outs (6.1%), 1 delayed union (3.0%), 1 cuff lesion (3.0%), 1 loss of reduction (3.0%), and 1 intraoperative fracture (3.0%). Overall re-operation rate was 6.1%.
Conclusions. During surgery, it is crucial to choose the right entry point when placing the nail. Failing at this level can lead to intraoperative and postoperative complications, in addition to worse clinical outcomes.

Key words: proximal humerus fracture, intramedullary nail, entry point

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Conflict of interest
The authors have no conflict of interest to declare.

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Introduction

Proximal humerus fracture is the most common fracture of the shoulder girdle, as well as an event that has become more and more frequent in recent years [1], both in elderlies and adults, accounting for approximately 4-7% of all fractures [2]. Some recent studies also show that this fracture has increased after the general lockdown imposed by governments due to the Covid-19 pandemic [3]. Many cases can be managed conservatively, such as compound fractures or those occurring in patients with significant comorbidities.
Generally, in young people these types of fractures result from high energy trauma, such as road or sport accidents; on the other hand, in the elderly even a low-energy trauma may be sufficient, as it acts on lower quality bone [4].
In order to manage these fractures, surgeons can choose between several techniques and intramedullary nailing is one of the most commonly used.
Over the years, various classifications of proximal humerus fractures have been proposed, but today the most important and clinically applied are three:

- Neer classification [5,6], based on the notion that proximal humerus consists of 4 main "segments" (head, greater tuberosity, lesser tuberosity and shaft) and that displace-

ment is considered significant if more than 1 cm or produces an angle of > 45°;
- the system of Arbeitsgemeinschaft für Osteosynthesefragen (AO classification) [7], where humeral fractures are classified considering the exact location of the fracture and its severity, in order to identify the most suitable procedure for the treatment of a single bone lesion;
- Hertel classification [8], which combines the four main anatomical structures of the proximal humerus with 5 different spatial planes on which the fracture can occur. This classification is very effectively represented by four LEGO bricks, which replace the four main components of the proximal humerus and that can be separated in 12 different ways, equivalent to 12 different types of fractures.

In our Department, we prefer to describe proximal humerus fractures with the Neer classification, because it leads to homogenous groups of fractures, allowing surgeons to choose the best therapeutic path to follow.

The aim of this study is to explain the intramedullary nailing technique adopted at our department for the management proximal humerus fractures, providing data relating to its results and pointing out tips that can be useful for surgeons and possible future developments.

Materials and methods

We retrospectively analyzed data relating to patients with a 3-fragment proximal humerus fracture, treated in our Department at the Guglielmo da Saliceto Hospital in Piacenza (Emilia-Romagna, Northern Italy) between January 2017 and December 2018. Inclusion criteria were: age between 60 and 80 years, silent anamnesis for major comorbidities, no previous upper limb functional limitation and/or deficit. On the other hand, we decided to exclude fracture-dislocations, head-splitting fractures, pathological fractures, open fractures, severe ipsilateral injuries to the shoulder girdle, accompanying neurovascular injuries and patients who died or were lost to follow-up. In addition, to make our cohort more uniform, we considered only patients treated with a specific intramedullary nail, the Diphos® short nail (Lima Corporate®, San Daniele del Friuli, Italy), which is the most widely used device to treat these fractures in our Department.

Following these criteria, the final cohort included 33 patients, with 19 men (57.6%) and 14 women (42.4%), with an average age of 68.4 years (min. 63 - max. 78, SD 3.67). According to the Hertel classification, 10 patients presented 7-pattern fracture (30.3%), 9 patients 8-pattern fracture (27.3%), 7 patients 9-pattern fracture (21.2%), 4 patients 10-pattern fracture (12.1%), and 3 patients 11-pattern fracture (9.1%).

For collection of data relating to surgery, period of hospitalization, and follow-up, we used the medical records of from our internal archives.

Follow-up was carried out with clinical and radiographical exams, at 1, 3, 6, and 12 months, with final check at the end of the follow-up (on average after 17 months). We applied clinical scores to evaluate the functionality of the upper limb and self-independence:
- DASH score (disabilities of the arm, shoulder and hand) [9]: evaluating the disability degree of patients with upper limb functional disorders;
- Barthel index [10]: scoring progresses obtained by patients during postoperative rehabilitation;
- Simple shoulder test (SST) [11]: evaluation of possible limitations in shoulder articulation during everyday activities;
- VAS score [12]: created in order to match pain, a subjective symptom, from 0 to 10.

For radiographical evaluation, X-rays were performed in antero-posterior and axillary views.

Finally, during follow-up we also looked for loss of reduction, device of synthesis mobilization, delayed union, nonunion, humeral head necrosis, screws cut-out, and secondary arthritis.

Patient positioning (Fig. 1)

The first key element for a good procedure is correct positioning of the patient. An orthopedic bed with removable back support for the shoulder is the best solution, because it allows sufficient mobility of upper limbs, without delaying the possibility of good visibility of the monitor. We prefer to use the "beach chair" position because it allows easy access to the shoulder and the effect of gravity advantages the surgeon in reduction manuvres. While positioning the patient, we pay attention to head, neck and any pressure zones; it can be useful to place soft supports, avoiding possible iatrogenic damage, especially if the patients undergoes general anesthesia.

Positioning the image amplifier right behind patient's shoulder, with the forearm perpendicular to the proximal humerus, will allow the operator to work laterally to the patient and perform serial checks by just moving the arm.

Before preparing the surgical field, we suggest an initial check with the image amplifier, because this allows us to verify one last time the status of the fracture, also checking that there are no unpleasant difficulties in the vision of the monitor and the fracture. It is also possible to use the "Taranto" projection, which allows good intraoperative visualization of the proximal humerus; it consists in rotating the image intensifier by 45°, giving a better view of the gleno-humeral joint.

Ethics approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Statistical analysis

Continuous variables were expressed by mean and stand-

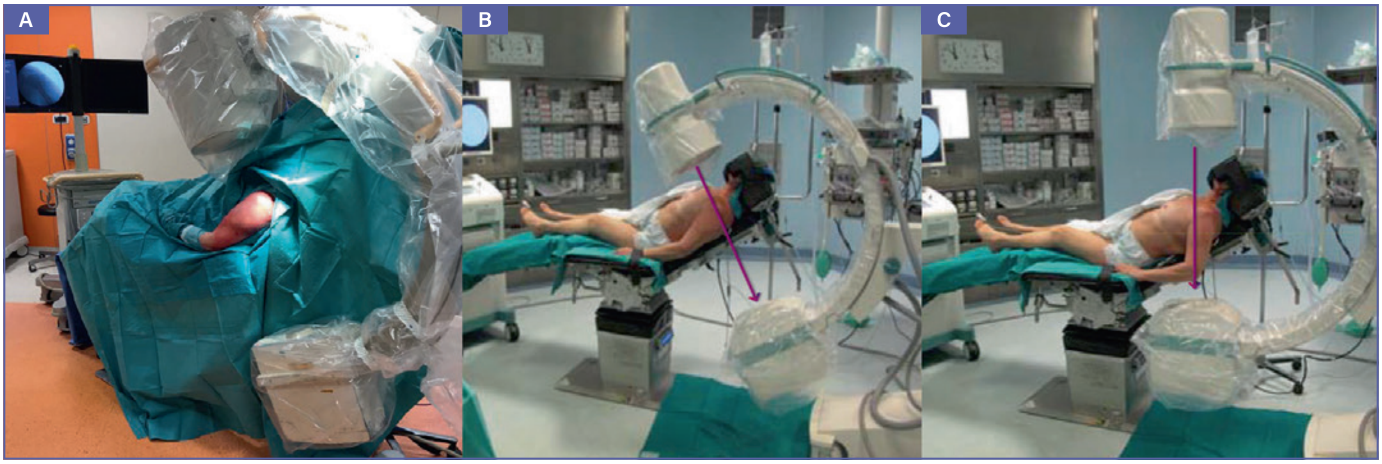

Figure 1. A) "Beach chair" position; B) Positioning of the image intensifier in the AP "Taranto" projection; C) Positioning of the image intensifier in the lateral "Taranto" projection.

ard deviation (SD) and were evaluated by Student T-test or Mann-Whitney U test. Categorical data were expressed as number and percentage (%) and were evaluated by chi-square or Fisher's exact tests. The significance level was set at $p < 0.05$. SPSS, version 23.0, was used to perform all tests (IBM, Armonk, NY, USA).

Results

Analyzing medical records of the 33 patients, the mean hospitalization period was 6.27 ± 2.87 days (min. 2 - max 12 days); in specific, patients attended on average 3.6 days before surgery (min. 0 - max. 5), while they remained hospitalized on average 2.7 days after surgery (min. 1 - max. 4). Mean surgical time was 27.36 ± 8.49 minutes (min. 12 - max. 41 minutes). On average, patients healed after 78.36 ± 15.34 days (min. 47 - max. 126 days), considering both clinical and radiological points of view. Table I shows the clinical results during follow-up (Fig. 3).

We also collected data relating to complications during both the intraoperative period and follow-up and related further surgical interventions.

We registered a total of 10 events, with an overall complication rate of 30.3% for plating. In specific, we recorded 4 cases of malunion (12.1%), 2 cases of screw-cut out (6.1%), 1 case of delayed union (3.0%), 1 case of cuff lesion (3.0%), 1 case of loss of reduction (3.0%), and 1 case of intraoperative fracture (3.0%).

Regarding Hertel's fracture pattern, type-7 fractures reported 2

Figure 2. The entry point.

Table I. Clinical results during follow-up.

	Average	SD	Error	Inferior limit	Superior limit	Min	Max
Bartel 1 month	67.63	17.70	3.08	61.35	73.91	33.00	87.00
Bartel 3 months	72.27	19.01	3.31	65.53	79.01	35.00	94.00
Bartel 6 months	77.81	20.41	3.55	70.57	85.05	39.00	100.00
Bartel 12 months	80.36	21.93	3.81	72.58	88.14	39.00	100.00
Final Bartel	80.42	21.94	3.81	72.64	88.20	39	100
Dash 1 month	56.39	18.27	3.18	49.91	62.86	28.30	91.00
Dash 3 months	46.60	21.09	3.67	39.11	54.08	22.00	89.00
Dash 6 months	42.01	19.56	3.40	35.07	48.95	19.66	76.00
Dash 12 months	42.02	19.56	3.40	35.07	48.95	19.66	76.00
Final Dash	40.59	18.29	3.18	34.10	47.07	19.66	75
SST 1 month	51.45	18.69	3.25	44.82	58.08	15.00	78.00
SST 3 months	57.09	19.56	3.40	50.15	64.02	20.00	85.00
SST 6 months	62.09	20.45	3.55	54.83	69.34	25.00	91.00
SST 12 months	63.63	21.44	3.73	56.03	71.23	25.00	93.00
Final SST	63.81	21.45	3.73	56.20	71.42	25.00	93.00
VAS 1 month	5.18	1.46	0.25	4.66	5.70	2	8
VAS 3 months	4.09	1.82	0.31	3.44	4.74	2	9
VAS 6 months	2.94	1.47	0.25	2.42	3.46	1	6
VAS 12 months	2.33	1.19	0.20	1.91	2.76	1	5
Final VAS	2.30	1.23	0.21	1.86	2.74	0	5

complications (2/10, 20.0%), type-8 fractures 3 complications (3/9, 33.3%), type-9 fractures 2 complications (2/7, 28.6%), type-10 fractures 2 complications (2/4, 50.0%) and type-11 fractures 1 complication (1/3, 33.3%). However, despite these events, we recorded a low number of re-operations. In fact, only 2 patients underwent a second surgery: in both cases surgery was necessary to reposition a screw following a cut-out, and thus the re-operation rate was 6.1%.

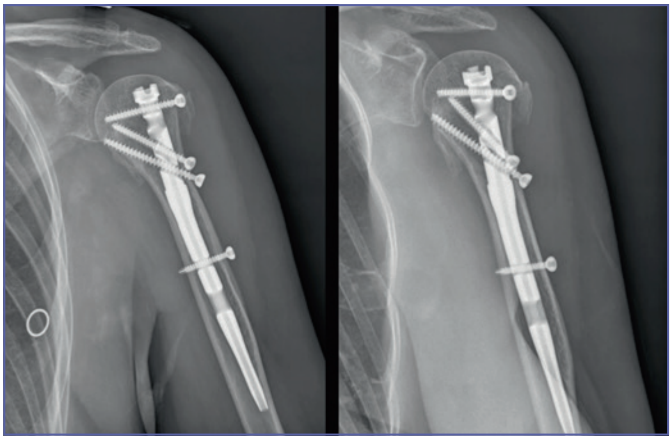

Figure 3. Radiographic result at the end of follow-up.

Discussion

Proximal humerus fracture is a very common event which the orthopedic surgeon has to deal with frequently. Its incidence seems to be increasing and the COVID-19 outbreak did not lead to a decrease. For these reasons, the scientific community is constantly debating about the best surgical solution for these fractures when surgery is needed. In fact, a large number of cases (such as compound fractures or those affecting patients with major comorbidities) can be treated conservatively, with arm immobilization. The surgical option is recommended for displaced fractures with a misalignment more than 2 mm, fracture-dislocation, metaphyseal comminution, head split, involvement of the anatomical neck, and vascular/nerve injuries [13]. Currently, the most widely used surgical solution is intramedullary nail fixation and plate fixation.

Compared to plate fixation, nailing offers several theoretical advantages: it is a faster and less invasive procedure, allowing smaller surgical approaches and preserving periosteal blood supply; it is associated with a reduced risk of complications by avascular necrosis of the head, a low incidence of postoperative adherences and short time to functional recovery. However, possible intra and postoperative complications are reported in literature [14,15], with an incidence up to 41.5% (including loss of reduction, screws migration or screws gleno-humeral joint perforation, vicious consolidation, avascular necrosis and subacromial conflict) that often leads to the necessity of a second surgery. On the other hand, the plate allows achieving a better reduction, which is more accurate from an anatomical point of view, even if more rigid [16,17].

Of course, the fracture-pattern is one of the most important predictive factors of outcomes, regardless of the osteosynthesis device chosen. Therefore, before surgery is fundamental for proper diagnosis, together with complete anamnesis and clinical evaluation based on radiological investigation (antero-posterior, lateral and axillary projections). To manage multi-fragmentary fractures, CT scan of the involved sector is also recommended. Only after all adequate radiological examinations is it possible to perform pre-operative planning, taking into consideration the patient's characteristics as well (especially age, functional requests before trauma, condition of neighboring structures) [18].

Definitely, in intramedullary nail surgery the turning point of the procedure is the choice of "entry point". The success of the operation and some postoperative complications, in fact, may depend on the nail entry point into the humerus.

Due to the action of the muscles inserted in the proximal humerus, bone fragments can be diastased and, if there are many fragments, it becomes more difficult for the surgeon to reduce the fracture and determine the correct "entry point" (Fig. 2).

Regardless of the type of fracture, reduction remains the essential moment of the procedure. For more complex cases, it is possible and advisable to use surgical instruments to obtain a good reduction. K-wires can stabilize the fracture, but they can also be placed in the humeral head and used as a joystick to facilitate head rotation and entry point identification. In this way, the procedure becomes reproducible.

Once good reduction is achieved, in order to determine the entry point the surgeon has to identify the humeral diaphyseal axis, trochite, and supraspinatus footprint, but must also consider the type of fracture and the surgical device chosen, even if the different types of proximal humerus, with different offsets between the supraspinatus footprint and the humeral diaphyseal axis [19], which can make the procedure more difficult.

It is necessary to extra-rotate the proximal humerus until the greater tuberosity and the spherical shape of the head becomes clear, pointing out a profile similar to a "beetle car". In the most complex cases, it is possible to place a K-wire in the head, in an antero-posterior direction and with an inclination of about 30°, to extra-rotate the proximal humerus until the "beetle car" image is reached; furthermore, other K-wires can be used to stabilize the greater tuberosity.

Now, we can establish the entry point with a three-dimensional way, by placing a K-wire in a vertical position on the first two planes of the space, checking the third by easily intra-rotating the head. If we consider the humeral head as a sphere, with a K-wire placed horizontally, it is possible to change the rotation of the humerus and confirm the correct position in the third plane.

Regarding the surgical approach, we prefer to adopt a percutaneous technique, choosing a medial entry point, moving towards the muscular portion of the supraspinatus. This precaution reduces muscle damage and permits complete healing of the tendon in a short time, as demonstrated during the procedures of surgical nail removal or with MRI. However, different approaches are possible, both in percutaneous and mini-open accesses.

An incorrect entry point can cause an increased risk of intra- and postoperative complications. The most frequent are:

- lesion headset rotators: the action of the subscapularis muscle often leads to internal rotation of the proximal part of the humeral head, with a complicated definition of the correct position. One of the risks is to place the K-wire and then the manual cannulated awl far too laterally, damaging the tendon footprint in the most delicate area, with a reduced chance of healing. Kralinger et al. [20] demonstrated that a safe distance between the nail and the insertion of the supraspinatus tendon is at least 8 mm (considering a proximal reaming for the 10 mm nail). A more medial entry point allows to preserve the tendon insertion, which has lower reparative capabilities, and access towards the muscular portion. Boileau et al. excluded any clinical repercussion on the articular surface because at that level the chondral humeral surface does not come into contact with the glenoid [21];
- tuberosity fractures: if the entry point is too lateral or if the chosen nail has a proximal diameter that is too large compared to the fractured humerus, the greater tuberosity is most frequently involved;
- malunion: in the literature, several studies have demonstrated that choosing an incorrect entry point can lead to secondary breakdown of the fracture fragments, negatively influencing the result of surgery [22]. In addition, an entrance that is too lateral can produce poor alignment of the head, which is poorly tolerated by patients and is related to worse clinical results [23];
- subacromial conflict: the choice of a too lateral entry point can cause impingement. During surgery good vision with an image intensifier is required, to ensure that the nail sinks up to the subchondral bone;
- nonunion: although this is mainly related to features that do not concern surgery (such as smoking, bone quality, type of fracture, comorbidity, etc.), there are still some tips to consider. A synthesis with diastasis of the fragments is inadvisable, particularly near the surgical neck. This may also occur with a nail with a distal diameter that is too large. The choice of a thin nail, with a low proximal profile and with various options for screw placement can help the surgeon by expanding the range of options in the synthesis;
- loss of proximal fixation: before performing surgery, it is mandatory to reach a good reduction of fragments. Otherwise, an unreduced fracture is not synthesizable with an intramedullary nail and can lead to poor functional results. However, other factors need to be considered once the reduction is achieved. If the bone stock quality is poor (frequent in elderly patients), one consequence is the risk of mobilization of screws if they are subjected to excessive stresses. To guarantee good fixation and avoid screw mobilization, it is advisable to use screws with thread-like features similar to cancellous bones and angular nail-screw stability, especially if they have a multiplanar direction (divergent) [24]. It must also be considered that the rupture forces of the proximal bone fragments of the humerus are horizontal and that the action of the supraspinatus and infraspinatus muscles causes displacement of the greater tuberosity (superiorly, medially and posteriorly), while the subscapularis displaces the lesser tuberosity (upward and medially). It would be optimal to be able to stabilize the fragments with screws applied perpendicular to the fracture gap, in order to have a more stable fixation, and thus the ideal osteosynthesis device should allow the surgeon to place screws in different planes and with multiple options;
- screw protrusion through the joint: this is a complication that in the majority of cases has to be handle with a reintervention. If there is loss of reduction or avascular necrosis, the protrusion may involve the joint, causing chondrolysis of the glenoid surface, irreversibly damaging the glenohumeral joint. Surgeons need to correctly position screws to ensure a stable fixation and adequate checks with an image intensifier, which investigate every plane, and help to avoid unpleasant surprises in the postoperative period;
- soft tissue damage: this is an important complication is the damage of the circumflex nerve while positioning the lateral screws of the intramedullary nail. To avoid this event, it is important to keep a safe distance from the acromial margin, quantifiable in 4-5 cm. Furthermore, it might be possible to damage the long head of the brachial biceps, either with the cannulated awl (in case of incorrect entry point) or with the anterior screw (if a careful check of arm and nail rotation is not done before screw placement);
- nail-bone malrotation: this can also lead to a malrotation of the head compared to the diaphyseal axis after fracture fixation. Often the mistake consists in positioning the distal screw while the arm is in a complete intra-rotation. The nail should be internally rotated about 20° compared to the shoulder in neutral rotation, according to the retroversion angle of the humeral head. Nail features and surgical technique (in particular a good choice of the entry point) are the most important factors in predicting the result of surgical intervention.

Conclusions

In our experience, intramedullary nailing seems to be a safe and effective option for the treatment of proximal humerus fractures. The complication rate reported in our study is lower compared to those reported in the literature. Furthermore, the need for reoperation is infrequent and always linked to a cut-out of the screw, which can be treated with a brief surgery, aiming only to reposition the affected screw.

During surgery it is crucial to choose the right entry point when placing the nail: failing at this level can lead to intraoperative and postoperative complications, in addition to worse clinical outcomes.

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