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*ORIGINAL STUDY*

# Retrograde intramedullary nailing for humeral midshaft fractures : a retrospective cohort study

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**This study evaluates the patient-reported functional outcome, clinical functional outcome and frequency of complications of simple oblique and transverse humeral midshaft fractures treated with a retrograde expert humeral nail.**

**A retrospective cohort study of humeral midshaft fractures (AO 12-A2, 12-A3) treated with retrograde nailing between January 2010 and February 2018 in a level II trauma center was performed. Patients' perception of functional outcome was measured using the Disabilities of the Arm, Shoulder and Hand (DASH) scores.**

**Thirteen patients with a median age of 20-years were treated with a retrograde nail. The median DASH score, administered 29 months (IQR 74) after surgery, was 7.9 (IQR 15.9). There were no perioperative fractures and the frequency of complications was 8%, being one nonunion.**

**Retrograde nailing for humeral midshaft fractures is a safe technique, with excellent patient reported and clinical functional outcome. No iatrogenic perioperative fractures occurred and the frequency of complications was low. We recommend the retrograde technique, if surgical fixation of humeral midshaft fractures is needed, especially in younger patients for who rotator cuff associated injuries will have a major impact on quality of life.**

**Keywords** : Humeral midshaft fracture ; intramedullary nailing, retrograde ; operative complications ; patient reported outcome measurement ; DASH.

*Abbreviations*

| | | |
|---|---|---|
| AO | = | Arbeitsgemeinschaft für Osteosynthesefragen |
| DASH | = | Disability of Arm, Shoulder and Hand |
| EHN | = | Expert Humeral Nail |
| HET | = | High Energy-impact Trauma |
| IMN | = | IntraMedullary Nailing |
| IQR | = | InterQuartile Range |
| LET | = | Low Energy-impact Trauma |
| SD | = | Standard Deviation |
| STROBE | = | Strengthening the Reporting of Observational Studies in Epidemiology |

## INTRODUCTION

Simple oblique and transverse humeral midshaft fractures are common humeral shaft fractures,

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comprising 35% of all fractures affecting the humeral midshaft *(4)*. Humeral midshaft fractures can be managed nonsurgical with splinting or a functional (Sarmiento) brace, with reported union frequencies of 90% *(13)*. However, conservative treatment is associated with discomfort, longer rehabilitation periods and risk of malalignment (varus or valgus deformity) affecting functional outcome, especially shoulder exorotation *(7,9,13)*. Evaluation of the different subtypes of humeral midshaft fractures shows higher frequencies of nonunion of conservative treated oblique (17.5%) and transverse midshaft fractures (8.9%) *(18)*. Therefore, these fractures could benefit considerably from primary surgical fixation. This provides stability and adequate alignment of the bone fragments, allowing rapid return of full arm mobilization *(27)*.

Multiple techniques are available for surgical fixation of oblique and transverse humeral mid-shaft fractures, such as closed reduction with intramedullary nailing (IMN) and open reduction with plate fixation *(7,30)*. IMN and plate fixation have similar frequencies of union, but the advantage of IMN over plate fixation is caused by the less invasive approach *(8)*.The closed insertion requires a smaller incision and less dissection, resulting in limited soft-tissue and vascular disruption and less scarring *(7,22,30)*. Furthermore, the periosteal blood supply can be maintained, the risk of iatrogenic radial nerve injury and postoperative infection is reduced, and the nail provides load-sharing mechanical properties which plates cannot provide *(7,12)*. Resistance regarding the use of antegrade IMN is caused by the higher incidence of shoulder and subacromial impingement complaints, chronic postoperative shoulder pain and iatrogenic rotator cuff injuries associated with antegrade insertion *(2,12,22,30)*. To avoid these complications, a retro-grade approach was developed. This technique uses an extra-articular dorsal entry portal in the distal humerus at the olecranon fossa *(2,7,29)*. However, retrograde nailing has been associated with higher frequencies of perioperative supracondylar fractures, limited elbow motion, triceps muscle weakness and periarticular ectopic ossification resulting in reluctance to use this technique *(2)*. Even though the first articles promoting retrograde over antegrade intramedullary nailing - based on less shoulder complications and better functional outcome - were published over twenty years ago, to this day retrograde nailing is not commonly accepted as a viable treatment option for humeral midshaft fractures *(15,21)*. In our clinical experience retrograde IMN using the expert humeral nail (EHN, DePuy Synthes, Oberdorf, Switzerland) is a viable treatment option for fixation of oblique and transverse humeral midshaft fractures. Therefore, this study evaluates the patient reported functional outcome, clinical functional outcome and frequency of complications of simple oblique and transverse humeral midshaft fractures treated with retrograde EHN.

## PATIENTS AND METHODS

Institutional review board approval for this single-center retrospective cohort study was a priori obtained. A study protocol was not registered or published. This article was written, if applicable, in adherence to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.

### Study design

Patients with humeral shaft fractures treated with the retrograde EHN at a large level II trauma center, were identified using the operation code ‘’humerus’’ in the hospital’s electronic patient database. Patients who received treatment by means of this technique during the period of January 2010 until February 2018 were manually identified from this search. This broad search was performed to reduce selection bias. All patients, regardless of age, with a non-pathological humeral shaft fracture (AO-classification 12-A2, 12-A3, see Fig 1a/Fig 1b) treated with the retrograde IMN technique were eligible for inclusion in this cohort study. The number of cases found during the study period determined the sample size.

For all patients, baseline characteristics (age, gender, AO-classification, injured side, concomitant injuries, trauma mechanism, fracture alignment, days between trauma and surgery, neurovascular

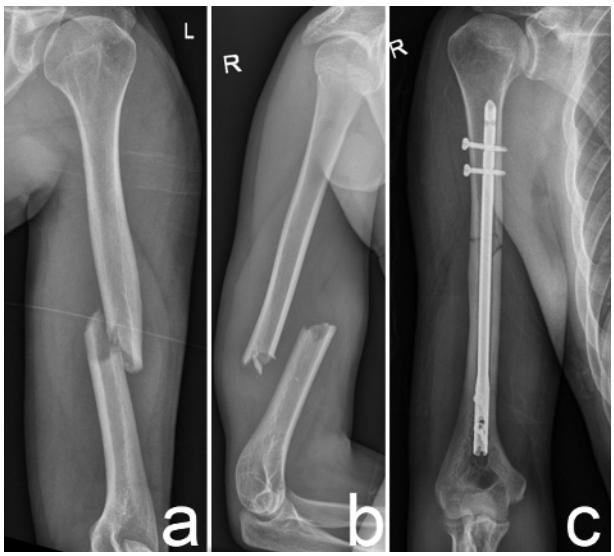


***Fig. 1.*** — Radiographs a) AO 12-A2 fracture ; b) AO 12-A3 fracture ; c) Postoperative radiograph after treatment with a retrograde intramedullary nail.

status), perioperative information (blood loss, duration of procedure, perioperative complications) and follow-up information (duration outpatient clinical follow-up, first sign of consolidation, elbow function, nail removal) were retrieved from the electronic patient database. Trauma mechanisms were categorized in high (HET) and low (LET) energy-impact trauma according to the Advanced Trauma Life Support guidelines (1). To evaluate long-term functional outcome, all patients were contacted by the researchers to fill out the Disability of Arm, Shoulder and Hand (DASH) questionnaire between January and June 2018. The questionnaire consists of 30 items, each scored on a scale of 1 (no disability) to 5 (severe disability). These scores are used to calculate a score from 0 to 100 reflecting patients' perception of disabilities and symptoms related to the injury (28). No to minimal impairment was defined as a score 0-20, 20-40 as mild, 40-60 as moderate, 60-80 as severe and 80-100 as disabling. If applicable, the patients were asked to fill out the work and sports/performing arts modules.

**Surgical technique**

The patient is placed in prone position with the upper arm resting on a radiolucent arm board with flexion in the elbow possible up to 100 degrees while the forearm is facing down (Fig. 2a). Over the posterior aspect of the distal humerus, a longitudinal incision (10 cm) is made towards the olecranon, followed by splitting of the triceps muscle insertion. The entry portal is made at the superior edge of the olecranon fossa with several drill holes, in an oval form of approximately 30mm x 10mm (Fig. 2 b/c). Using a cone-shaped burr, the entry portal is formed and further extended into the medullary canal (Fig. 2 d/e). The aim is to create a longitudinal entry hole from the fossa into the medullary canal. Making a triangular based hole should be avoided, as we believe that this configuration is at risk for iatrogenic fractures of the distal humerus. A guide wire is then introduced passing the fracture up to the proximal humerus. The medullary canal is reamed, first with rigid hand reamers followed by flexible reamers to further expand the medullary canal, until the nail can be easily inserted without extensive force or any signs of obstruction. If necessary, the entry point and medullary canal should be reamed further. This part of the surgical procedure is essential for avoiding iatrogenic fractures. The nail is gently inserted along the guide wire followed by placing one or two distal interlocking screws using the aiming guide (Fig. 2f). One or two proximal interlocking screws are placed with the free hand technique (see Fig 1c for postoperative radiograph). Finally, the triceps muscle fascia, subcutis and skin are closed. The patient is given a pressure bandage for 48 hours. Directly after surgery, depending on the pain, active and passive movements are allowed, including loading and rotational movements of the shoulder, humerus and elbow.

**Statistical analysis**

Descriptive statistics were applied to the baseline characteristics. For continuous data medians were presented with the interquartile range (IQR). Categorical data were presented as frequencies with percentages. Missing data were handled using pairwise deletion to reduce information bias. The primary outcome of this study was the patient reported functional outcome reported as a median DASH score. The secondary outcomes were the

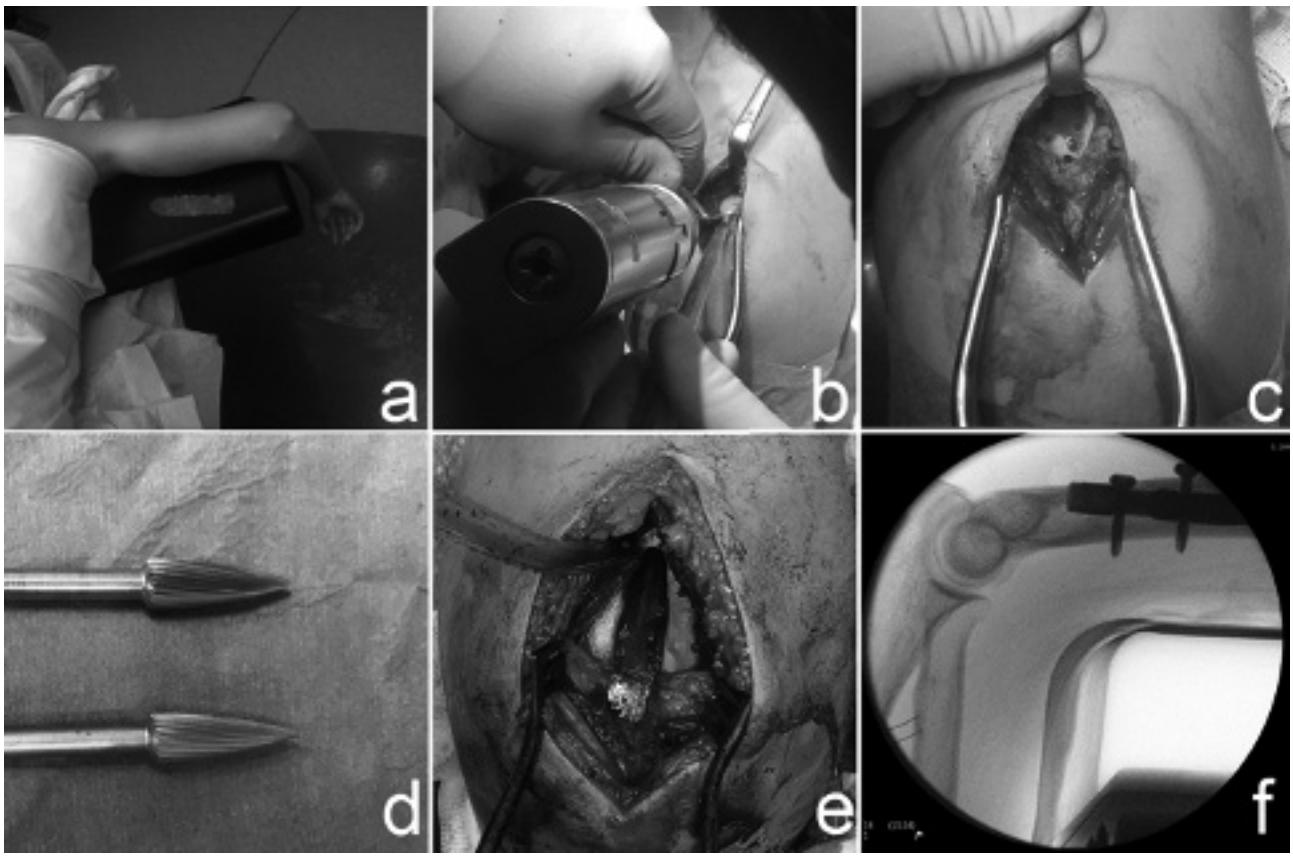


***Fig. 2.*** — Surgical procedure a) Positioning ; b) Creating an oval entry portal using several drill holes ; c) The multiple drill holes in an oval shape to be connected with a cone-shaped burr ; d) The cone-shaped burr ; e) Finished oval entry portal after molding with the cone-shaped burr ; f) Perioperative fluoroscopic image of distal position of EHN.

clinical functional outcome reported as elbow range of motion and the frequency of complications in percentages. No statistical tests were performed due to the small sample size. Data were analyzed with SPSS version 25.0 (IBM Corp. Armonk, NY, USA).

## RESULTS

### Baseline characteristics

Thirteen patients treated with retrograde intramedullary nailing were identified and all were included in this study. One patient was lost to follow up due to residency abroad. The baseline characteristics are listed in Table I. The median age was 20 years (IQR 17 to 38). Nine patients were male (69%). Eight patients (62%) had closed displaced transverse humeral midshaft fractures (AO 12-A3) and five (38%) patients had closed displaced oblique humeral midshaft fractures (AO 12-A2). Four patients had concomitant upper extremity injuries. One patient had an ipsilateral fracture of the clavicle and three patients had nerve injuries ; one patient had neurapraxia of the brachial plexus which resulted in loss of motoric function of the biceps muscle, the other patient reported pre-operative paresthesia of the radial nerve and another patient experienced pre-operative sensory and motor loss of the ulnar nerve. All these concomitant upper extremity injuries were trauma related, not procedure related. Median time between trauma and surgery was three days (IQR 1 to 11). The main reasons for choosing surgical fixation using retrograde IMN in this cohort was the combination of a relatively young age, presence of severe dislocation and an oblique or transverse midshaft fracture. All surgical procedures were

Table I. — Baseline characteristics of patients treated with the retrograde intramedullary nail for oblique and transverse humeral midshaft fractures

| | n = 13 |
|---|---|
| Median age (min-max, IQR) | 20 (14 - 59, 21) |
| Sex | |
| Male | 9 (69%) |
| Female | 4 (31%) |
| Side | |
| Left | 7 (54%) |
| Right | 6 (46%) |
| Trauma mechanism | |
| Low energy-impact trauma | 7 (54%) |
| High energy-impact trauma | 6 (46%) |
| AO fracture classification | |
| 12-A2 | 5 (38%) |
| 12-A3 | 8 (62%) |
| Pre-operative associated arm injuries | |
| Radial nerve injury | 1 (8%) |
| Ulnar nerve injury | 1 (8%) |
| Neuropraxia brachial plexus | 1 (8%) |
| Clavicle fracture | 1 (8%) |

AO = Arbeitsgemeinschaft für Osteosynthesefragen ; IQR = InterQuartile Range.

performed by experienced orthopedic trauma surgeons. The operation had a median duration of 80 minutes (IQR 80 to 90) with 100 ml blood loss (IQR 50 to 150). Median outpatient clinical follow-up was five months (IQR 3 to 7). At eight weeks postoperatively the first signs of consolidation were seen in all patients, no earlier radiographs were made. A detailed overview of all patients can be found in table II.

### Outcome

The median score of the DASH-questionnaire, administered at a median of 29 months (IQR 7 to 81) after surgery, was 7.9 (IQR 2.1 to 18.0). None to minimal impairment was reported by ten patients (84%) one patient reported mild disability (8%) and one patient reported moderate disability (8%). The DASH work and sport/arts module had a median score of 0 (IQR 0 to 50) and 25 (IQR 3 to 75), respectively (Table III).

The frequency of postoperative complications was 8% (n = 1), being a clinically relevant nonunion of the midshaft humeral fracture. This patient had a suspected (not radiological confirmed) traumatic refracture two weeks after surgery. Secondary surgery (nail removal and plate fixation) was performed after a year due to hypertrophic nonunion. This patient reported the highest DASH score of this cohort. The nail was removed without complications in another patient five years after primary fixation due to irritation of the nail at the distal humerus. No perioperative iatrogenic fractures occurred. All patients had an excellent elbow function at 6 months, all with full range of flexion and on average a minimal extension limitation (Table II). Furthermore, no other postoperative complications (e.g. wound complications, infection, triceps muscle weakness, periarticular ectopic ossification) were reported during follow-up.

## DISCUSSION

This study shows that retrograde IMN using the EHN provides excellent treatment results for transverse and oblique humeral midshaft fractures in a young patient population. Excellent patient-reported functional outcomes (median DASH score 7.9) and clinical functional outcomes were obtained. No perioperative complications were encountered and high frequencies of union (92%) were achieved.

The advantage of retrograde over antegrade IMN is based on the absence of rotator cuff injury. Multiple studies have assessed the frequency of shoulder impingent and shoulder dysfunction following antegrade nailing, reporting frequencies from 3.7% up to 31.6% *(5,8,9,14,20)*. Kurup et al. found that 13% of all antegrade inserted nails were removed, for which shoulder impingement complaints was the most prominent reason *(14)*. Due to the extra-articular insertion point of the retrograde nail at the olecranon, the rotator cuff and articular cartilage are not violated, resulting in better functional outcome of the joint in contrast to the longer shoulder recovery seen with antegrade nailing *(9)*. Postoperative regainment of elbow function after retrograde IMN has previously been described as complete in 87.5-100% of all cases *(6,9,11,15,21,22)*. Adding to this evidence, our study showed no limitation in elbow motion. This is the first study reporting the patient's perception

Table II. — Details of thirteen patients with oblique and transverse humeral midshaft fractures treated with retrograde intramedullary nailing

| Case no. | Age (years) | Sex | Side | Trauma mechanism | Additional injuries | AO-code | Time to surgery (days) | Peri-operative complications | First consolid-ation seen (weeks) | Follow-up (months) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 18 | M | L | Scooter accident (HET) | Paresthesia radial nerve | 12-A2 | 1 | None | 8 | 5 |
| 2 | 17 | M | R* | Scooter accident (HET) | Isolated | 12-A3 | 2 | None | 6 | 5 |
| 3 | 20 | F | R* | Fall from standing height (LET) | Isolated | 12-A3 | 11 | None | 8 | 2 |
| 4 | 19 | M | L | Car accident (HET) | Metatarsal fractures L, neuropraxia of brachial plexus | 12-A3 | 3 | None | 7 | 6 |
| 5 | 17 | M | L* | Scooter accident (HET) | Isolated | 12-A3 | 10 | None | 6 | 2 |
| 6 | 40 | M | L | Bicycle accident (LET) | Isolated | 12-A2 | 25 | None | 4 | 2 |
| 7 | 35 | F | L | Fall from horse (HET) | Isolated | 12-A2 | 1 | None | 8 | 8 |
| 8 | 34 | M | R* | Fall from height (1m) (LET) | Isolated | 12-A3 | 12 | None | 4 | 9 |
| 9 | 59 | M | L* | Bicycle accident (HET) | Isolated | 12-A2 | 0 | None | 6 | 6 |
| 10 | 41 | M | R | Fall sports (LET) | Isolated | 12-A3 | 10 | None | 6 | 4 |
| 11 | 17 | F | L | Fall from horse (HET) | Isolated | 12-A2 | 6 | None | 7 | 5 |
| 12 | 14 | F | R | Bicycle accident (HET) | Clavicle fracture R, sensory and motoric loss of ulnar nerve | 12-A3 | 1 | None | 4 | 7 |
| 13 | 24 | M | R | Fall sports (LET) | Isolated | 12-A3 | 2 | None | LFU | LFU |

AO = Arbeitsgemeinshaft für Osteosynthesefragen; DASH = Disability of Arm, Shoulder and Hand; EHN = Expert Humeral Nail; F= Female; M = Male; L = Left; R = Right; HET = High Energy-impact Trauma; LET = Low Energy-impact Trauma; LFU = Lost to Follow-Up; NA = Not Applicable; * = Dominant hand.

Table III — Patient-reported functional outcome of the retrograde intramedullary nail for oblique and transverse humeral midshaft fractures

| | Median scores (min-max, IQR) | n = |
|---|---|---|
| General DASH questionnaire score | 7.9 (0.8 - 42.2, 15.9) | 12 |
| DASH work module score | 0.0 (0.0 - 68.8, 50.0) | 11 |
| DASH sports/performing arts module score | 25.0 (0.0 - 100, 71.9) | 9 |
| DASH = Disability of Arm, Shoulder and Arm; IQR = InterQuartile Range | | |

Table II. — Details of thirteen patients with oblique and transverse humeral midshaft fractures treated with retrograde intramedullary nailing

| Full elbow function (months) | DASH score | DASH work module | DASH sports/ arts module | Surgery to DASH score (moths) | EHN removal | Additional comments |
|---|---|---|---|---|---|---|
| 5 | 4.3 | 0 | NA | 90 | No | Complete recovery of nerve injury after surgery |
| 5, hence 5 degree extension limitation | 1.7 | NA | NA | 92 | Yes | |
| 2 | 1.7 | 0 | 0 | 81 | No | Indication for surgery after week of conservative treatment due to increase of varus deformity |
| Unknown | 19.0 | 50 | 25 | 80 | No | After trauma weakness of biceps brachii muscle due to neuropraxia of the brachial plexus, resulting in inability to flex elbow. During follow-up delayed union was seen without clinical consequences. After 7 years still limited eccentric contraction of biceps muscle and loss of sensibility in arm due to brachial plexus injury |
| 2, hence 5 degree extension limitation | 15.0 | 50 | 100 | 78 | No | |
| Unknown | 27.5 | 0 | NA | 31 | No | Pre-operative limited elbow extension due to surgical delay of 3 weeks with conservative treatment |
| 4 | 7.5 | 0 | 62.5 | 27 | No | |
| 2 | 0.8 | 0 | 0 | 24 | No | |
| 6 | 42.2 | 68.8 | 87.5 | 8 | Yes | Possible refracture after new trauma two weeks after surgery. Re-operation with nail removal and plate fixation one year later due to non-union |
| 4 | 12.5 | 0 | 25 | 7 | No | |
| 5 | 3.3 | 18.8 | 31.5 | 5 | No | |
| Unknown | 8.3 | 12.5 | 6.3 | 3 | Planned for 11 months after initial fixation | Post-operative persistent sensory and motoric loss of ulnar nerve, complete recovery after 7 months |
| LFU | LFU | LFU | LFU | LFU | LFU | |

of functional outcome after retrograde IMN for displaced humeral shaft fractures by using a patient reported outcome measurement tool (e.g. DASH score), so no comparative results are available

Our study shows that if the entry portal is created carefully, iatrogenic fractures can be avoided. One of the reported reasons for hesitance towards using retrograde IMN is caused by fear for supracondylar perioperative fractures during nail insertion and/or reaming *(5,20,23)*. Perioperative fractures are thought to be caused by the smaller diameter of the distal humeral canal, the small angle at which the nail needs to be inserted and the over-reaming needed for retrograde nail insertion *(9,17)*. As the presence of the olecranon prevents a pure linear approach to the axis of the medullary canal, a diagonal insertion angle with a slight slope (+/- 10 degrees) is necessary *(3)*. Therefore, carefully creation of an oval entry point at least 10 mm in width and 20-30 mm in length is key for limiting perioperative fractures by providing more linearity and thereby reducing high stress on the bone margins during nail insertion *(5,9)*. Since the distal medullary canal is narrow, it is advised to hand ream the canal at least 2 mm larger

than the width of the chosen nail and insert the nail with small rotatory hand movements and not by hammer *(3,5)*. However, care should be taken, since excessive reaming can cause devascularization of the bone resulting in bone necrosis, possibly causing nonunion and infection *(9,16)*. Studies comparing antegrade with retrograde IMN found that the retrograde approach has a longer learning curve and is technically more demanding due to the nonlinear approach to the medullary canal axis *(3,9)*. Some authors even discourage the retrograde approach and advice the antegrade approach in patients with a narrow medullary canal *(3,24)*. However, our study shows that retrograde IMN is safe and provides excellent functional results, especially in a young patient population.

Radial nerve palsies have been reported as one of the possible complications in humeral shaft fractures due to the close proximity of the radial nerve to the humeral shaft *(7,10,12)*. Transverse and spiral fractures, especially of the mid-third and distal third of the humerus, are associated with higher frequencies of radial nerve palsies *(25)*. Iatrogenic radial nerve injury could occur if the radial nerve is incarcerated between both fracture fragments, or due to elongation or torsion of soft tissue, including the radial nerve, during nail insertion *(10,29)*. In patients with primary radial nerve palsy, it could be contemplated to perform IMN under direct vision of the radial nerve by exploring the nerve through a separate incision or to perform an open reduction and plate fixation, whereby the radial nerve can be inspected *(10,11,20,29)*. Most radial palsies reported in literature recovered completely without needing surgical nerve exploration *(11,29)*. In our cohort one patient had preoperative mild radial nerve paresthesia, which recovered immediately postoperative. Furthermore, one of our patients had an ulnar nerve palsy at initial presentation, which is extremely rare. Ulnar nerve injury caused by humeral shaft fractures has only been described in two cases in the English literature *(19,26)*. Our patient most likely endured the ulnar nerve injury due direct impact on the arm caused by the trauma.

The frequency of union within our cohort was 92%, which is in line with previously reported union frequencies for IMN in general and specifically for retrograde IMN, 88-97% and 91-100%, respectively *(6,7,9,11,23,24)*. When nonunion does occur in humeral shaft fractures treated with IMN, it most often concerns transverse midshaft fractures due to rotational instability *(24)*. Our previously reported patient suffered from a hypertrophic nonunion, which has been associated with loss of mechanical stability *(29)*. In this case, the nail was distally locked with only one screw and the patient sustained a possible traumatic refracture two weeks after surgery, both possibly contributing to loss of stability. Resulting from this case, we recommend ensuring optimal stability by using two interlocking screws distally as well as proximally.

In current literature, removal of the nail is not advised, since it has been associated with a cumulative complication risk of 17.3% (e.g. supracondylar fractures during or after nail removal) (11,22,24). In our study, the nail was removed in two patients without any complications.

Several limitations affect our generalizability. First, our relatively young cohort limits extrapolation of our findings, with confidence, to an older demographic group. In our clinic, the elder patient is more frequently treated with an antegrade IMN due to pre-existent rotator cuff damage resulting in this selection bias. Especially for this younger demographic group, for which our results are applicable, limited shoulder and elbow function has the most devastating consequences. Second, the retrospective nature of this study and the cross-sectional data collection of DASH scores limits the ability to provide firm conclusions regarding the time frame in which patients regained the excellent functional outcome. Third, the work and sports module are based on the work and sports most important to the individual patient, therefore, labor intensive work or sports requiring extensive arm force and movement results in relative higher scores. Fourth, the DASH score can be influenced by concomitant ipsilateral arm injuries, making it difficult to distinguish disability solely caused by the humeral fracture or the concomitant injury. Finally, elaborate recording of the desired variables in the patients' charts resulted in few missing variables limiting the risk at information bias.

## CONCLUSION

The retrograde approach for IMN is a safe surgical technique with satisfactory results for fixation of displaced humeral oblique and transverse midshaft fractures. Our findings suggest an excellent clinical and patient reported functional outcome with a low frequency of nonunion. The risk of iatrogenic distal humeral fractures can be limited if the entry portal is created carefully. We therefore recommend the retrograde nailing technique if surgical fixation of displaced midshaft humeral fractures is required, especially in younger patients for who rotator cuff associated injuries will have a major impact on quality of life.

## REFERENCES


1. **American college of Surgeons.** Advanced Trauma Life Support ATLS : student course manual. 9th ed. *American College of Surgeons ;* 2012.
2. **Baltov A, Mihail R, Dian E.** Complications after interlocking intramedullary nailing of humeral shaft fractures. *Injury.* 2014 ; 45 : S9-S15.
3. **Bencic I, Cengic T, Prenc J, Bulatovic N, Matejcic A**. Humeral Nail : Comparison of the Antegrade and Retrograde Application. *Acta Clin Croat*. 2016 ; 55 : 110-116.
4. **Bergdahl C, Ekholm C, Wennergren D, Nilsson F, Möller M.** Epidemiology and patho-anatomical pattern of 2,011 humeral fractures : Data from the Swedish Fracture Register. *BMC Musculoskelet Disord.* 2016 ; 17 : 159.
5. **Blum J, Janzing H, Gahr R, Langendorff HS, Rommens PM**. Clinical performance of a new medullary humeral nail : Antegrade versus retrograde insertion. *J Orthop Trauma.* 2001 ; 15 : 342-349
6. **Blum J, Machemer H, Baumgart F, Schlegel U, Wahl, et al**. Biomechanical comparison of bending and torsional properties in retrograde intramedullary nailing of humeral shaft fractures. *J Orthop Trauma.* 1999 ; 13 : 344-350.
7. **Carroll EA, Schweppe M, Langfitt M, Miller AN, Halvorson JJ.** Management of Humeral Shaft Fractures. *J Am Acad Orthop Surg.* 2017 ; 20(7) : 423- 433.
8. **Changulani M, Jain UK, Keswani T.** Comparison of the use of the humerus intramedullary nail and dynamic compression plate for the management of diaphyseal fractures of the humerus. A randomised controlled study. *Int Orthop.* 2007 ; 31 : 391-395.
9. **Cheng HR, Lin J.** Prospective randomized comparative study of antegrade and retrograde locked nailing for middle humeral shaft fracture. *J Trauma - Inj Infect Crit Care*. 2008 ; 65 : 94-102.
10. **Farragos AF, Schemitsch EH, McKee MD**. Complications of intramedullary nailing for fractures of the humeral shaft : A review. *J Orthop Trauma.* 1999 ; 13 : 258-267.
11. **Fernandez FF, Matschke S, Hülsenbeck A, Egenolf M, Wentzensen A**. Five years' clinical experience with the unreamed humeral nail in the treatment of humeral shaft fractures. *Injury.* 2004 ; 35 : 264-271.
12. **Hollister AM, Saulsbery C, Odom JL, Anissian L, Garon MT, et al**. New technique for humerus shaft fracture retrograde intramedullary nailing. *Tech Hand Up Extrem Surg.* 2011 ; 15 : 138-143.
13. **Koch PP, Gross DFL, Gerber C.** The results of functional (Sarmiento) bracing of humeral shaft fractures. *J Shoulder Elb Surg*. 2002 ; 11 : 143-150.
14. **Kurup H, Hossain M, Andrew J**. Locked Intramedullary Nailing versus Dynamic Compression Plating for Humeral Shaft Fractures. *Cochrane Database of Systematic Reviews.* 2011 ; 6.
15. **Lin J, Hou SM, Hang YS, Chao EY**. Treatment of humeral shaft fractures by retrograde locked nailing. *Clinical orthopaedics and related research*. 1997 ; 342 : 147-155.
16. **Lin J, Shen PW, Hou SM.** Complications of locked nailing in humeral shaft fractures. *J Trauma.* 2003 ; 54 : 943-949.
17. **Mahaisavariya B, Jiamwatthanachai P, Aroonjarattham P, Aroonjarattham K, Wongcumchang M, et al**. Mismatch analysis of humeral nailing : Antegrade versus retrograde insertion. *J Orthop Sci.* 2011 ; 16 : 644-651.
18. **Papasoulis E, Drosos GI, Ververidis AN, Verettas DA.** Functional bracing of humeral shaft fractures. A review of clinical studies. *Injury.* 2010 ; 41 : e21-e27.
19. **Pathak R, Kalakoti P, Prasad DV, Peeyuusha D, Sharma R**. Ulnar nerve injury after a comminuted fracture of the humeral shaft from a high-velocity accident : A case report. *J Med Case Rep.* 2012 ; 6 : 192.
20. **Rommens PM, Kuechle R, Bord T, Lewens T, Engelmann R, et al**. Humeral nailing revisited. *Injury.* 2008 ; 39 : 1319-1328.
21. **Rommens P, Verbruggen J, Broos P.** Retrograde Locked Nailing of Humeral Shaft Fractures. *J Bone &Joint Surg.* 1995 ; 77 : 84-9.
22. **Ruffilli A, Traina F, Pilla F, Fenga D, Faldini C**. Marchetti Vicenzi elastic retrograde nail in the treatment of humeral shaft fractures : review of the current literature. *Musculoskelet Surg.* 2015 ; 99 : 201-209.
23. **Sanzana E, Dümmer R, Castro J, Diaz E**. Intramedullary nailing of humeral shaft fractures. *Int Orthop*. 2002 ; 26 : 211-213.
24. **Scheerlinck T, Handelberg F**. Functional Outcome after Intramedullary Nailing of Humeral Shaft Fractures : Comparison between Retrograde Marchetti-Vicenzi and Unreamed Ao Antegrade Nailing. *The Journal of Trauma Injury, Infection and Critical Care*. 2002 ; 52 : 60-71.
25. **Shao Y, Harwood P, Grotz M, Limb D, Giannoudis P**. Radial nerve palsy associated with fractures of the shaft of

the humerus : a systematic review. *J Bone Jt Surg - Br Vol.* 2005 ; 87 : 1647-1652.

26. **Stahl S, Rosen N, Moscona R.** Ulnar Nerve Palsy Following Fracture of the Shaft of the Humerus. *J Orthop Trauma.* 1998 ; 12 : 363-364.
27. **Van Middendorp JJ, Kazacsay F, Lichtenhahn P, Renner N, Babst R, et al**. Outcomes following operative and non-operative management of humeral midshaft fractures : A prospective, observational cohort study of 47 patients. *Eur J Trauma Emerg Surg*. 2011 ; 37 : 287-296.
28. **Veehof MM, Sleegers EJA, Van Veldhoven NHMJ, Schuurman AH, Van Meeteren NLU**. Psychometric qualities of the Dutch language version of the disabilities of the arm, shoulder, and hand questionnaire (DASH-DLV). *J Hand Ther.* 2002 ; 15 : 347-354.
29. **Walker M, Palumbo B, Badman B, Brooks J, Van Gelderen J, et al.** Humeral shaft fractures : A review. *J Shoulder Elb Surg*. 2011 ; 20 : 833-844.
30. **Zhao JG, Wang J, Meng XH, Zeng XT, Kan SL.** Surgical interventions to treat humerus shaft fractures : A network meta-analysis of randomized controlled trials. *PLoS One.* 2017 ; 12 : e0173634.