Original Article

Humeral Interlocking Intramedullary Nailing without Image Intensifier in a Developing Country

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Abstract

Background: Interlocking intramedullary nailing under image intensifier has been a standard approach to surgical treatment of humeral fractures. **Aim:** We present the outcome of humeral interlocking nailing without image intensifier in a developing country. **Materials and Methods:** This is a prospective study of consecutive patients with humeral shaft fractures who were treated with Surgical Implant Generation Network interlocking nailing for humeral shaft fractures using an external jig system. They were followed up for at least 6 months if there was no evidence of fracture healing and restoration of functional activities. Data collected were processed with the Statistical Package for the Social Sciences and summarised in percentages and means. **Results:** Forty-five patients with 46 humeral shaft fractures were studied, with a mean age and standard deviation of 46 ± 14.6 years and male-female ratio of 1.8:1. At 3 months, 44 (95.7%) of the patients have had radiographic evidence of fracture healing. Over the same period, 35 (76.1%) of them had achieved shoulder abduction >90°, 37 (80.5%) had achieved painless shoulder flexion-abduction-external rotation movement and 42 (91.3%) had achieved full activities of daily living. **Conclusion:** In a resource-constrained population where image intensifier is difficult to come by, humeral interlocking intramedullary nailing could still be performed using external jig system with a satisfactory outcome.

Keywords: Developing country, external jig, humeral fracture, interlocking intramedullary nailing

Introduction

Humeral shaft fractures constitute about 3% of all fractures in adults.[1] The fractures can be treated non-operatively, with good results in most cases,[2] but nowadays, an all-encompassing approach to the care of patient is emphasised. Hence, the approach to the management of fracture of humeral shaft has changed from manual manipulation, splintage and prolonged immobilisation to internal fixation, which permits early joint mobilisation and return to normal activities of daily living (ADL) as early as possible.[3]

Treating humeral fractures by dynamic compression plate fixation or intramedullary nailing allows earlier mobilisation and rapid return to work.[3,4] Plate fixation provides satisfactory results, and it is a common operative modality for treating humeral shaft fractures in the developing world but has the disadvantage of long incision, excessive periosteal stripping, less stable fixation in an osteoporotic bone, increased risk of infection and iatrogenic radial nerve palsy.[5-8]

Interlocking intramedullary nailing has a number of relative biological and biomechanical advantages over plating, some of which include less invasive surgery, hence less blood loss,[4] undisturbed fracture hematoma (for close nailing), it uses a load-sharing implant,[9] it has less fatigue failure and less infection rate.[10]

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For efficient and effective performance of locked intramedullary fixation of long bone fractures, intra-operative image intensifier is usually required. However, in resource-poor environments like ours, an external jig system for nailing with or without an image intensifier is an option. Surgical Implant Generation Network (SIGN) nails were used in this study and were provided with the external jig.[11]

We hereby evaluate the treatment of humeral shaft fractures using interlocking intramedullary nails with external jigs without intra-operative image guidance.

Materials and Methods

This is a prospective study of consecutive patients with humeral shaft fractures who were treated with intramedullary interlocking nailing over a period of 5½ years between July 2014 and December 2019 in a Nigerian Missionary Teaching Hospital. The humeral shaft was defined as the part of the humerus, that is, 2 cm below the surgical neck and 3 cm above the olecranon fossa. Inclusion criteria were fractures within the above-stated boundaries. All open fractures were included irrespective of the Gustilo–Anderson Classification. Fractures outside the boundaries were excluded from the study. Informed consent was obtained from the patients and ethical clearance obtained from the ethical committee of the hospital.

Patients with fresh fractures had either closed reduction or reduction through about 3 cm incision for finger-assisted reduction, while those with non-union had a completely open reduction. In finger-assisted reduction, after making above-mentioned incision at the fracture site, it was deepened through the subcutaneous tissue and fascia, then with one finger, the muscles were split to access the fracture site. With traction and manual manipulation, the introduced finger was used to achieve fracture reduction, after which reaming was done to a step higher than the nail to be inserted. Internal fixation with SIGN® standard interlocking nails and SIGN® intramedullary fin nails using an external jig system [Figure 1a and b] without an image intensifier was performed for all of them [Figure 2a and b]. Both antegrade and retrograde approaches were utilised. Compression at the fracture site was achieved manually and bone grafting performed where necessary. All the surgeries were performed by two surgeons.

Antibiotics were administered for 5 days or longer in case of open fractures or other injuries. The patients were followed up clinically and radiographically according to SIGN follow-up protocol for at least 6 months if there was no evidence of fracture healing and restoration of functional activities.

Data collected were processed with the Statistical Package for the Social Sciences (IBM SPSS Statistics for Windows version 16, Armonk, NY, USA: IBM Corp.) and summarised in percentages and means. $P = 0.05$ was considered statistically significant.

Results

Forty-five patients with 46 humeral shaft fractures were included in this study. The age range of the patients was from 20 to 75 years, with a mean age and standard deviation of 46 ± 14.6 years. Twenty-nine of them were male, whereas 16 were female, giving a male-female ratio of 1.8:1. The major cause of the humeral fractures was road traffic crash (36 [80%]). Others (9 [20%]) included fall and assault. Twenty-five (54.3%) of the fractures involved the right humerus, whereas 21 (45.7%) involved the left. Forty-four (95.7%) of the fractures were closed, whereas two (4.3%) were open fractures. The open fractures were Gustilo–Anderson IIIA. Thirty-two (71.1%) patients presented with isolated humeral shaft fractures, six (13.3%) had associated head injury, three (6.7%) had associated soft-tissue injury and four (8%) presented with multiple fractures. Twenty-six (57.8%) patients had no previous treatment for the fracture, 11 (24.4%) had previous traditional bone setters' (TBS) treatments, four (8.9%) had cast application and two (4.4%) had open reduction and internal fixation (ORIF) with plate and screws and rush nails, respectively. The AO classification of the fractures, parameters of the fracture fixation, evaluation of the fracture healing and functional outcome are presented in [Tables 1,2 and 3].

All the standard SIGN nails were locked with four screws except the first patient whose fracture was locked with three screws and the most proximal screw removed due to its penetration into the shoulder joint, leaving the nail with two screws. All the fin nails were proximally fixed with two screws. The mean post-operative days before discharge home and standard deviation were 5.7 ± 1.4. Only one of the patients was lost to follow-up. Two of the patients presented with joint stiffness before the surgery, which limited their post-up functional outcome. The results of the evaluation of fracture healing and functional outcome were expressed in Table 3. The data of the patient who was lost to follow-up were not utilised in the analysis of fracture healing and functional outcome and those who presented with joint stiffness were also not utilised in the analysis of functional outcome.

Post-operative complications included two (4.3%) cases of deep infections (one was infected non-union), two (4.3%) cases of the prominence of the nails above the greater tuberosity, one (2.2%) case of screw penetration into the shoulder joint and three (6.5%) cases of radial nerve injury (neuropraxia). There was no mortality.

Discussion

Many studies have reported encouraging success in the treatment of humeral shaft fractures with interlocking intramedullary nailing.[12-15] The humeral fractures presented in various patterns with AO 12-A3 being the most common presentation. In a study done by Raja Gopal *et al.*, AO 12-A3 also constitutes the majority (55%) of the fractures they studied.[13] This explains that the most common pathomechanism associated with humeral fracture is that of

direct impact generating a tensional stress, which eventually results in a transverse fracture.[16] Close reduction was used for all the fresh fractures without an image intensifier. The only patient who had retrograde nailing initially had ORIF with plate and screw in another centre but presented to our centre with implant failure and humeral non-union. He had removal of broken plate, fibrolysis and fixation with a fin nail through a retrograde approach, and by 3 months, the fracture had united.

Size 8 mm nail constituted the greatest percentage (71.7%) of the nail used in this study followed by size 9 mm. Raja Gopal *et al*. who also performed reaming before nail insertion used nails of 7–8 mm in their own study which was carried out in India.[13] The difference in the nail sizes may have reflected racial variations.

Table 1: Fracture distribution according to AO classification. AO 12-A3 constitutes the greatest percentage of the fractures

	Frequency (%)
12-A1	2 (4.3)
12-A2	10 (21.7)
12-A3	13 (28.3)
12-B2	9 (19.6)
12-B3	5 (10.9)
12-C2	3 (6.5)
12-C3	4 (8.7)
Total	46 (100.0)

Table 2: Characteristics/parameters of the fracture fixation

	Frequency (%)
Fracture reduction	
Open	25 (54.3)
Reduction through about 3 cm incision	4 (8.7)
Closed	17 (37.0)
Surgical approach	
Antegrade	45 (97.8)
Retrograde	1 (2.2)
Type of nail used	
Standard nail	35 (76.1)
Fin nail	11 (23.9)
Diameter of nail used (mm)	
7	2 (4.3)
8	33 (71.7)
9	11 (23.9)

Fracture union in this study was based on the combination of radiographic, clinical and mechanical evidences of fracture healing. Fracture union in this study was not absolutely based on the appearance of three cortices bridging callus. Studies have shown that disagreement and variability exist amongst clinicians and researchers with regard to clinical and radiographic definitions of fracture healing.[17,18] Certain studies on the reliability of plain radiography in assessing fracture healing concluded that radiographs do not define union with enough accuracy and are generally inconclusive in determining the stage of union.[19-21] In a systematic review done in 2008, out of 59 studies that used clinical criteria in defining union, absence of pain or tenderness at the fracture site on weight bearing, absence of pain on palpation at the site of fracture and the ability to weight bear were the most commonly used criteria to define fracture healing.[18] Patient-centred approaches which assess the quality of life and function are therefore gaining popularity in the evaluation of fracture union.[18,22] These are the points on which SIGN protocol on the assessment of fracture healing is now based.

By 3 months, 44 (95.7%) patients have had radiographic evidence of healing [Figures 1c and 2c]. The rate of fracture healing in this study is strongly comparable with similar reported studies, in which intra-operative image intensifier was utilised. With the use of intra-operative image intensifier, the fracture union rate achieved in the study by Raja Gopal *et al*. at corresponding 3 months was 80%.[13] Previous studies have shown that healing at 6 months ranged between 90% and 95.8%.

The functional outcome of the studied patients is as follows: 35 (76.1%) and 42 (91.3%) of the patients could perform shoulder abduction at 3 and 6 months, respectively. Thirty-seven (80.5%) and 42 (91.4%) of them could perform painless shoulder flexion-abduction-external rotation movements at 3 and 6 months, respectively [Figures 1d and 2d]. Patient-satisfactory ADL was achieved amongst 42 (91.3%) as early as 3 months, and by 6 months, all the patients have had restoration of their ADL.

The two cases of post-operative deep infections presented pre-operatively with infected broken plate and gunshot injury, respectively, but both of them eventually had fracture healing. Robinson *et al*. also reported two (6.7%) cases of deep infection, which were controlled with the nail *in situ*.[23]

Table 3: Evaluation of fracture healing and post-operative functional outcome

Evaluation of fracture healing	At 6 weeks, *n* (%)	At 3 months, *n* (%)	At 6 months, *n* (%)	After 6 months, *n* (%)
Radiographic evidence of healing	27 (58.7)	17 (37)	1 (2.2)	-
Evaluation of functional outcome				
Shoulder abduction >90°	18 (39.1)	17 (37.0)	7 (15.2)	1 (2.2)
Painless shoulder FABER movement	13 (28.3)	24 (52.2)	5 (10.9)	1 (2.2)
Full ADL	15 (32.6)	27 (58.7)	1 (2.2)	-

FABER: Flexion, abduction, external rotation; ADL: Activities of daily living

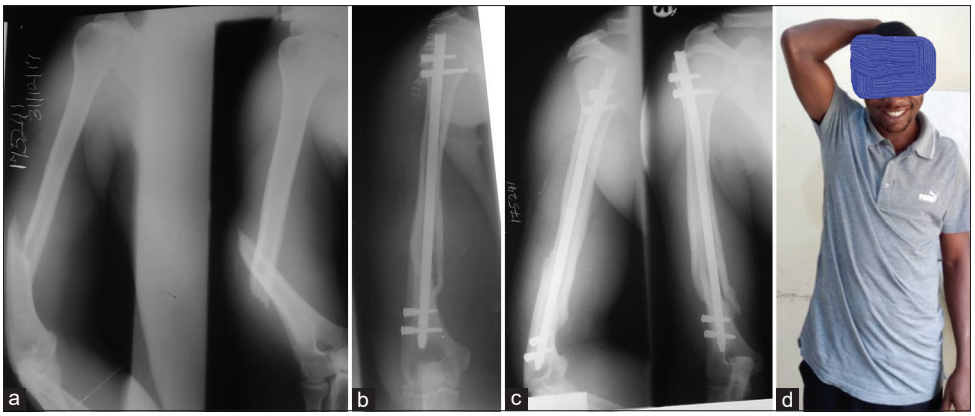

Figure 1: (a) Pre-operative radiographs showing AO 12-A2 fracture. (b) Immediate post-operative radiograph showing standard Surgical Implant Generation Network interlocking nail. (c) Three-month post-operative radiographs showing fracture union. (d) Shoulder flexion-abduction-external rotation exercise at 3-month post-operative period

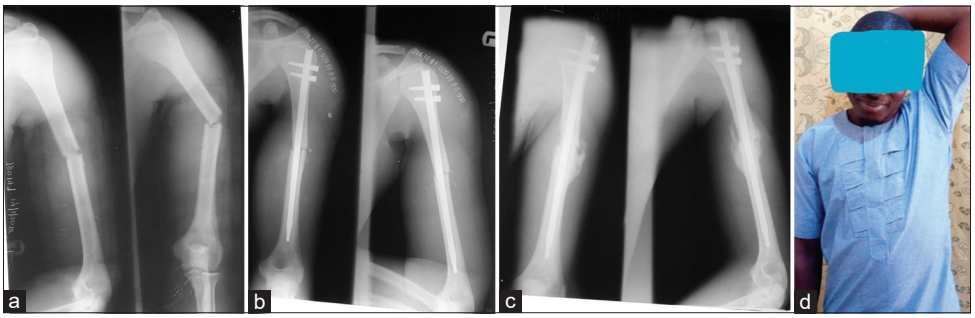

Figure 2: (a) Pre-operative radiographs showing AO 12-A3 fracture. (b) Immediate post-operative radiograph showing Surgical Implant Generation Network fin nail. (c) Three-month post-operative radiographs showing fracture union. (d) Shoulder flexion-abduction-external rotation exercise at 3-month post-operative period

In the two (4.3%) cases of nail prominence above the greater tuberosity, there was the unavailability of shorter nails, hence the constraint to use the relatively longer nail. The fractures united at 3 months, after which the nails were removed. Nail prominence and impingement have been reported[3,12,24] as causes of shoulder pain and limitation of shoulder movement.[25] In this study, one of the patients had shoulder pain and limitation of shoulder movement beyond 6 months, which resolved thereafter.

Two of the three cases of radial nerve injury recovered by 3 months, while the remaining one recovery at 6 months with physiotherapy. Chandan *et al*. and Kivi *et al*. reported 5% and 1.3% of cases of radial nerve injury, respectively.[3,26]

Conclusion

In a resource-constrained population where image intensifier is difficult to come by, humeral interlocking intramedullary nailing could still be performed using an external jig system with satisfactory outcome. However, adequate pre-operative planning, adequate reduction and static locking are all essential to ensure an excellent result.

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Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that names and initials will not be published, and due efforts will be made to conceal identity, but anonymity cannot be guaranteed.

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Nil.

Conflict of interests

Surgical implant generation Network (SIGN) at 451 Hills Street, Suite B, Richland, WA 99354 USA provided the instrumentations and implants free of charge for all the patients. The provision was not specifically for this study, but it is in line with their efforts to generally help patients in the developing countries have their fractures treated by internal fixation if indicated without paying for the implants.

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