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Functional outcome of humeral shaft fractures with antegrade intramedullary interlocking nail: A prospective study

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Abstract
Background: Humeral shaft fractures are a common orthopedic injury, accounting for a significant percentage of upper limb fractures. Various treatment methods exist, but the use of antegrade intramedullary interlocking nails has gained popularity due to their ability to provide stable fixation while minimizing soft tissue damage. This study evaluates the functional outcomes of patients who underwent antegrade intramedullary interlocking nailing for humeral shaft fractures which is assessed by Constant Murley score.
Materials and Methods: 30 patients with fracture of shaft of Humerus were treated by using antegrade intramedullary interlocking nail in Karnataka Institute of Medical Sciences, Hubli, Karnataka from July 2022 to July 2024.
Results: In our study conducted between the average age of patients was 36.4 years. At a six-month follow-up, 66.66% of patients had very good outcomes, with excellent and good results more common in those aged 20 to 40 years. Complications occurred in 20% of patients, including screw backout, non-union, radial nerve injury, and infection in these follow ups of 24 months of duration.
Conclusion: Antegrade intramedullary interlocking nailing is an excellent and minimally invasive surgical option for managing humeral shaft fractures, promoting early fracture healing and achieving high union rates with outcomes ranging from good to excellent as per Constant Murley scoring system.

Keywords: Humeral shaft fractures, antegrade intramedullary, interlocking nail

Introduction
Fractures of the shaft of humerus account for approximately 3-5% of all fractures treated[1]. Historically humeral shaft fractures have been classified by fracture location, fracture pattern, associated soft tissue injuries and quality of bone. This fracture has been treated by closed reduction & cast application with/without cast bracing and open reduction & internal fixation using dynamic compression plate. Many authors have documented the general good outcome that occurs after compression plate fixation [2], which is considered as the gold standard for operative treatment of acute humeral shaft fractures [3]. Though plate fixation has given high rates of union, it involves extensive soft tissue stripping, potential injury to radial nerve and poor fixation in osteoporotic bone. Later flexible nails of many varieties were used. The advantages of intramuscular nailing are minimal surgical exposure, better biological fixation, minimal disturbances of soft tissues and early mobilization of neighboring joints [4]. The technique of interlocking nailing represents the newer approach of the treatment of humeral fractures. Interlocking nailing also helps prevent complications such as loss of rotational control, nail migration, and the need for additional bracing [4]. The Seidel nail was the first nail to be tested clinically [5]. Eventually several nail systems evolved.
There are certain situations in which treatment by primary operative fixation of fractures may have to be considered. These are patients whom satisfactory alignment cannot be achieved or maintained by conservative method, patients with multiple injuries in whom early mobilization is desirable, bilateral humeral shaft fractures, segmental fractures, fractures associated with vascular deficits, Holstein and Lewis type of fracture associated with Radial Nerve Palsy, fractures associated with ipsilateral ulna & radius fractures, pathological fractures, radial nerve palsy following closed reduction etc.

Various methods of osteosynthesis have been evolved through the years to achieve union of fracture shaft of humerus [7]. Available treatment options include thoraco brachial immobilization, closed reduction and hanging arm cast, body arm bandage, functional cast bracing, closed reduction and U-slab splinting, Open or closed reduction and internal fixation with plate osteosynthesis or intramedullary nailing, external fixator application.

Kuntscher proposed Intramedullary nailing for management of diaphyseal fractures of femur, the Tibia and Humerus during World War II. This was later promoted by Maatz [8]. Flexible nails in multiple numbers can be inserted into the humerus from both ante grade and retrograde entry portal. Though they are found to have good prognostic outcome higher complication rates of non-union, nail cut through into articular surface are always to be kept in mind. Interlocking intramedullary nailing was the obvious sequel for this and the first nail introduced was the Seidel's nail [9]. Here the distal locking was achieved by expandable fins, which are opened within the barrel. This fell into disrepute due to the complications associated with flange failure. Newer developments include the Marchetti Vincenzi nail, the Russell Taylor nail, Synthes design which have lesser complication rates of implant failure, iatrogenic radial nerve palsy and infection than plate osteosynthesis [10].

Further refinements led to the development of anatomically contoured nails, which are specifically shaped to conform to the unique structure of the humerus. These nails provide better biomechanical stability and reduce the likelihood of implant-related complications. One of the most significant advancements in nail design was the incorporation of locking mechanisms. Locking nails feature holes at both ends through which screws are inserted, locking the nail to the bone. This innovation prevents the nail from migrating and provides additional stability, particularly in comminuted or osteoporotic fractures. Modern nails often feature multidirectional locking options, allowing surgeons to insert screws at various angles. This flexibility enhances the ability to secure the nail in cases of complex fractures, including those near the proximal or distal ends of the bone.

Interlocking nailing has been also found useful in treatment of non-union of fracture of the humerus and pathological fractures of the humerus.

Material and Methods

This research study was approved by the ethical committee and institutional review board before the commencement of study. The study was conducted on the patients with lateral clavicle fractures admitted under the department of Orthopaedics, at Karnataka institute of Medical sciences, Hubli. It was conducted between July 2022 To July 2024 for a period of 2 years. It was a prospective type of clinical study.

Inclusion Criteria: Age above 18 years, closed diaphyseal humeral fracture, fractures located between 5 cm distal to surgical neck and 7 cm proximal to the olecranon fossa, segmental fractures, spiral fractures, compound fractures, Type 1,type 2,type 3A open fractures, elderly patients with osteoporotic bones.

Exclusion Criteria: Age group less than 18 years, Type 3B open fractures, Pathological fractures

Once the patient is systemically stabilized the patient is made fit for surgery. Till the time of surgery a U-slab is applied as a temporary method. The nail size is measured with the full length x-ray from tip of greater tuberosity to 3cms above the proximal tip of olecranon fossa. Clinically it is measured by subtracting 5 cms from the tip of acromian to the lateral epicondyle of humerus.

Patient was operated either in general anaesthesia or regional (supraclavicular) nerve block. Patients were operated either in supine or beach chair position with proper padding of bony prominences.

A longitudinal skin incision 1–3 cm centered over the tip of the greater tuberosity was given. This exposes the multi-pennate deltoids muscle, which is split along its fibres, and it must be kept in mind that the axillary nerve is on an average 4.56 cms below the angle of acromian. This expose the white glistening rotator cuff, which has to be split at the tendon of supraspinatous just medial to its insertion at the greater tuberosity. This being vascular heals better. An awl was passed just medial to the tip of the greater tuberosity, 0.5 cm posterior to biceptal groove to make an entry point. The entry point awl is removed, inserting the guide wire in the humerus. With image intensifier the guide wire is passed through the distal fragment. Then serial reaming was done.

Progressive reaming is done upto 1mm more than the proposed size of the cannulated nail. The nail is mounted on the jig, and inserted through the guide wire. For non cannulated solid nails after mounting the nail onto the jig it is inserted through the entry point and negotiated carefully across the fracture site under the control of image intensifier. The nail size should be carefully selected because over size nail may end up splintering the distal fragment.the nail is pushed to a level where the nail is not protruding out through the articular surface of the proximal humerus (Figure 1).

Fig 1: Instruments and implants

Two sizes of nails were used which are the 6mm solid nails and the 7mm cannulated nails. The distal locking in the 6mm nails are the self-tapping 2.9 mm locking screws. The distal locking for the 7mm cannulated nail was 3.4 mm self-tapping locking screws. The distal locking are antero-posterior locking. Under image guidance a stab incision is made at the anterior aspect of forearm, the bicep and brachialis is split to expose the surface of thew bone. Under image guidance the appropriate K wire is used and the distal screws are inserted.

Proximal locking is done using the proximal jig that is mounted with the nail. There are 2 slots for proximal locking.3.9 mm self-tapping screws for dynamic slot and 3.4mm self-tapping screw for static slot. Care must be given to avoid the axillary nerve. The proximal locking are in the medio-lateral plane (Figure 2).

Fig 2: Intraoperative C-arm images

After surgery, patients who had general anaesthesia were asked nil per oral for 4 to 6 hours. They were given painkillers and antibiotics, and their operated arm was placed in a sling for support. X-rays were taken to make sure the fracture fragments were properly aligned. On the second day after surgery, the wound dressing was changed,

and depending on how they were doing, patients were sent home with the arm sling. Simple arm exercises, like pendulum movements, were also started on the second day to help with gentle movement.

Two weeks later, patients came back for a check-up, where their stitches were removed. At this stage, they were encouraged to start active range of motion exercises, though they were still advised to avoid lifting their arm overhead.

Around four to six weeks after surgery, patients could begin more actively, though they were still advised to hold off on sports and exercises that involved resistance. They could start doing their daily activities again, but anything that involved heavy lifting was delayed until the fracture was fully healed.

At the six-week check-up, they were examined to see how well they were recovering, checking for any tenderness at the fracture site, and another X-ray taken to confirm the fracture was healing satisfactorily. If the healing process was good, patients were allowed to start doing resistance exercises to strengthen their arm. However, they were still advised to avoid contact sports or activities involving unpredictable movements for at least 12 weeks after surgery. Patients had regular follow-ups at two weeks, six weeks, three months, and six months after surgery. During these visits, they were checked for any tenderness, instability, or deformities, and monitored shoulder movement. X-rays were taken at each visit to keep an eye on the union progress and to ensure the implant was in the right place. Rehabilitation exercises were adjusted based on how well the fracture was healing and how much time had passed since the surgery. Throughout the recovery process, the Constant Shoulder Scoring System was used to measure the shoulder's strength and function.

The Constant-Murley score (CMS) is a 100-points scale composed of a number of individual parameters. These parameters define the level of pain and the ability to carry out the normal daily activities of the patient. It was introduced to determine the functionality after the treatment of a shoulder injury. The test is divided into four subscales: pain (15 points), activities of daily living (20 points), strength (25 points) and range of motion: forward elevation, external rotation, abduction and internal rotation of the shoulder (40 points). The higher the score, the higher the quality of the function (Table 1).

Table 1: Constant shoulder murley score

Rating	Score
Excellent	86-100
Good	71-85
Fair	56-70
Poor	<56

Complications such as neurovascular injury, infection, non-union, malunion, implant migration, implant failure, soft tissue irritation, refracture and cosmetic outcomes were noted.

Implant removal was not done routinely in our study. It was done as per the need and will of the patient after fracture union. The number of days to return to normal activities after implant removal was noted.

Results

Mean age in this study was 36.4 years. Among 30 patients, 11 patients belonged to age group of 30-39 which contributed to 36.66% of the participants. In this study, Youngest patients in this series was 20 years and eldest was 64 years old (Figure 3a).

Among 30 patients, 25 patients (83.33%) were male and 5 patients (16.66%) were female. Hence males were most commonly involved with diaphyseal fracture of humerus. Shaft of Humerus fractures are more commonly seen on the Left side contributing around 70% of the fractures while right sided shaft of humerus fractures contributed to 30% of shaft of humerus fractures.

In our study the most common mode of injury causing shaft humerus fractures was Road Traffic Accident (RTA) 73%, followed by fall on outsterched hand with incidence of 13.33% and Slip and fall contributing to 13.33% of overall mode of injury. Out of 30 study participants, 19 patients had 12A type of fracture which contributed to 63.33% of all types of fracture according to AO classification.

Final evaluation in our series was done at 6 Months follow up on the basis on Constant murley score. The minimum duration of follow-up for final evaluation in our series was six months. In our series 6 patients had Very good results accounting for 66.66%, 05 patients had good results accounting for 16.66%, 03 patients has fair results accounting for 10% and 02 patients had poor results accounting for 6.66% (Figure 3b).

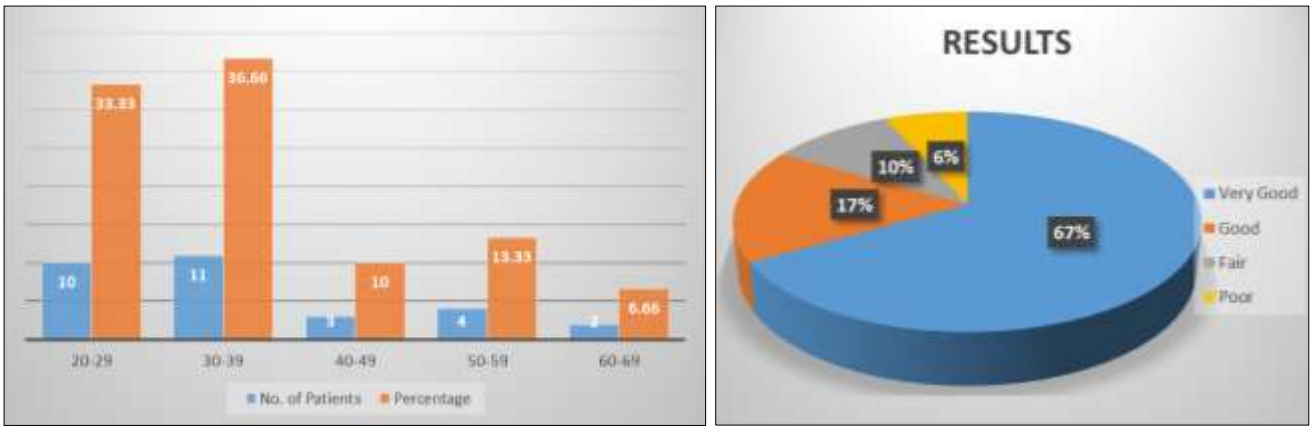

Fig 3: (a) Age distribution of study participants (b) Functional outcome of study participants

These results show that Excellent and Good results were more commonly seen in patients of age group 20 to 40 years (Figure 4a).

Among 30 study participants, 20% of the patients had complications from antegrade humerus nailing.

2 patients had proximal screw backout, 2 had non-union of shaft fracture, 1 patient had radial nerve injury, 1 patient had surgical site infection (Figure 4b).

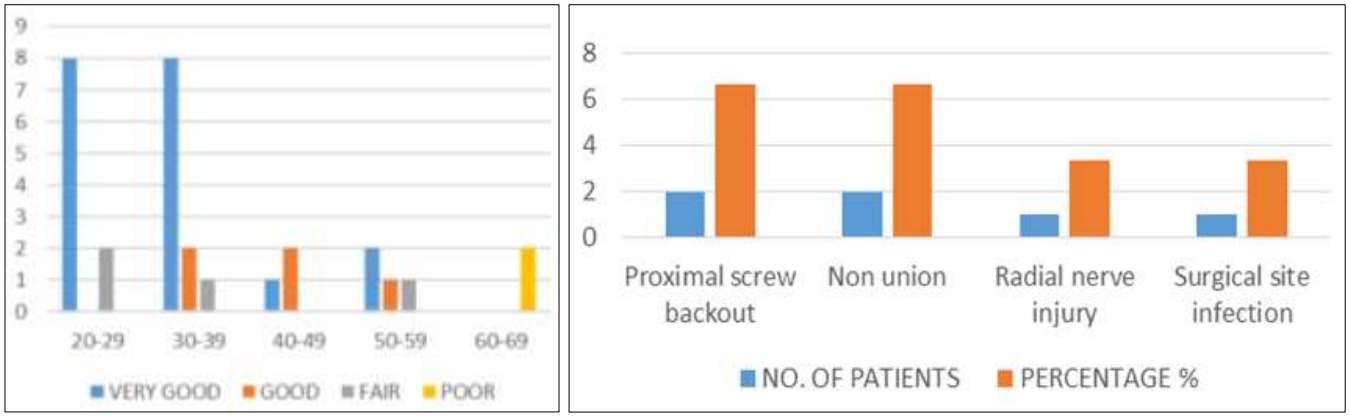

Fig 4: (a) Results association with age among participants (b) Complication distribution chart

Discussion

The results of use of interlocking nailing for shaft fractures of the humerus has been mixed in various studies with some studies showing good outcome and a few showing poor outcome.

The management of humeral shaft fractures has been a subject of considerable debate, particularly in choosing between conservative and surgical interventions. In recent years, the use of antegrade intramedullary interlocking nails has gained popularity as a preferred surgical treatment for these fractures due to its minimally invasive nature and biomechanical advantages. This study aimed to evaluate the functional outcomes of humeral shaft fractures treated with antegrade intramedullary interlocking nailing.

The mean age of patients in this study was 36.4 years. Among the 30 participants, 11 (36.66%) were aged between 30 and 39. The youngest patient was 20 years old, while the oldest was 64 years old. Of the 30 patients, 25 (83.33%) were male, and 5 (16.66%) were female, indicating that males were more frequently affected by shaft fractures of the humerus. Crates *et al*. 31 treated 73 acute humeral shaft fractures in 71 patients with intra-medullary nailing. There were 43 male and 28 female with an average age of 32 years (range 13 to 70 years).

Fractures of the humeral shaft were more commonly observed on the left side, accounting for 70% of the cases, while the right side contributed to 30% of the fractures. The most frequent cause of humeral shaft fractures was road traffic accidents (73%), followed by falls on an outstretched hand (13.33%) and slips and falls (13.33%). In Rommenss *et al*. [11] series out of 39 patients, 21 gave history of road traffic accident. In study by Bell MJ *et al*. [12], Jinn Lin *et al*. [13] and Tings tad *et al*. [14] road traffic accident was commonest mode of injury.

In this study, 19 patients (63.33%) had a 12A type fracture, which was the most common fracture type observed. The final evaluation was conducted at a six-month follow-up using the constant murley score. The minimum follow-up duration was six months. In terms of outcomes, 66.66% of patients had Excellent results, 16.66% had good results, 10% had fair results, and 6.66% had poor results. Notably, excellent and good outcomes were more frequently seen in patients aged 20 to 40 years.

The union rate in this study was 93.33% consistent with other studies. Crates *et al*. [15] reported 97% union of fractures treated with ante grade Russell Taylor nailing, with mean time of 3.2 months. Among the 30 study participants, 20% experienced complications from antegrade humerus nailing. These included 2 cases of proximal screw backout, 2 cases of non-union of the shaft fracture, 1 case of radial nerve injury, and 1 case of surgical site infection. Crates *et al*. [31] reported 2.7% iatrogenic radial nerve palsies after locked intra-medullary nailing. Vander Griend *et al*. [16] reported 5.9% infection after plate fixation humeral fractures. Brumback *et al*. [17] reported 1.7% infection after fixing humeral shaft fractures with various flexible nails.

Fig 6: (a) Pre op x ray (b) Post op x ray (c) Follow up x ray at 6 months (d) Follow up clinical pictures at 6 months

Fig 6: (a) Pre op x ray (b) Post op x ray (c) Follow up x ray at 6 months (d) Follow up clinical pictures at 6 months

Conclusion

Intramedullary interlocking nailing is a minimally invasive and effective method for treating humeral shaft fractures, with excellent outcomes as assessed by the Constant-Murley scoring system. Key factors for success include careful reaming, accurate entry point, minimal rotator cuff damage, proper nail placement, good fracture alignment, and static locking. These elements contribute to the reliability of antegrade intramedullary nailing in achieving successful fracture union and optimal shoulder function.

Consent

Written informed consent were taken from the patients.

Conflict of Interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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None.

Author Contributions

Author 1: Supervision, Validation.

Author 2, 3: Writing - Original Draft Preparation.

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