

# DISPLACED TWO-PART SURGICAL-NECK FRACTURES: SURGICAL CLASSIFICATION AND RESULTS OF THIRD-GENERATION PERCUTANEOUS INTRAMEDULLARY NAILING

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## SUMMARY

**Background:** Locking plate and screw constructs are the primary fixation method for displaced two-part surgical neck fractures of the proximal humerus, yet they are associated with various clinical complications. While antegrade intramedullary (IM) nailing offers a potential alternative, early-generation nail designs frequently resulted in high rates of reoperation and morbidity, including rotator cuff irritation and hardware migration.

**Objective:** This study aims to evaluate the clinical and radiological outcomes of a third-generation, straight, locked IM nail using a percutaneous insertion technique and to establish a classification-based strategy for optimizing nail entry points.

**Key Points:** A retrospective analysis was conducted on 41 patients (mean age 57 years) with displaced two-part surgical neck fractures (AO/OTA Type 11A3). The third-generation nail design features a straight profile to minimize supraspinatus tendon injury, polyethylene bushings for angular-stable proximal fixation, and tuberosity-oriented screws to prevent glenoid erosion. Surgical neck fractures were classified into three types—valgus, translated, and varus—to guide the specific percutaneous entry portal. At a mean follow-up of 26 months, all fractures achieved union with a mean neck-shaft angle of 132°. The mean Constant-Murley score was 71, and the subjective shoulder value was 80%. Complications included one case of asymptomatic partial avascular necrosis and two reoperations (5%) for hardware-related irritation.

**Conclusion:** Percutaneous fixation using a third-generation IM nail is a viable alternative to locking plates for two-part surgical neck fractures. The technique provides stable biomechanical fixation and high union rates while minimizing soft-tissue dissection and hardware-related complications.

## KEYWORDS

Fracture Fixation, Intramedullary; Humeral Fractures; Shoulder Fractures; Bone Nails; Minimally Invasive Surgical Procedures

## INTRODUCTION

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The most commonly used fixation option for two-part surgical neck fractures requiring surgical treatment is a locking plate and screw construct, though many complications have been reported throughout the literature related to this option. [6],[11],[12],[13],[21],[22],[23],[25],[28],[30],[31],[32],[35],[40],[45],[47],[49],[51],[52],[53],[56],[57] Antegrade intramedullary nailing for surgical neck fractures of the proximal humerus could be an alternative treatment option to locking plates. However, the high rate of complications and reoperations observed with the early designs of first- (unlocked) and second-generation (bent design) intramedullary humeral nails has discouraged their use by most surgeons. [1],[39],[44],[48],[50]

In an effort to overcome these problems, we developed a third-generation humeral IM nail (Aequalis IM Humeral nail, Wright-Tornier, Bloomington, USA). This new generation of humeral IM nail is cannulated, has a low-profile and straight design, and the proximal screws are tuberosity-oriented and locked by polyethylene bushing inside the proximal part of the nail. [3],[4] In the present study, we report our clinical experience with percutaneous intramedullary nailing, using this third-generation nail.

The aims of the present study are [1] to classify displaced surgical neck fractures to determine the optimal entry points for percutaneous IM nailing, and [2] to report the functional and radiological results of this third-generation nail for the treatment of displaced two-part surgical neck fractures, using a percutaneous technique for nail insertion.

## THIRD GENERATION IM HUMERAL NAIL DESIGN RATIONALE

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The Aequalis IM humeral nail (Tornier-Wright, Bloomington, MN, USA) is a third-generation IMN (Figure 1), This cannulated nail is short, has a small diameter (9-mm), a straight design (to enter the muscular portion of the supraspinatus), and uses locking screw technology with orientation of the screws for tuberosity fixation. [3],[9] The straight nail respects the 3D-geometry of the proximal humerus acting as a mechanical strut to support humeral head under compressive forces [3],[4],[5],[7],[54] The proximal locking-screws are captured by a polyethylene bushing, which provides an angular-stable construct preventing screw back-out and migration. [9] The proximal screws are tuberosity oriented (i.e., not humeral-head oriented), in order to avoid glenoid erosion in case of humeral head avascular necrosis and collapse. Finally, the two distal screws are 20° divergent to center the nail inside the medullary canal increasing constructs stability. [3],[5],[9]

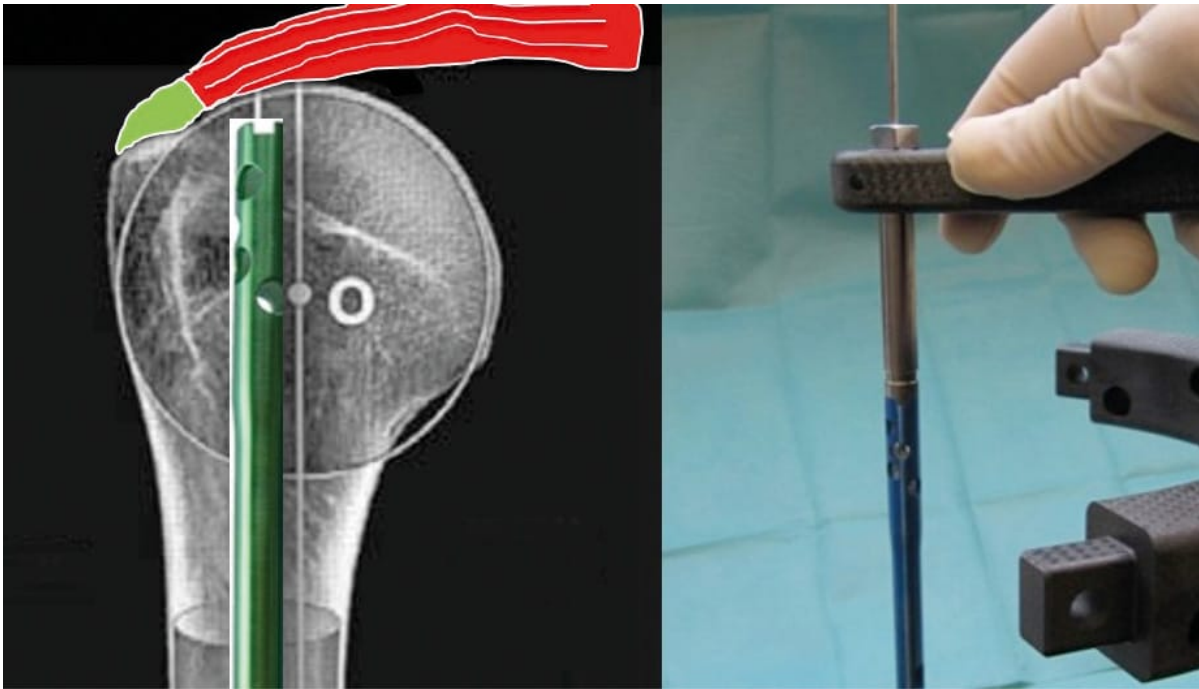


Figure 1: Entry point of a straight, locked (third-generation) intramedullary humeral nail (Aequalis™ humeral nail). The straight design allows to enter the muscular part of the supraspinatus (and not the tendinous part), and to respect the 3D-geometry of the proximal humerus with alignment along the diaphyseal axis (diaphyseal cylinder); the IM nail, which is cannulated, enters through the cartilage, approximately 10-mm posterior and medial to the bicipital groove. Because of tuberosity-based fixation, there are two different nails: a green one for the right side, and a blue one for the left side.

## PERCUTANEOUS IM

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## NAILING OF TWO-PART SURGICAL NECK FRACTURES

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Patients are placed in the sitting position and the C-arm image intensifier control, approaching from the contralateral side of the table to visualize the proximal humerus, is placed orthogonal to the shoulder (Figure 2). The goal of the minimally invasive percutaneous technique is to enter the cartilage of the humeral head (entering the supraspinatus muscle fibers, not the tendon) before entering the medullary canal of the diaphysis to align the head fragment and the shaft, and then to derotate the diaphysis (Figure 3).



Figure 2: Installation for IM Nailing. The patient is placed in the sitting position and the C-arm image intensifier control, approaching from the contralateral side of the table to visualize the proximal humerus, is placed orthogonal to the shoulder. This avoids misplacement of the IM nail in height.

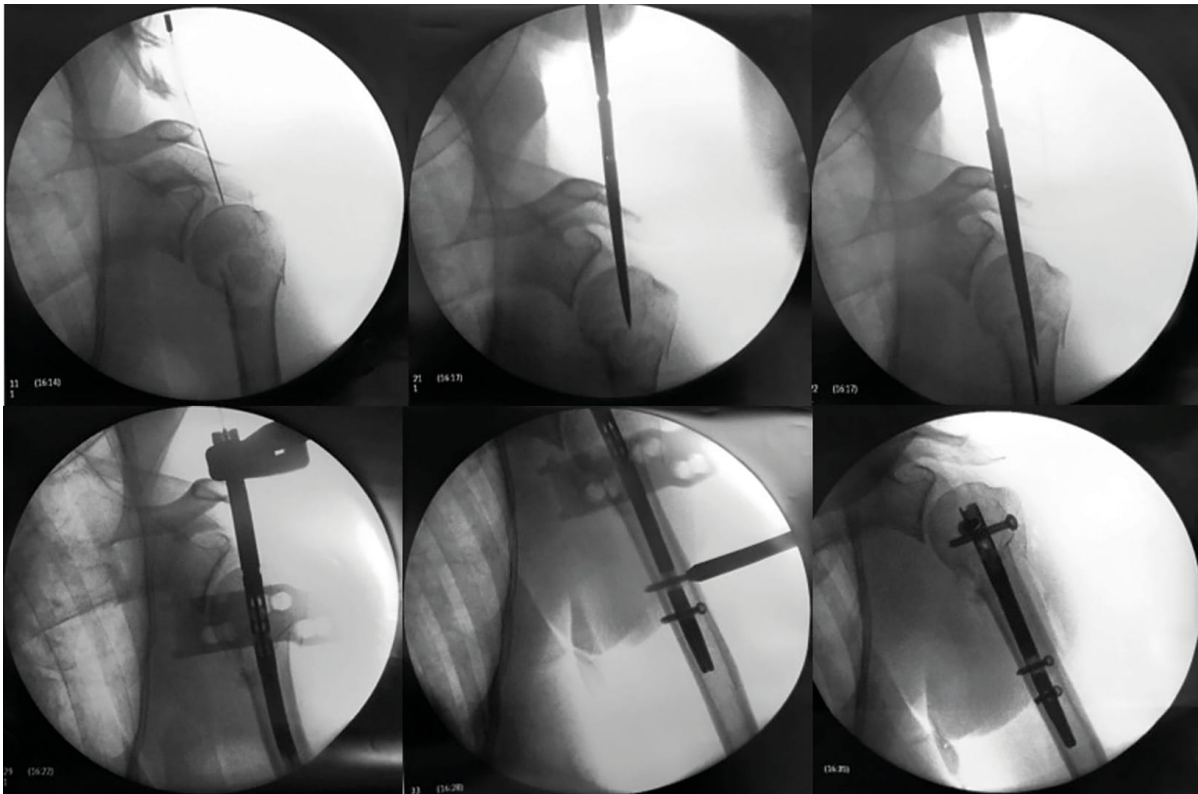


Figure 3: Percutaneous intramedullary nailing of a two-part surgical neck fracture. The goal is to enter the cartilage of the humeral head segment (and NOT the greater tuberosity) before entering the medullary canal of the shaft. After location of the entry point under fluroscopy with a spinal needle, a cannulated awl is used to perforate the cartilage and manipulate the head fragment to allow for the passage of the guide-wire in the diaphysis; the cannulated nail is then inserted along the guide-wire. After fluoroscopic control of humeral nail height, the diaphysis is derotated by aligning the jig on the forearm. Distal locking is first performed, and slapback technique allows immediate fracture compression before proximal locking.

Under C-arm guidance, optimizing the starting point of the nail in the humeral head was essential to obtain anatomical reduction.<sup>[46]</sup> The entry point of a straight nail must be located approximately 10mm posterior and medial to the bicipital groove.<sup>[14],[26],[29],[38],[42]</sup> Once proper entry portal is defined, a cannulated bone awl is used for entry and joystick the humeral head under fluoroscopic guidance. A guide-wire is placed through the bone awl into the humeral head. After manipulation of the arm to obtain the best alignment between the epiphysis and the diaphysis, the guide-wire is then advanced inside the humeral shaft.

Once adequate guide pin placement is achieved, a 9-mm hole is created in the humeral head using a cannulated reamer. The cannulated nail is placed over the guide wire, inserted at the apex of the humeral head, and then inside the diaphysis, providing appropriate fracture alignment. The arm is placed in neutral rotation to achieve adequate derotation of the humeral diaphysis, whereas adequate rotation of the nail is achieved with the assistance of an external jig aligned with the forearm (Figure 4).

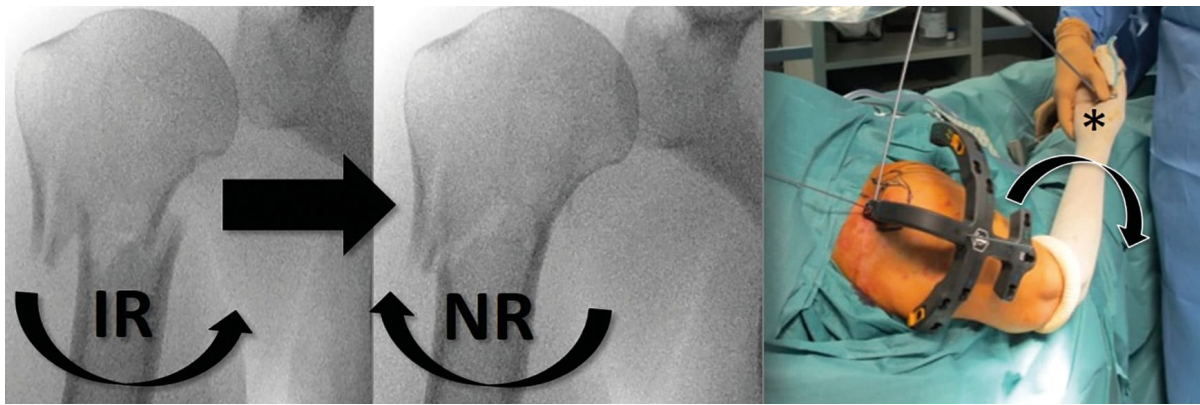


Figure 4: Closed reduction of a displaced surgical neck fracture by derotation of the diaphysis. Before reduction, the diaphysis is displaced in adduction, translation and internal rotation (IR) by pulling of the thoracic muscles (Pectoralis major, latissimus dorsi and teres major). Placing the arm in neutral rotation (NR) allows derotation of the diaphysis and almost complete fracture alignment. Once the nail has been inserted percutaneously inside the humerus, the version rod is aligned with the forearm (\*) to control the nail rotation.

After assessment of the reduction and the nail's depth under fluoroscopy, the guide wire is retrieved and the two distal screws were first placed in the diaphysis. Once distal fixation is obtained, gentle retrograde impaction of the distal to the proximal segment via a sliding slap-hammer is then performed ("backslap" hammering) to allow intraoperative immediate compression of the fracture site (Figure 5). Finally, proximal fixation is obtained by percutaneous insertion of a minimum of two proximal locking-screws via the attached jig. Postoperatively, the shoulder is placed in a sling for 1 week postoperatively. Passive elbow and shoulder mobilization with pendulum exercises (5 times a day and 5 minutes per session) is performed immediately. Patients are encouraged to remove the brace at day one, and to use their hand for ADLs.



Figure 5: "Backslap" hammering technique allows immediate fracture site compression. After fracture alignment and diaphysis derotation, distal locking of the IM nail is performed first, followed by intraoperative retrograde hammering, and then proximal locking.

## CLINICAL STUDY

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We performed a retrospective and were able to follow and review 41 patients who underwent placement of the Aequalis™ IMN to treat a displaced two-part surgical-neck fracture (AO/OTA Type 11A3). All surgical-neck fractures were displaced with displacement of the shaft of > 25% of its width and/or > 45° of angulation. Mean age at surgery was 57 years old (range: 17-84). There were 25 females and 16 males. Mechanism of injury was due to a low energy trauma (fall) in 78% of cases (32 patients). The dominant side was involved in 55% of the cases. The mean operative time was 42 minutes (range: 20-110 minutes). Patients were reviewed and radiographed with minimum one year follow up; the mean follow up was 26 months (range: 12-53).

## CLASSIFICATION OF DISPLACED TWO-PART SURGICAL NECK FRACTURES

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Using preoperative radiographs and CT-scans, surgical-neck fractures were classified in 3 types, according to the displacement of the humeral head fragment (Figure 6):

- Valgus Surgical-Neck Fractures (Type A- 8 cases): the medial translation of the diaphysis is partial and combined with some abduction which leads to valgus deformity of the humeral head.
- Translated Surgical-Neck Fractures (Type B- 19 cases): when the shaft is entirely translated medially and anteriorly by the pectoralis major and internally rotated by the latissimus dorsi and teres major, there is no more contact between the head fragment and the diaphysis, and therefore, no humeral head deformity.
- Varus Surgical-Neck Fractures (Type C- 14 cases): the shaft is translated laterally with some adduction, leading to varus head deformity.

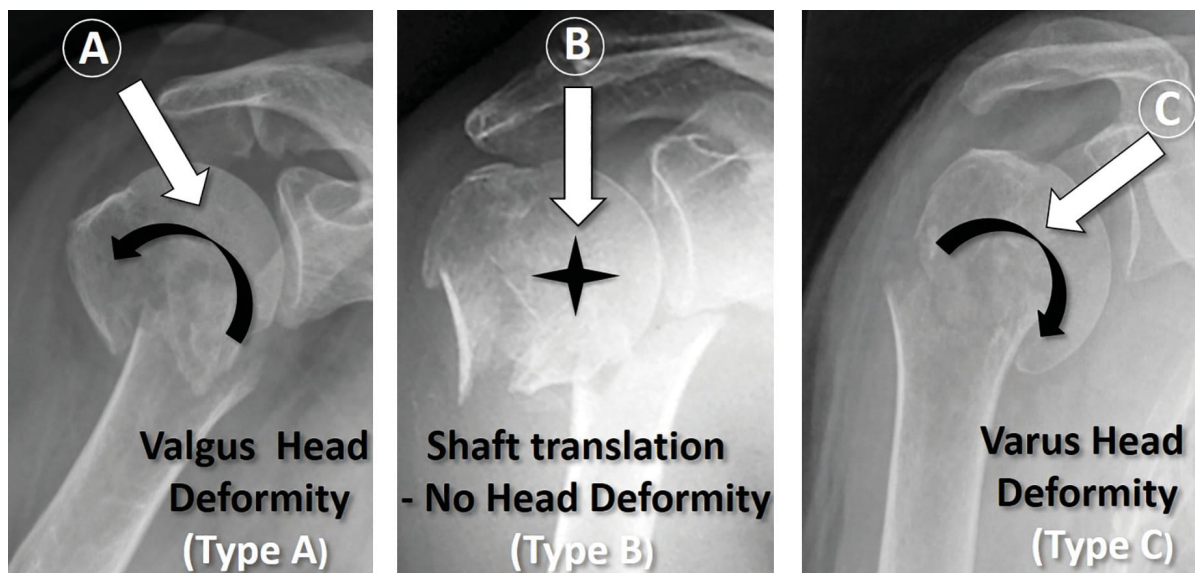


Figure 6: Surgical classification of displaced surgical-neck (Neer 2-part) fractures and relationship with the nail entry point. Three type of surgical-neck fractures have been identified. Surgical-neck fracture with valgus head deformity (Type A): partial shaft translation and abduction of the diaphysis leads to valgus tilt of humeral head. Surgical-neck fracture with shaft translation and no head deformity (Type B): Because of the complete shaft translation and the absence of contact between the two bone segments, the head is not tilted. Surgical-neck fracture with varus head deformity (Type C): partial shaft translation and adduction of the diaphysis leads to varus tilt of humeral head. The white arrows is materializing the IM nail entry point which must be individualized according to the humeral head displacement: the more valgus, the more lateral, the more varus, the more medial.

With increasing surgical experience, we have used this classification to choose the optimal percutaneous entry point for the IM nail (Figure 7).

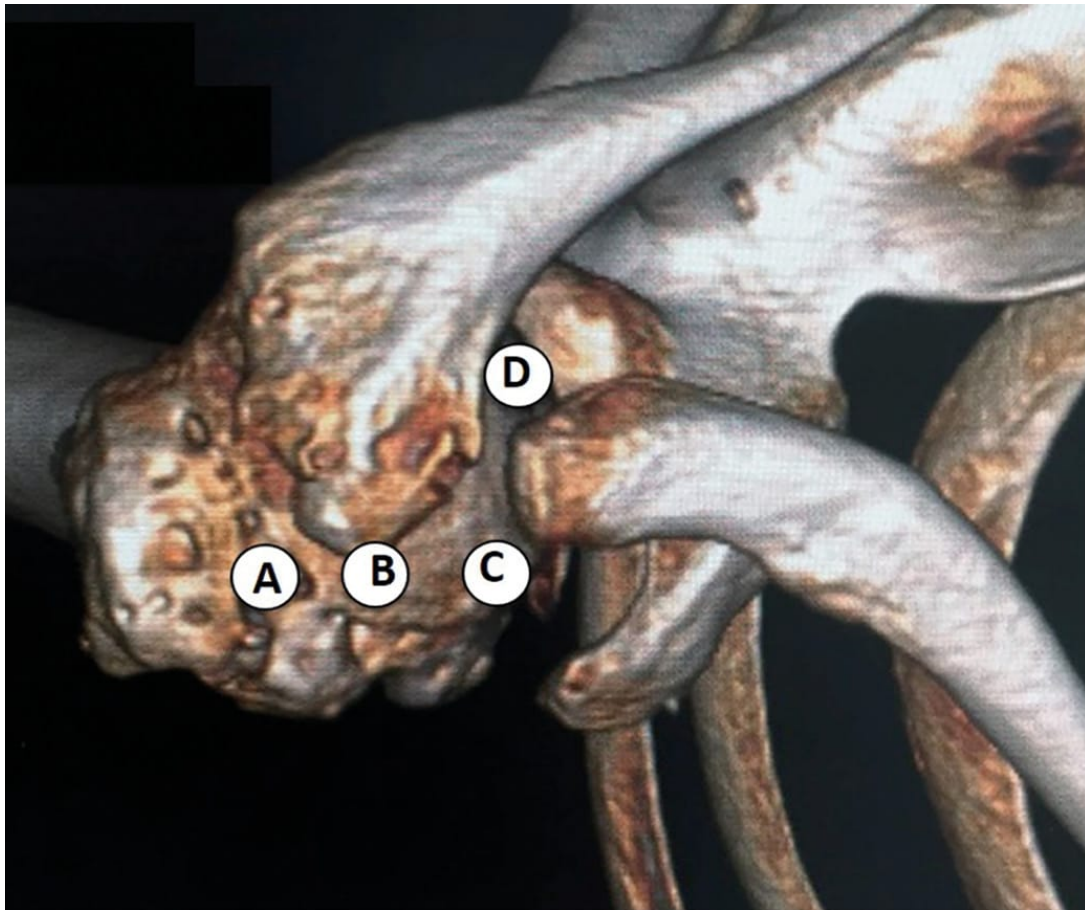


Figure 7: 3D-CT image showing the different entry portals used to insert a straight IM Nail. Portal (A) is used in case valgus deformity of humeral head; Portal (B) is used in the absence of head deformity with shaft translation; Portal (C) is used in case of varus deformity of humeral head, and Portal (D) is used in case of combined varus and posterior tilt of the humeral head (Neviaser portal).

## COMPLICATIONS

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## AND REOPERATIONS

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At the final follow up, one patient had partial avascular necrosis of the humeral head, which remained asymptomatic at the last review, three years postoperatively. Two patients (5%) were reoperated. One patient had removal of a too proud causing rotator cuff irritation, and impingement. A second patient with shoulder stiffness and pain underwent arthroscopic scar release and removal of anterior proximal screw which was not tightened enough.

## RESULTS

At last review, mean active forward elevation was  $145^{\circ}$  (range:  $90^{\circ}$ - $180^{\circ}$ ), and external rotation  $50^{\circ}$  (range:  $20^{\circ}$ - $80^{\circ}$ ). Mean Constant-Murley Score and subjective shoulder value (SSV) were 71 (range: 43-95) and 80% (range: 50-100%), respectively. At the last follow up, the mean SSV was  $80\% \pm 12$  (Figure 8).



Figure 8: Radiological, functional and aesthetic results after percutaneous IM locked nailing and "backslap" technique. High energy varus-displaced surgical-neck fracture in a young (18 yo) active patient; postoperative anteroposterior and axial views demonstrate healing and restoration of proximal humeral anatomy; functional results and cosmetic shoulder aspect three months after surgery.

At final follow-up, all fractures went onto union, and the mean humeral neck-shaft angle was  $132^{\circ} \pm 5^{\circ}$  (Figure 9). No cases underwent screw migration or intra-articular penetration. The mean correction of the angulation was  $16.5^{\circ} \pm 8.3^{\circ}$  (Table 1).

Initial Fracture Displacement	Initial Fracture	Last Follow up	Final Malunion
Valgus Deformity (Type A) N=8	150° [141°-156°]	135° [120°-139°]	residual valgus = 0
Shaft Translation (Type B) N=19	75% [30%-100%]	8% [0%-50%]	residual translation =
Varus Deformity (Type C) N=14	112° [91°-120°]	130° [120°-135°]	residual varus = 1

Table 1: Correction of fracture displacement (\*translation refers to the diameter of the surgical neck)

We observed one partial humeral head avascular necrosis, as already mentioned, and two malunions, early in our experience: one patient had incomplete reduction of humeral translation whereas the other one developed a varus malunion of the surgical neck. Both fractures were noted to be mal-reduced at the time of surgery because of intraoperative technical error: the entry point of the nail was incorrect (i.e., too lateral). With increasing surgical experience, we developed a strategy to enter the nail at the correct spot, based on the type of displacement of the humeral head fragment (Figures 5, 6).

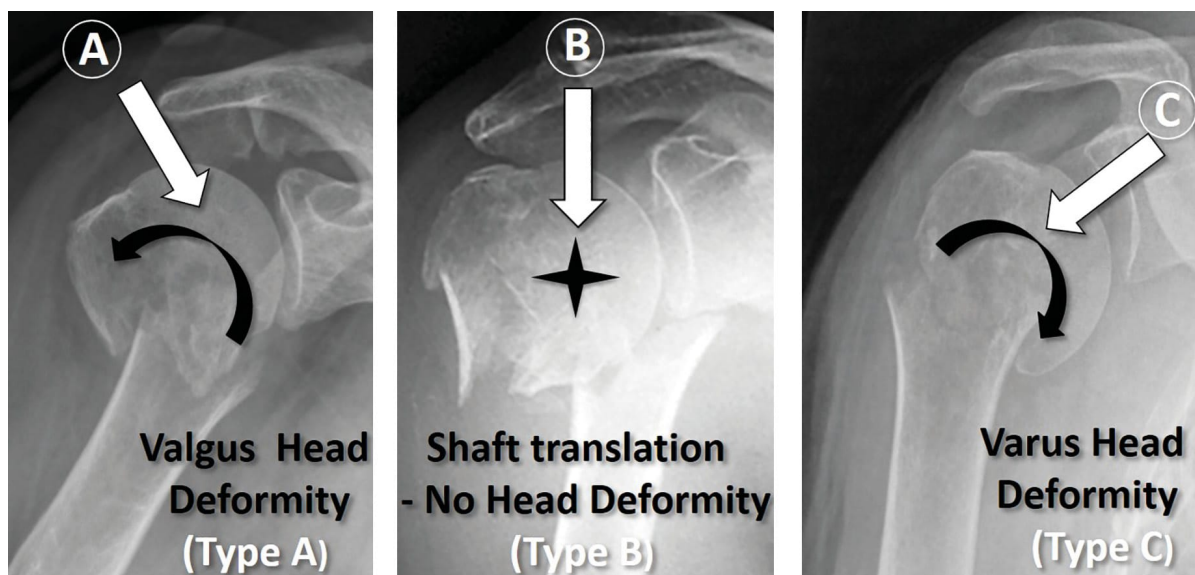


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## DISCUSSION

Our study shows that antegrade insertion of third-generation IMN through a percutaneous approach provides high rate of fracture healing, excellent clinical outcome scores with low rates of complications. Such IM nail has a low-profile and straight design, and the proximal screws are tuberosity-oriented and locked by polyethylene bushing inside the proximal part of the nail. We found several advantages for using this new generation of humeral IMN through a percutaneous approach for the treatment of displaced two-part surgical neck fractures,

including minimal soft-tissue damage with minimal risk of humeral head osteonecrosis (only one case in our series), short operative time (42 minutes in average, including our learning curve) and improved cosmesis (Figure 9 and 10).

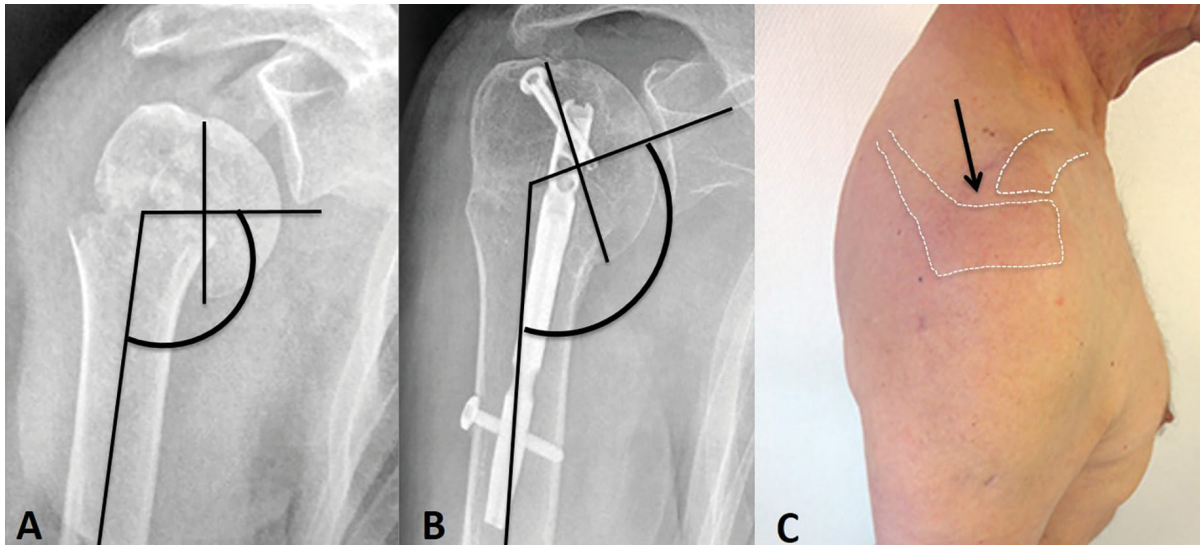


Figure 9: Correction of a varus-displaced fracture using the Neviaser portal for IM nail insertion. Preoperative humeral inclination is  $95^{\circ}$ , whereas postoperative inclination is measured at  $125^{\circ}$ . The Neviaser portal is defined by the clavicle anteriorly, the spine of the scapula posteriorly, and the medial border of the acromion. The nail is entering the trapezius muscle and then the supraspinatus muscle. This portal is useful to correct a severe varus tilt associated to some posterior tilt of the humeral fragment.

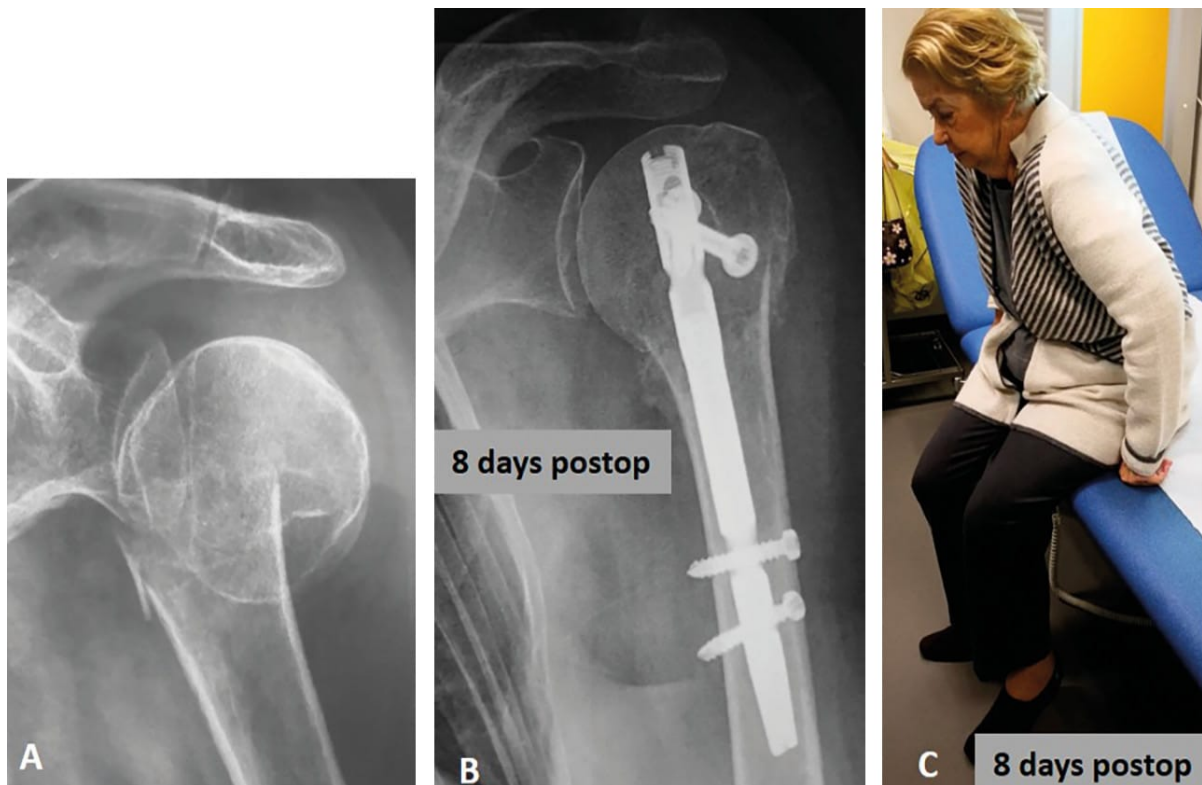


Figure 10: The solidity of the construct given by the third-generation IM locking humeral nail is demonstrated by this 91-year-old patient who is able, 8 days after surgery, to push up spontaneously, without any pain, on her left operated upper limb to stand up from the table.

The results of our study suggest that the use of this new generation of IMN minimizes complications reported with existing current IM nails, and is a reliable and safe alternative to locking plate fixation for the treatment of displaced two-part surgical neck fractures. The straight design and small dimensions (for diameter and length) of the Aequalis™ IMN avoid iatrogenic cuff and cartilage problems seen in the past with first- (unlocked) and second-generation (bended) of humeral nails. Except the one patient with a proud nail, no patient complained about cuff tendinitis or pain. Our results also confirm the benefits of locking screw technology applied to IM humeralnails (no cases of screw migration), and tuberosity-based fixation for proximal screws (no screw penetration and glenoid erosion in case of humeral head necrosis).

From a technical standpoint, optimal entry point for the nail is of paramount importance and must be based on the displacement of the humeral head fragment: the nail should enter more lateral in case of valgus tilt and more medial in case of varus tilt. The use of intraoperative fracture site impaction (“backslap” technique) reinforces the construct and allows immediate activity and rehabilitation.

## CONCLUSION

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Percutaneous IM nailing, using a third-generation of humeral nail, is a reliable and safe alternative to locking plate fixation for the treatment of displaced 2-part surgical neck fractures. It provides high rate of fracture healing and excellent clinical outcome scores. No morbidity related to the passage of the nail through the supraspinatus muscle and the cartilage was observed. Our results encourage us to pursue our experience. In our opinion, percutaneous IM nailing of displaced surgical-neck fractures using a third-generation IM nail provides the combined advantages of pinning (biological fixation with minimal dissection of the fracture site) and plating (biomechanical strong construct), without the drawbacks of both techniques.

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