

## Antegrade interlocking nailing of humeral shaft fractures

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**Abstract** The results of 39 humeral shaft fractures (37 patients) treated with antegrade locked nailing using a Russell–Taylor nail were reviewed. There were 30 acute fractures, 6 fractures malaligned in a hanging cast or brace, and 3 pathological fractures. Patient age ranged from 26 to 80 years (average, 59.7 years) and average follow-up was 25.7 months (range, 6–48 months). Fracture union was achieved in 92.3% of our cases, while shoulder function was excellent or good in 87.2% of cases. Antegrade locked nailing offers a dependable solution for the treatment of humeral shaft fractures, especially in polytrauma patients and cases of segmental or pathological fractures. Far less satisfactory results were obtained in comminuted fractures of the proximal third in the humerus, especially in osteoporotic patients, and we therefore advocate caution with the use of intramedullary nailing in this type of fracture. Certain technical aspects such as avoiding nailing the fracture in distraction, properly countersinking the tip of the nail, and achieving adequate fixation stability have been found to be of paramount importance to reduce the incidence of delayed union/non-union rate and to obtain better functional results from the shoulder joint.

**Key words** Humeral shaft fractures · Antegrade locked nailing

### Introduction

The majority of humeral shaft fractures can initially be treated conservatively, with a reported rate of success greater than 90%.<sup>30,31,33</sup> Indications for surgical intervention include open fractures, vascular injury, progressive radial nerve palsy, polytrauma patients, bilateral frac-

tures, concomitant fractures in the ipsilateral upper extremity, associated burns, obese patients, certain transverse, segmental, and spiral fractures without bony contact due to potential soft tissue interposition, pathological fractures, and inability to achieve or maintain satisfactory reduction.<sup>12,15,17,23,26,29–32</sup> Locked intramedullary nailing and plate fixation are the most popular operative options. In theory, humeral fracture fixation with locked intramedullary nailing offers an appealing solution, as it is less invasive, has a superior biomechanical behavior, especially in osteopenic bone, and provides autograft material through reaming.<sup>6,14</sup> Although numerous reports and comparative studies have provided inconsistent results, there is a growing interest in the use of locked intramedullary nailing for the treatment of humeral shaft fractures because of its proposed biomechanical and biological advantages, coupled with the recent technical advancements in the implants used.<sup>5–9,12,16–18,22,24,29,32</sup>

### Patients and methods

During the period between March 1999 and December 2002, 40 patients with 42 humeral shaft fractures were treated surgically with reamed intramedullary nailing in our department, using a Russell–Taylor humeral nail (Smith & Nephew, Richards, Memphis, TN, USA). The Russell–Taylor humeral nail is designed with a built-in proximal offset, allowing its safe insertion laterally to the articular surface of the humeral head and just medially to the tip of the greater tuberosity. It allows for proximal lateral-to-medial locking with one screw that can be inserted at a variable angle adjusted by as much as 20°, and for distal anterior-to-posterior locking, in an effort not to endanger the adjacent neurovascular structures.

All humeral nails were inserted through an antegrade approach with the patient in a deck-chair position

through an anterolateral deltoid-splitting approach. Fracture reduction was aided by C-arm image intensification and was performed closed in all but 2 patients. Proximal locking with one screw was performed in every case using the targeting device; distal locking was decided depending upon fracture pattern and was performed with a freehand, image intensifier-assisted technique in 27 cases. All nails were 8 or 9 mm wide, and nail length ranged from 20 to 28 cm.

Thirty-seven patients with 39 fractures were followed up for a minimum period of 6 months (range, 6–48 months; average, 25.7 months) and were included in this study. Our patient population consisted of 25 women and 12 men with an average age of 59.7 years (range, 26–80 years). The mechanism of injury was a road traffic accident in 14 cases (35.9%), falling from a height in 7 cases (17.9%), and falling on an outstretched arm in the remaining 18 cases (46.2%) (Table 1).

Thirty acute humeral fractures were operated upon within a week after the initial injury (range, 1–8 days), and 6 were operated following an unsuccessful attempt of conservative treatment (range, 2–4 weeks following the initial injury). The remaining 3 fractures were pathological, 2 caused through lytic lesions of a multiple myeloma and 1 through a metastatic lesion of a lymphoma. Five of our patients were polytrauma patients, having sustained either concomitant head or chest injuries or other severe musculoskeletal injuries (Fig. 1).

Fractures were classified according to the AO classification; 20 fractures were type A (6 type A1, 7 type A2,

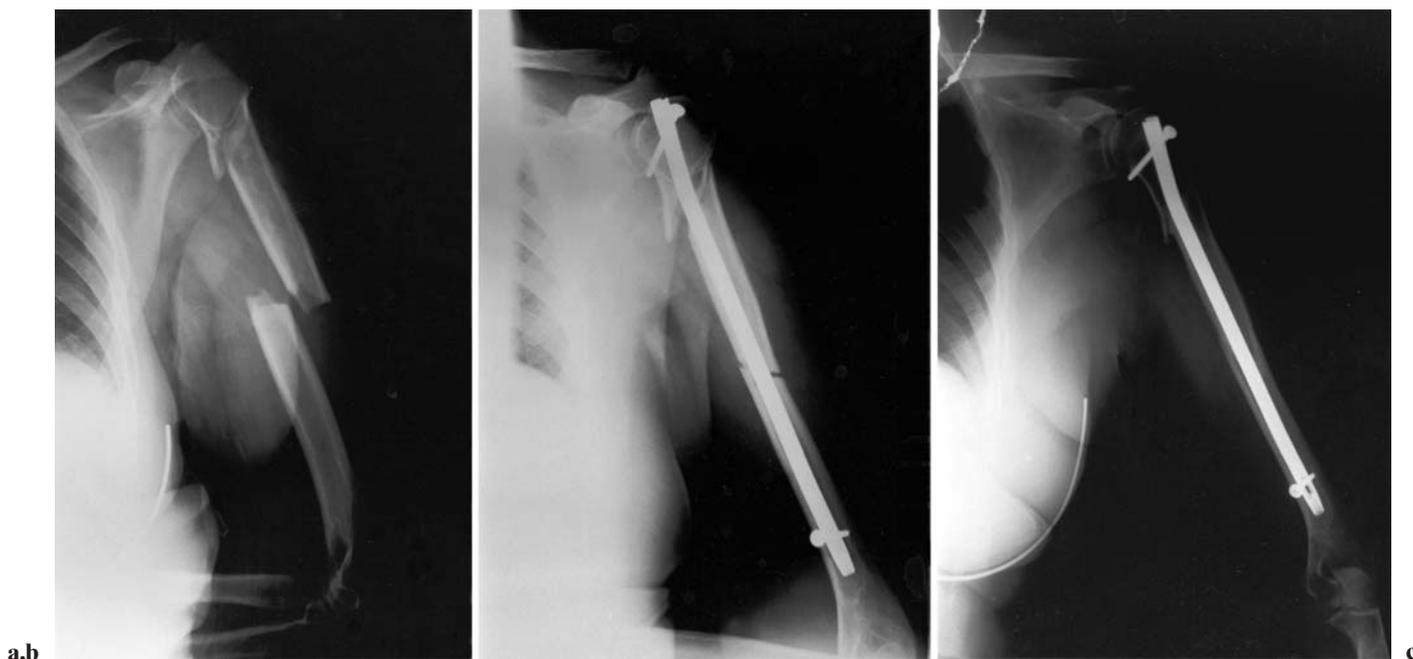
and 7 type A3), 17 fractures were type B (10 type B1 and 7 type B2), and 2 fractures were type C (1 type C1 and 1 type C2) (Fig. 2). Twelve fractures were located in the proximal third of the humeral shaft, 22 in the middle third, and 5 in the distal third (Table 2). None of the fractures was open, and none of the patients included in this study had preoperative radial nerve palsy.

Postoperative regimen included pendulum exercises from the first postoperative day and active shoulder movement as soon as pain allowed. The patients were followed both clinically and radiologically 2, 4, and 6 months postoperatively and yearly thereafter. Union was assessed radiologically as the presence of bridging callus in three cortices seen on anteroposterior (AP) and lateral views in a fully functional arm. Cases of delayed union were those where union was achieved in >4 months,<sup>6</sup> whereas nonunion was defined as failure of the fracture to unite within 6 months.<sup>10</sup> Shoulder func-

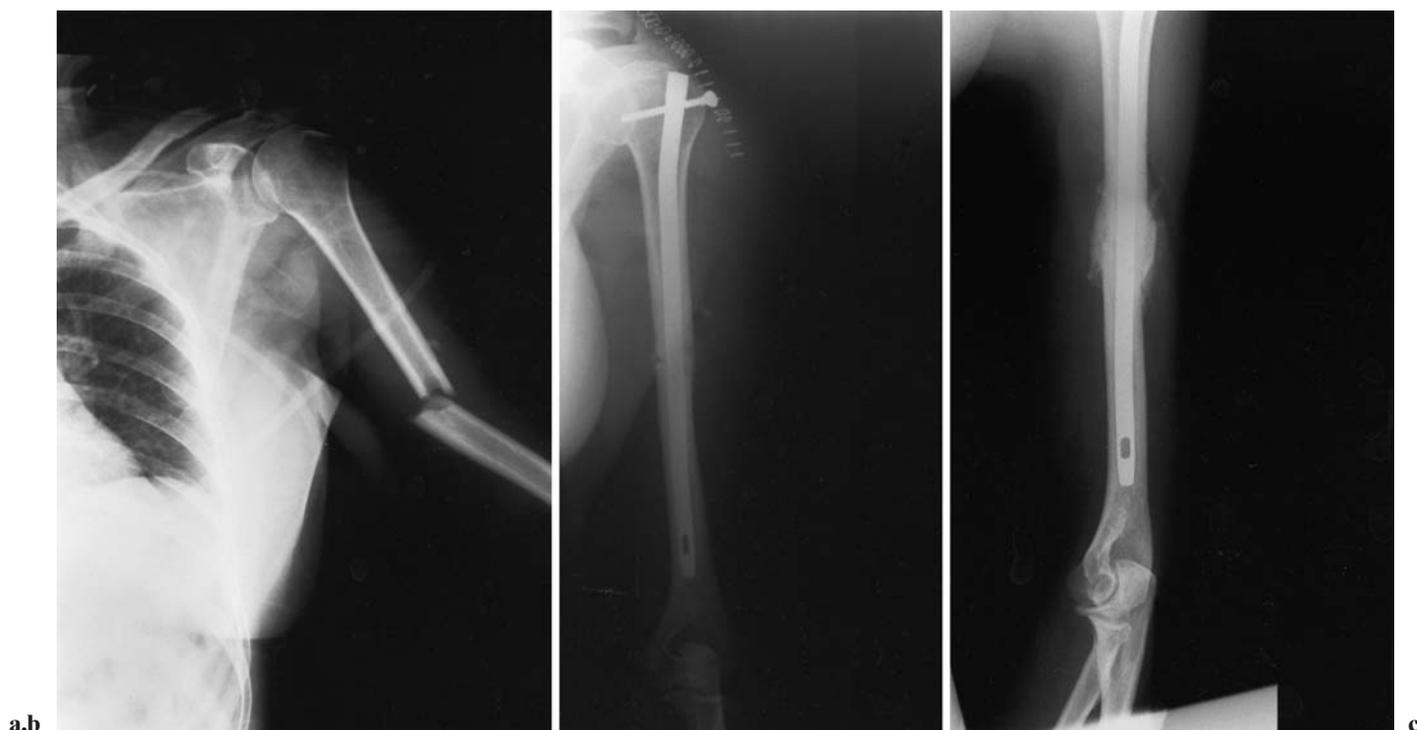
**Table 1.** Population

Patients (fractures)	37 (39)
Sex (male/female)	25:12
Age (average, range)	59.7 years (26–80 years)
Duration of follow-up (average, range)	25.7 months (6–48 months)
Fracture mechanism:	
1. Fall on outstretched arm	18 (46.2%)
2. RTA	14 (35.9%)
3. Fall from height	7 (17.9%)

RTA, road traffic accident



**Fig. 1.** **a** Preoperative radiograph of C2 type fracture in 58-year-old woman. **b** Postoperative radiograph following locked intramedullary nailing. **c** Radiograph 6 months postoperatively showing fracture union



**Fig. 2.** **a** Preoperative radiograph of A3 type fracture in 61-year-old female polytrauma patient. **b** Postoperative radiograph following locked intramedullary nailing. **c** Radiograph 4 months postoperatively showing fracture union

**Table 2.** Fracture classification

	Proximal third	Middle third	Distal third	Total
A1	2	2	2	6
A2	1	4	2	7
A3	2	5	—	7
B1	5	4	1	10
B2	2	5	—	7
B3	—	—	—	—
C1	—	1	—	1
C2	—	1	—	1
C3	—	—	—	—
Total	12	22	5	

tion was assessed with the Neer score.<sup>25</sup> According to this scoring system, which evaluates pain, function, range of shoulder motion, and anatomy, a result is considered excellent for a score >89 points, good for a score of 80–89 points, unsatisfactory for a score of 70–80 points, and a failure for a score of <70 points.

## Results

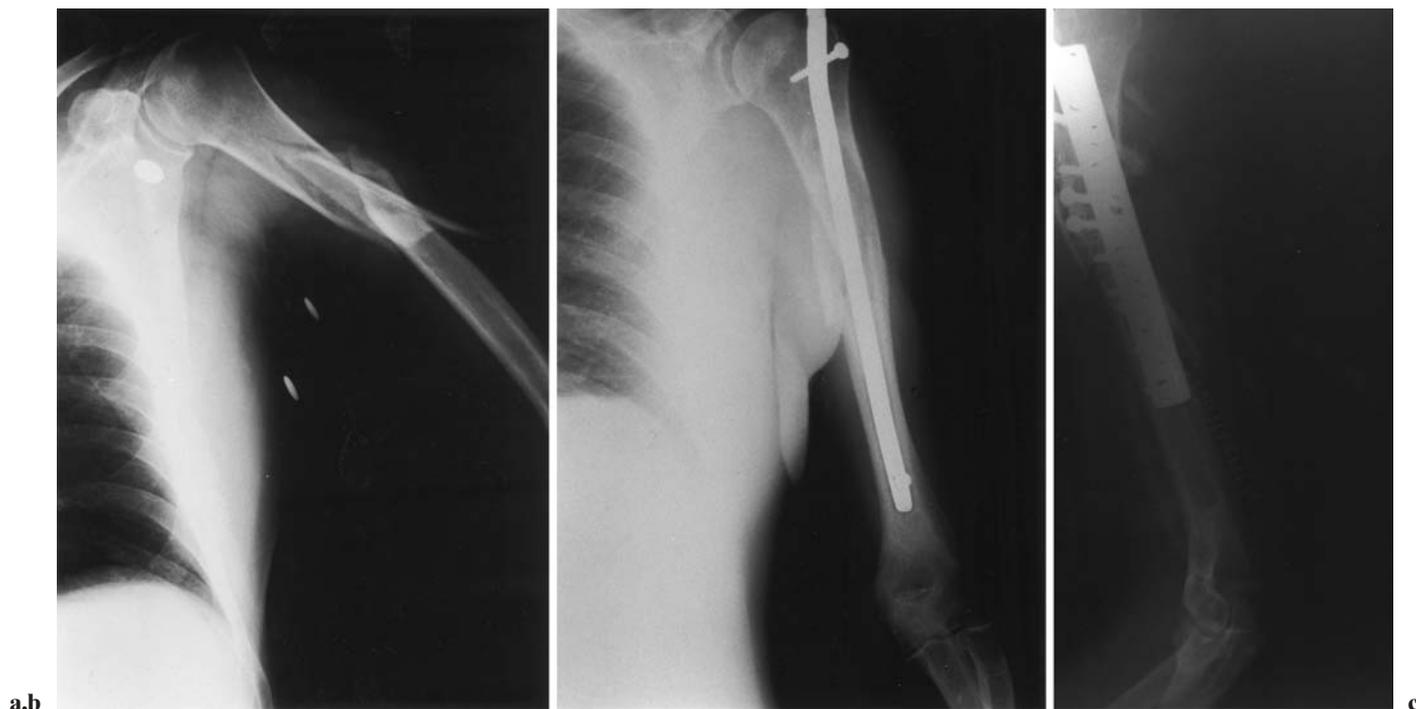
The majority of our patients were hospitalized for a period ranging from 2 to 8 days postoperatively; five

polytrauma patients who were included in this study were hospitalized for 10–19 days, thus bringing the average period of post-operative hospitalization to 6.1 days (range, 2–19). With the exception of the five polytrauma patients, no other patient required a blood transfusion following humeral nailing. X-ray exposure time during the procedure was less than 30s in all cases.

Union was achieved within 4 months in 33 cases (84.6%); 3 cases of delayed union (7.7%) and 3 cases of nonunion (7.7%) were recorded. Average time to union was 14.1 weeks (range, 11–33 weeks). All 3 cases of delayed union eventually united, bringing the overall union rate to 92.3%. Satisfactory function and pain relief as well as bony union were achieved in all 3 patients who had an intramedullary nailing following a pathological fracture (Table 3).

Shoulder function was assessed with the Neer score. In 15 patients (38.5%) shoulder function was excellent, in 19 patients good (48.7%); we had 3 unsatisfactory results (7.7%) and 2 failures (5.1%), bringing the satisfactory results (excellent and good) to 34 (87.2%). The mean Neer score was 84.3 (range, 28–97). Elbow range of movement was full and painfree in all patients (Table 3).

In all three patients who had an unsatisfactory result, the humeral nail was not countersunk properly or had backed out, resulting in a degree of subacromial im-



**Fig. 3.** **a** Preoperative radiograph of B1 type fracture in 68-year-old man. **b** Radiograph 4 months postoperatively showing pronounced proximal nail migration and pseudarthrosis

due to proximal locking screw missing. **c** Postoperative radiograph following nail extraction autologous bone grafting and internal fixation with a plate

**Table 3.** Results

Union:	
a. In <4 months	33 (84.6%)
b. Delayed union (union in >4 months)	3 (7.7%)
c. Nonunion (no signs of union in 6 months)	3 (7.7%)
Shoulder function (Neer score):	
a. Excellent	15 (38.5%)
b. Good	19 (48.7%)
c. Unsatisfactory	3 (7.7%)
d. Failure	2 (5.1%)
Neer score	84.3 (28–97)
Postoperative hospitalization	6.1 (2–19 days)
Complications:	
a. Transient radial nerve paresis	1
b. Delayed union	3
c. Nonunion → Reoperation	2

pingement, pain, and shoulder function compromise. Two of them had a delayed union, while one also complained of pain and tenderness on the lateral aspect of the humerus, ~5 cm below the tip of the acromion, at an area coinciding with the head of the proximal interlocking screw.

Of three patients who suffered a delayed union, one was male and two were female. They had a type A3 fracture of the middle third and a B1 and B2 fracture of the proximal third of the humerus, respectively. All

these fractures eventually progressed to union, but both proximal third fractures were associated with an unsatisfactory result. Both female patients were aged >65 and osteoporotic, and all three patients were heavy smokers, whereas two of three had the fracture nailed in overdistracted.

Both patients in the failure group had sustained a proximal third B1-type fracture, which resulted in nonunion and required a reoperation. The first one was a 62-year-old osteoporotic lady with painful pseudarthrosis accompanied by proximal nail migration and subacromial impingement; this was caused by poor grip of the proximal locking screw in the osteoporotic bone of the humeral head. The second patient was a 68-year-old man who also had a painful pseudarthrosis coupled with pronounced proximal nail migration and subacromial impingement. In this second case the proximal locking screw missed the hole of the nail, leading to pronounced proximal migration and pseudarthrosis resulting from the entailing inadequate fracture site stability. Both cases were successfully managed with nail removal and a subsequent open reduction, autologous bone grafting, and internal fixation with a plate.

It should be noted that of the seven proximal third B-type fractures in our series, four resulted in a nonunion or a delayed union and a functionally unsatisfactory result or a failure. There were no superficial or deep wound infections, and the only postoperative complica-

tion recorded was a case of transient radial nerve paresis that occurred in one of the two patients for whom we had to perform an open fracture reduction before nail insertion. The patient's symptoms resolved fully within a week.

## Discussion

Although the majority of humeral shaft fractures are still treated conservatively with a satisfactory rate of success, there is a growing tendency toward operative treatment, as prolonged plaster cast immobilization of the upper arm against the thoracic wall is becoming increasingly unpopular among both patients and surgeons.<sup>23,28</sup> This tendency has led to a progressive expansion of our indications for surgical treatment.<sup>12,15,17,23,24,26,28–32</sup>

When operative treatment is indicated, plate fixation probably still remains the primary choice of most surgeons, producing satisfactory functional results and union rate.<sup>15,23,30</sup> Comparative studies between plate fixation and intramedullary locked nailing have given contradictory results.<sup>5,17,22,24</sup> Plate fixation, however, has been associated with a higher iatrogenic nerve palsy rate, longer operating time, an increased need for blood transfusion, and possibly an increased infection rate.<sup>2,7,17,26</sup>

The theoretical advantages of minimal soft tissue trauma, fracture hematoma preservation, and superior biomechanical properties offered by closed interlocking nailing have recently made it increasingly popular among surgeons in the treatment of humeral shaft fractures. Additionally, intramedullary nails, being load-sharing devices, allow for safe and early motion, thus being more suited for polytrauma patients who require early mobilization.<sup>24,26</sup>

Although nailing is a well-established method in the treatment of tibial and femoral diaphysis fractures, its use in the treatment of humeral shaft fractures is still controversial. Many authors have reported very satisfactory results in the treatment of acute humeral shaft fractures,<sup>5,8,9,16–19,29</sup> pathological fractures,<sup>13,27</sup> humeral shaft delayed unions and nonunions,<sup>21</sup> or even humeral neck fractures<sup>20</sup> with locked nailing, while others still have serious reservations and recommend its use with caution.<sup>1,3,11,12,22,23,30,33</sup> Skeptics contend that notwithstanding its proposed biomechanical and biological advantages, antegrade intramedullary nailing of the humerus is associated with a considerable rate of complications and a high rate of nonunions.<sup>1,3,4,10–12</sup> Retrograde nail insertion has been proposed in an effort to eliminate the problem of shoulder pain and functional loss, but this has come at a cost of elbow joint stiffness and an increased danger of iatrogenic fractures.<sup>14,28,29</sup>

At this point, one should be reminded that the various types of intramedullary devices developed for the treatment of humeral shaft fractures differ significantly in both design and insertion technique.<sup>30</sup> Some humeral nails used in the past were far more rigid and insulting to the shoulder joint and the rotator cuff than more recent nail designs.<sup>14,30</sup> The use of various types of nails and surgical techniques may explain, to some extent, the significant variation in functional results reported in the literature. The Russell–Taylor humeral nail is designed with an built-in proximal offset, thus enabling its safe insertion just medially to the tip of the greater tuberosity with the least possible damage to the rotator cuff tendons. An ever-growing body of authors has recently presented very satisfactory results following antegrade locked nailing of humeral shaft fractures using modern nail designs. Lin et al.<sup>17–19</sup> Crates and Whittle,<sup>9</sup> and Ikpeme<sup>16</sup> have all reported union rates up to 100%, good shoulder function, and an acceptably low number of complications. It is believed that new, less-rigid nails, proper nail countersinking, and meticulous rotator cuff repair lead to improved shoulder function.<sup>9,18</sup> So far as fracture union is concerned, most authors believe that achieving adequate fixation stability and avoiding fracture overdistraction are of paramount importance to achieve high union rate.<sup>9,18</sup>

The greatest number of failures or unsatisfactory results in our series was associated with comminuted fractures of the proximal third of the humerus in osteoporotic patients. Insufficient proximal locking screw purchase in osteoporotic bone, coupled with proximal third comminution, often result in an unstable construct, which in turn may lead to delayed union or nonunion. A similar conclusion was drawn by Bernard et al.<sup>3</sup> regarding three-part displaced subcapital humeral fractures treated with intramedullary nailing. A more-rigid fixation construct is thought to be more suitable for comminuted proximal third fractures.

In conclusion, in this series of patients locked humeral nailing has offered a dependable solution for the treatment of humeral diaphysis fractures, providing a satisfactory functional outcome and a high union rate, allowing at the same time early use of the limb, which is of great importance, especially in multiple trauma patients and those having sustained a pathological fracture. Reservations have to be raised, however, as regards the use of humeral nailing in comminuted proximal third fractures, especially in osteoporotic patients. Certain technical aspects, such as proper countersinking of the proximal end of the nail, avoidance of overdistraction at the fracture site, and achievement of adequate fixation stability, must be given adequate attention in our effort to reduce delayed union and nonunion rates and to obtain better functional results.

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