Antegrade Intramedullary Nailing in Humeral Shaft Fractures

P. Dimakopoulos
M. Papas
A. Kaisidis
A. Panagopoulos
E. Lambiris

Abstract

Purpose: To evaluate union time and functional recovery of the shoulder joint in humeral shaft fractures treated with intramedullary nailing.

Material and Methods: During the period 1990–2001, 43 patients with humeral shaft fractures were treated with intramedullary nailing. 38 patients (21 males and 17 females, mean age 48 years) were available at the final follow-up evaluation after 21 months on average. In 25 patients the entry point was below the greater tuberosity to avoid rotator cuff injury and in the other 18 patients the entry point was intra-articular. Passive shoulder and elbow motion was allowed from the second postoperative day followed by active assisted exercises from the second postoperative week. Union progress was assessed radiologically at 2nd, 4th, 8th, and 16th postoperative week whereas final shoulder function was evaluated using the parameters of the Constant-Murley scoring system.

Results: Solid callus formation was noted in all fractures, except one, between the 8th and 35th postoperative week. Patients with extra-articular application of the nail had full passive shoulder motion between the 2nd and the 4th postoperative week whereas patients with intra-articular application had delayed passive shoulder motion and final functional limitation. Seven patients had painful shoulder motion 3 months postoperatively. There were 4 patients with transient radial nerve palsy, who demonstrated full functional recovery after 3 to 6 months and 3 patients with proximally migration of the nail underwent reoperation.

Conclusions: Intramedullary nailing in humeral shaft fractures seems to be a reliable method of treatment regarding union and functional recovery. Advantages are shorter operative time, minor blood loss, small incision with shorter soft tissue detachment and early mobilization of the shoulder, especially in the patients with extra-articular nail application without rotator cuff injury.

Key words
Intramedullary nailing · humeral shaft · fractures · entry point

Fractures of the shaft of the humerus account for approximately 3 % of all fractures of the skeleton and are preferably treated non-operatively, with a functional orthosis. Function of the upper extremity after closed treatment was not usually affected by as much as 20 degrees of anterior angulation, 30 degrees of varus angulation and 3 cm of shortening of the humeral shaft [12]. Since several reports [1, 21] have already shown the consistent success of non-operative treatment, with resultant excellent alignment, early restoration of joint motion and minimal morbidity, closed treatment of humeral shaft fractures remains the gold standard unless specific indications for operative intervention exist. Open reduction and internal fixation of humeral shaft fractures should be considered for [3, 5, 23]:

- Unacceptable alignment with conservative measures and inability to maintain reduction due to obesity, intolerance of orthosis, prolonged recumbency and specific fracture patterns (segmental, comminuted, Holstein and Lewis spiral type).
- Patients with multiple trauma.
- Bilateral fractures.
- Open fractures.
- Pathological fractures.

Affiliation
Orthopaedic Department of Patras University Hospital, Patras, Greece

Correspondence
Panayotis Dimakopoulos M.D. · Orthopaedic Department · Patras University · Papanikolaou str. · 26500 Rio-Patras · Greece · Phone: +30/26-10-99 95 51 · E-mail: andpan21@medscape.com

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- Ipsilateral associated injuries of the extremity (floating elbow or shoulder).
- Spinal cord and brachial plexus injuries.
- Fractures associated with major vascular injuries.
- Progressive or new onset of a radial nerve palsy after the beginning of non-operative treatment.

In these situations, the surgeon can choose from a variety of methods including external fixation, compression plating and intramedullary nailing.

In this paper a modification of the entry point of antegrade intramedullary nailing is presented. The indications for surgery, overall operative technique, postoperative rehabilitation, physiotherapy protocol and final results are discussed also.

Material and Methods

During the last 10 years (1990–2001), 43 of 97 patients with humeral shaft fractures underwent antegrade, proximally locked, intramedullary nailing in our Department. There were 21 male and 22 female, average age 48 years (range 17 to 82). A case documentation form was used for peri-operative data, including age, gender, mechanism of injury, type and location of fracture according to AO/ASIF classification (Tables **1**, **2** and **3**). There were 4 cases with preoperative radial nerve palsy who underwent surgical exploration.

Patients were followed-up at 2 to 4 week intervals for the first 4 months and at 1-year intervals thereafter. Fracture healing was assessed clinically and radiologically. Radiological fracture healing was defined as the presence of bridging callus and indefiniteness of the fracture line on normal antero-posterior and lateral views. The Constant-Murley scoring system was used at the last clinical assessment of shoulder motion. Mean follow-up period was 21 months (ranged 6–120 months).

Table **1** Type of initial injury

Type of injury	*No. of patients*
fall	26
traffic accident	16
gunshot	1
pathological fracture	5

Table **2** Type of fracture

Type of fracture (AO classification)	*No. of patients*
A	17
B	12
C	9
pathological	5

Table **3** Location of the fracture

Location of fracture	*No: of patients*
proximal	12
middle	22
distal	9

The indications for operative treatment were:
- 18 fractures with unsatisfactory reduction after closed treatment,
- 16 fractures in multitrauma patients,
- 4 non-unions after closed treatment,
- 5 pathological fractures (due to metastatic or primary tumor).

Operative technique

a) Patient positioning and preparation: With the patient supine, in the beach chair position, the head was turned to the contralateral side to increase exposure of the shoulder. Rotational alignment was obtained by placing the shoulder in an anatomical position and rotating the distal fragment so that the arm and hand were pointing toward the ceiling and the elbow was flexed at 90 degrees. Preparation and draping of the patient included the operative field of the shoulder proximal to the nipple line, the midline of the chest to the nape of the neck, and the entire extremity to the fingers.

b) Approach and preparation of the humerus: A standard longitudinal skin incision (3 to 5 cm) from the most lateral point of the acromion was used, centered over the tip of the greater tuberosity. Incision of the fascia, longitudinal splitting of the deltoid and palpation of the greater tuberosity were the next steps. With the small curved awl, the entry portal site was established in two different ways: 1) next to rotator cuff insertion or intraarticular (Group A) and 2) 1 cm below the tip of greater tuberosity (Group B) (Fig. **1**). Advancement of the curved awl was confirmed by image intensification. (The entry portal should be centered on anteroposterior and lateral views to ensure that the nail will be in the midplane of the humerus.)

c) Guide rod insertion: Withdrawal of the curved awl was followed by the 2.4-mm, ball-tiped reamer guide rod insertion.

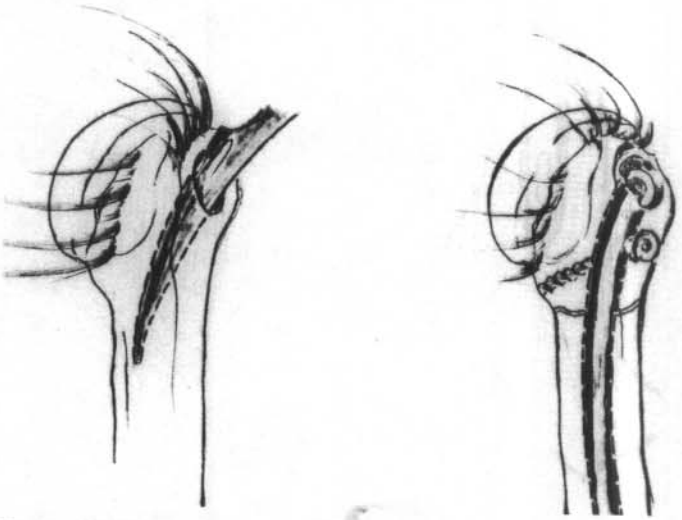

Fig. **1** Modification of the entry point. The curved awl is inserted 1 cm below the greater tuberosity to avoid rotator cuff damage.

Bending of the tip of the guide rod facilitates reduction of the fracture. The rod was advanced down to the medullary canal at about 1 to 2 cm proximal to the olecranon fossa and the correct placement was confirmed by image intensification. In some cases an open reduction at the site of the fracture was considered necessary for the insertion of the guide rod.

d) Determination of nail length: Proper nail length was verified with the guide rod method: with the distal end of the rod 1 to 2 cm proximal to the olecranon fossa, a second guide rod was overlapped extending proximally from the humeral entry portal. Subtracting the length (in millimeters) of the overlapped guide rod from 500 mm one can determine with accuracy the correct length of the nail.

e) Limited proximal reaming: The proximal metaphysis of the humerus was reamed to a diameter of 10 mm, for approximately 4 cm, to enlarge the medullary canal.

f) Nail insertion: With the guide rod in place the nail was advanced gently over it to the fracture. Confirmation of fracture reduction with image identification is always necessary in this step, followed by gently passing of the nail to the distal fragment and removal of the guide rod. Finally, the nail was impacted 1 to 2 cm proximal to the olecranon fossa (Fig. **2**). This impaction of the nail in the narrow distal medullary canal is very important, provided that an accurate measurement of nail length has been made, so there is no need for distal locking in most of the cases. This impaction of the nail ensures rotational stability.

g) Proximal interlocking: The nail was locked proximally with one 4-mm locking screw, using the proximal drill guide, which allowed adjustment of the screw angle to 20 degrees to obtain the best purchase in the cortical bone of the medial humeral metaphysis.

After treatment: A posterior plaster splint and collar-and-cuff are worn for 2 to 3 days. Passive range-of-motion including pendulum and assisted forward elevation exercises initiated from the 2nd postoperative day until the 2nd postoperative week, followed by active assisted exercises (forward elevation and external rotation) until the 4th postoperative week and finally active dynamic shoulder motion and strengthening exercises until the 8th to 10th postoperative week.

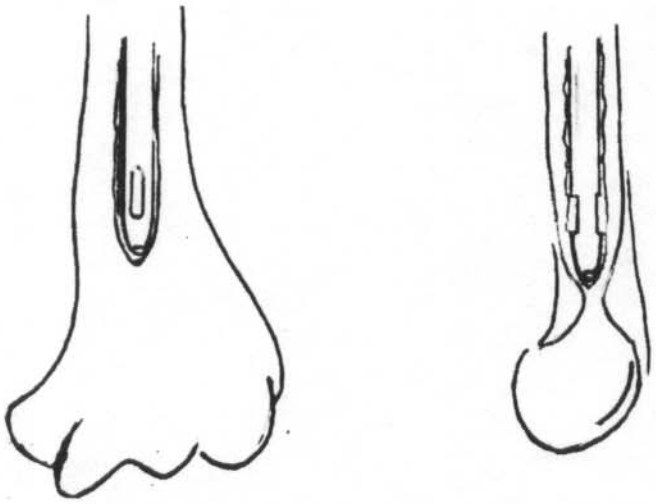

Fig. **2** Modification of the distal impaction of the nail. No distal interlocking is used. The nail is advanced 1 to 2 cm into the olecranon fossa to ensure rotational stability.

Results

Forty-three patients with humeral shaft fractures, underwent antegrade, proximally locked, intramedullary nailing in our Department the last 10 years (1990–2001). There were 21 male and 22 female, average age 48 years (range 17 to 82 years). The mean operative time (skin to skin) was 60 minutes (range 40–95 min) and the mean estimated intra-operative blood loss 0.4 units. In three patients the nail was applied without locking. The other 40 patients underwent proximal locking of the nail. Limited proximal reaming of the humerus shaft was considered necessary in 24 cases, whereas in 16 cases an open reduction of the fracture was unavoidable (Table **4**). Two different groups of patients can be distinguished relative to the entry point of the nail in the proximal humerus. In Group B (18 pts.) the nail was inserted intra-articular (2 pts.) or near the rotator cuff insertion medial to the great tuberosity (16 pts.). In Group A (25 pts.) there was a modification of nail insertion; 1 cm below the great tuberosity avoiding rotator cuff damage. Distally locking was performed in only one patient. Another modification was made relative to the nail impaction at the olecranon fossa. After accurate measurement of nail length, using the guide rod technique, the nail was carefully impacted in all patients 1 to 2 cm into the olecranon fossa, obtaining rotational stability of the fracture and no need for distal locking. Four patients with preoperative radial nerve palsy underwent nerve exploration at the time of fracture fixation. In two cases entrapment of the nerve was found at the fracture site. The postoperative rehabilitation protocol was modified with the use of special functional braces for radial nerve palsies, preserving the wrist and fingers extension. Full nerve recovery was seen in all there patients within 3 to 6 months post injury.

Thirty-eight patients were finally available for the outcome analysis. The mean follow-up period was 21 months. 5 patients were lost from the last follow up evaluation (3 with pathological fractures). Thirty-seven fractures (97%) showed solid callus between the 2nd to 4th postoperative month. Union was obtained from the third postoperative month in 70% of the fractures (type B2, B3, C1–C3) whereas delayed union until the 6th postoperative

Table **4** Details of the operative technique

Details of the operative technique	*No. of patients*
locked nails	40
proximal	39
distal	1
unlocked nails	3
reamed	24
unreamed	19
open reduction	16
closed reduction	27

month was seen in 2, A3 type fractures. The overall mean time of union was 3.5 months (Figs. **3** and **4**).

Complications included 3 proximal migrations of the nail, 1 intraoperative supracondylar humerus fracture and 1 delayed union. Two elderly patients with proximal migration of the nail due to proximal interlocking screw loosening were treated with removal of the nail in one case (Fig. **5**) and revision of the proximal locking and application of Sarmiento cast in the other. The third patient, in whom migration was attributed to the inability of proximal locking at the first operation, was treated with revision of the nailing at the 12th postoperative week. In the case with the supracondylar fracture a Sarmiento cast was applied for 4 weeks whereas the case with the delayed union underwent open reduction and internal fixation of the fracture with plate and screws.

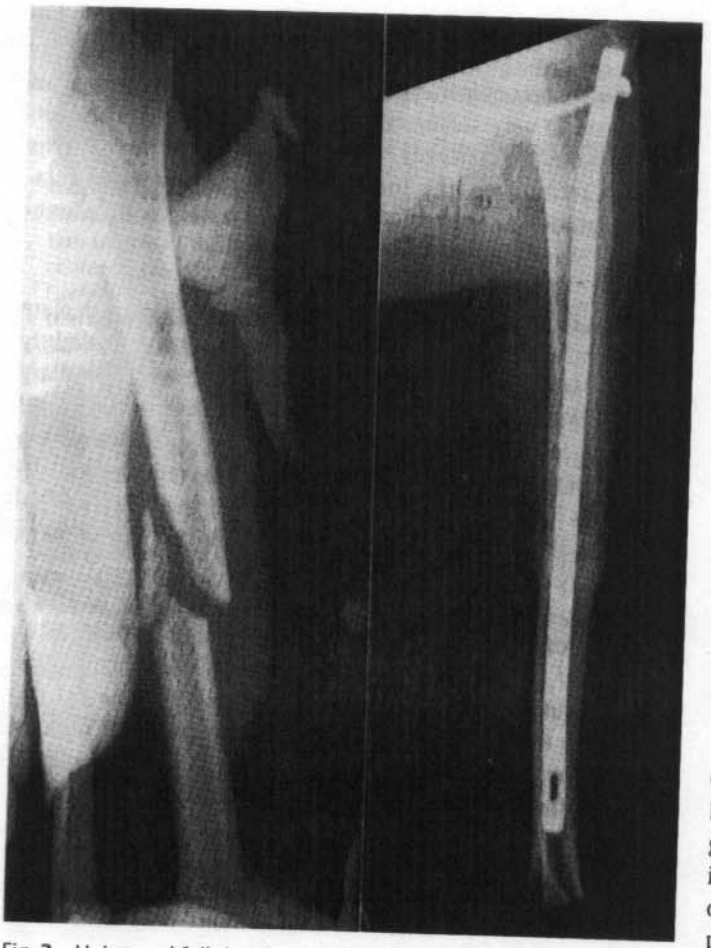

Fig. **3** Union and full shoulder motion after 4 months postoperative.

Assessment of shoulder function, using the Constant-Murley scoring system, was performed at the 2nd, 4th, 8th and 16th postoperative week. There was significant difference in shoulder function between group A and B (Table **5**). The patients in group A (entry point below the greater tuberosity) showed excellent shoulder function and only 6 patients had minor complaints after the 16th postoperative week. On the other side, patients of group B (entry point near the rotator cuff or intra-articular) had significant pain problems of the shoulder and 4 of them demonstrated clinical symptoms of subacromial impingement due to proximal migration of the nail. Three of these cases, that are already mentioned above, underwent reoperation.

Discussion

Stable internal fixation of upper arm fractures enabling early active functional treatment is enjoying growing popularity. The use of external fixation in humeral shaft fractures should be restricted to injuries with severe soft tissue compromise or loss [22, 24].

Compression plate fixation is considered as the gold standard for humeral shaft fractures and can be performed for any of the surgical indications, listed in the introduction of this paper. Before intramedullary nails became widely used, plate fixation was the only surgical option available. If the stabilization procedure is performed properly, the rate of union is high and the rate of mechanical, infectious or neurovascular problems is low [2, 6, 18].

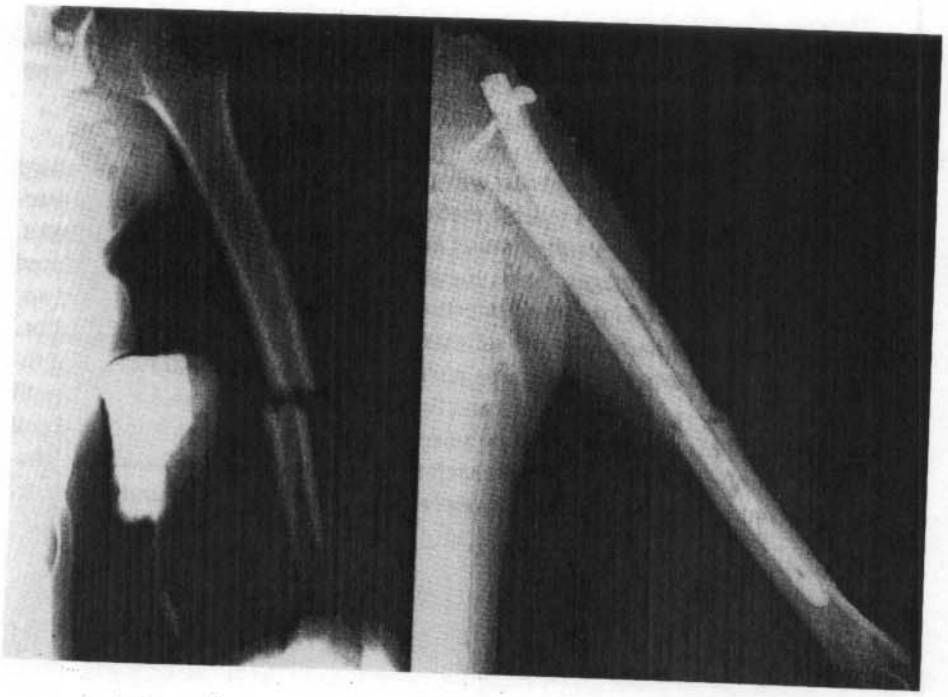

Fig. **4** Union and full range of motion after 3.5 months postoperative.

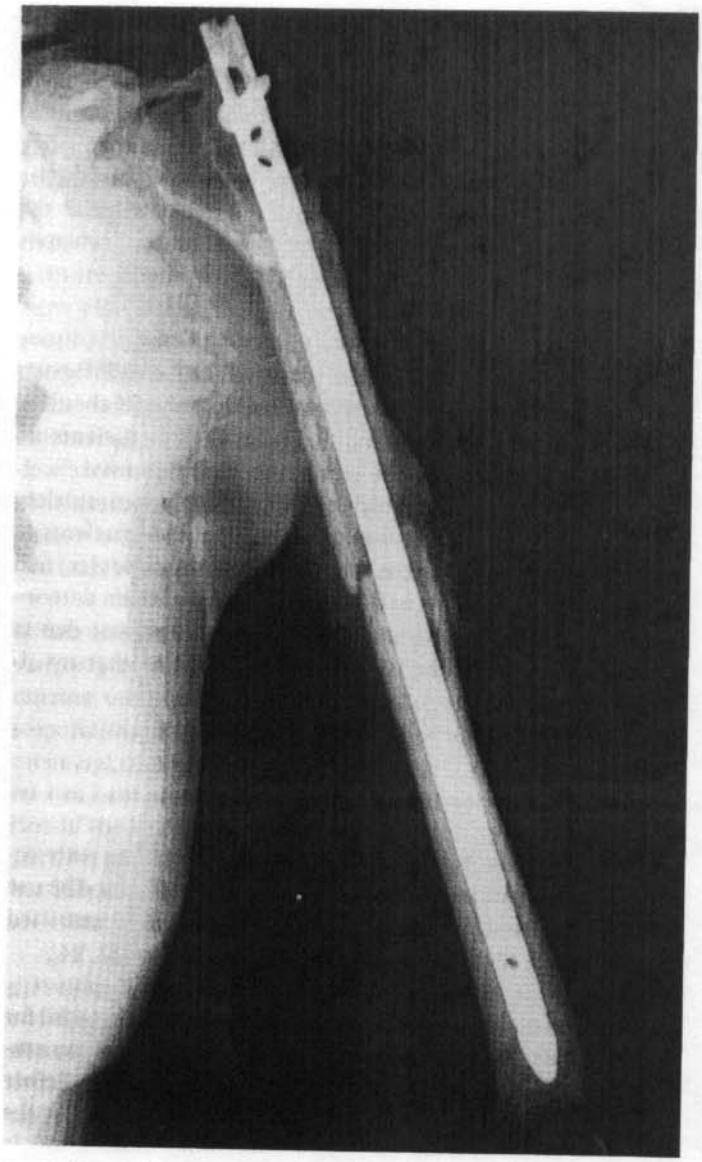

Fig. 5 Proximal migration of the nail with clinical symptoms of impingement syndrome of the shoulder. The patient underwent exchange intramedullary nailing.

Table 5 Mean Constant-Murley score in the two groups

Time from operation	*Group B (25 pts.)*	*Group A (18 pts.)*
2nd week	86 (satisfactory)	79 (poor)
4th week	92 (satisfactory)	83 (satisfactory)
8th week	96 (excellent)	86 (satisfactory)
16th week	98 (excellent)	88 (satisfactory)

The reasons behind the lower popularity of compression plate fixation during the last years include difficulties with the surgical exposure, the concern about radial nerve injury and technical aspects of plating.

Experience with non-interlocked intramedullary implants, such as Ender nails or Rush pins showed that this technique is possible and reasonable [8, 9, 13]. Intramedullary fixation for humeral shaft fractures has gained popularity in recent years for many reasons including improved image intensification, relatively percutaneous insertion techniques, the need for proficiency in plate application and the overall good results with intramedullary nails for fractures of the other long bones. In comparison with compression plate fixation, intramedullary nailing surmounts to lesser operative time, no need of any external support, reduced blood loss, low infection rate and early recovery of function.

Literature reports of intramedullary nailing differed from great enthusiasm to very strong criticism [13–17, 19, 20]. This critism was based on concerns regarding the type of the nail, the insertion techniques, the inability to achieve rotational stability, migration of the nail and problems with shoulder function.

Several studies have directly compared the results between plate fixation and antegrade intramedullary nailing showing a slightly increased rate of complications associated with intramedullary nailing primarily related to a substantial increase in functional symptoms, such as shoulder pain and stiffness [4, 7]. Retrograde insertion of the Russell-Taylor nail proved to be reliable, but disadvantages include the bulky targeting device, the solitary interlocking possibility proximally and distally, and the lack of interfragmentary compression [10, 11].

In this retrospective clinical study, two major modifications in the surgical technique of antegrade intramedullary nailing are under consideration. The first is the entry point of the nailing; 1 cm below the greater tuberosity to avoid rotator cuff damage and the second is the distal impaction of the nail into the olecranon fossa, after accurate measurement of its length, to ensure rotational stability.

Comparing our first cases (Group A) in which an intra-articular insertion of the nail had been done with the later ones (Group B) in which the extra-articular application of the nail was selected, we ascertain similar union rates but significant differences in shoulder motion, migration of the nail and final rehabilitation. Most of our complications concerning nail migration, decreased shoulder motion and impingement syndrome were noted in the first group.

We concluded that antegrade, proximally locked, intramedullary nailing is a reliable method of treatment for humeral shaft fractures, regarding union and functional recovery of the shoulder. Advantages of this method are shorter operative time, reduced blood loss, lower infection rate, smaller incision and surgical approach, minimal soft tissue detachment and early mobilization. When an antegrade nailing is performed, an extra-articular insertion of the nail at a lower entry point, preserving rotator cuff tendons, should be selected. Accurate measurement of the nail length and firm impaction of it at the olecranon fossa made distally interlocking unnecessary, decreasing significantly the overall operative time.

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