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Anatomic and surgical basis for posteroanterior distal locking of the endomedullary antegrade humeral nailing.

Ballesteros-Betancourt JR [1,2], Ríos M [1], García-Tarriño R [1], Domingo A [1], Peidro Ll [1], Llusá M [1,2].

1 Department of Traumatology and Orthopaedic Surgery. Hospital Clínic. University of Barcelona. Spain.
2 Macro- and Micro-Dissection and Surgical Anatomy Laboratory, Human Anatomy and Embryology Department, Faculty of Medicine, University of Barcelona. Spain.

Abstract

Recent years have witnessed the increasing use of endomedullary nails in diaphyseal long-bone fractures. These rods have considerably become a significant advance in fracture treatment. However, one of their weak points has been the need to lock them at a distal level at their point of insertion.
Since the introduction of these nails, many ideas have been proposed to make their locking easier, to reduce possible iatrogenic neurovascular damage, and surgical and exposure-to-radiation times. In the particular case of the humerus, when the option is antegrade nailing, locking is usually carried out in an anteroposterior direction, with an anterior approach at a distal arm level and a potential associated morbidity including vein damage, traumatic dissection through muscles, and damage to the musculocutaneous nerve.
Sometimes locking is carried out in a lateromedial direction with a lateral arm approach at a distal level, also with associated morbidity, including damage to the radial nerve, to the cubital nerve, to veins, and to the humeral and the radial recurrent arteries.
The authors of this paper propose, in order to perform the distal locking of humeral antegrade endomedullary nails easier, a posteroanterior distal locking with a minimum posterior percutaneous approach of the arm. The anatomical study of the extremity shows that this technique is the least damaging for muscular and neurovascular structures in the extreme distal end of the arm and, therefore, decreases possible complications; particularly, neurovascular pre- and post-surgical complications. Finally, the authors describe the details of patient positioning to carry out their proposed technique.

Keywords

Endomedullary nail, humerus fracture, posteroanterior locking.

Introduction

Recent years have witnessed the increasing use of endomedullary nails in diaphyseal long-bone fractures. These rods have considerably become a significant advance in fracture treatment. In connection with the use of osteosynthesis plates, they have contributed to reduce surgical time and infection indexes, and have allowed patients a fast rehabilitation and an early return to their usual tasks (1-3). However, one of their weak points has been the need to lock them at a distal level at their point of insertion. Since the introduction of these nails, many ideas have been proposed to make their locking easier, to reduce possible iatrogenic neurovascular damage, and surgical and exposure-to-radiation times (4-8).

In the particular case of the humerus, inserting endomedullary nails has been discussed in its relation to antegrade insertions and their complications at rotator cuff levels, while retrograde insertions have been questioned due to their complications at entrance point levels (9,10). In such cases, when the option is

antegrade nailing, locking is usually carried out in an anteroposterior direction, with an anterior approach at a distal arm level and a potential associated morbidity (vein damage, traumatic dissection through muscles, damage to the musculocutaneous nerve, etc.).
Alternatively, locking is carried out in a lateromedial direction with a lateral arm approach at a distal level, and it´s also with associated morbidity such as damage to the radial nerve, to the cubital nerve, to veins, and to the humeral and the radial recurrent arteries (11–16).

The authors of this paper are proposing, in order to make the distal locking of humeral antegrade endomedullary nails easier, a posteroanterior distal locking with a minimum posterior percutaneous approach of the arm. The anatomical study of the extremity shows that this technique is the least damaging for muscular and neurovascular structures in the extreme distal end of the arm and, therefore, decreases possible complications; particularly, neurovascular pre- and post-surgical complications. Finally, the authors describe the details of patient positioning to carry out their proposed technique.

Material and Methods

Ten cryopreserved corpse specimens were dissected in the Anatomy Laboratory. Their humeral arteries were previously injected with color latex at their arms' levels, with repletion of the vascular tree to arteriole levels.

A formal dissection procedure was carried out for the study of the main muscular and neurovascular structures at the arm's distal level. The structure of the humerus was specifically studied with transverse sections at its lower third.

During clinical and surgical practice, distal locking was modified using a posterior approach instead of anterior or lateral approaches. Twenty two patients were operated using this technique. The next steps followed exactly what the original technique describes.

Surgical technique

1. Patients are placed on a beach-chair position. Radioscopy equipment is located beside the operating table at the patient's cranial end. The fluoroscope is oriented 45º in relation to the vertical. Then, the long endomedullary humerus nail is implanted with its proximal locking according to the formal technical procedure.

2. Patients should be kept in the same beach-chair position at the time of the distal locking of the nail, with no angular variation of the back of the table. It is recommended to raise the operating table to a maximum height and move the fluoroscope closer to the elbow's anterior face. Besides, it should have an 80º–90º inclination, in such a way that the x-ray beam angle of incidence may be almost parallel to the floor. A good anteroposterior projection of the humerus' distal end can be obtained this way, and work can be done easily in that area (Fig. 1).

3. A surgeon's assistant should hold the operated superior extremity at the level of the wrist to achieve the best projection of the distal humerus with rotating and flexion and extension movements. You can decide the correct position, aided by a metal instrument such as scissors (Fig. 2).

Advice: As an optional procedure, assistants may rest their hands on the operating table's lateral support to achieve more stability when securing the extremity. Surgeons may work seated. It is recommended to keep

Figure 1. Patient positioning

Figure 2. Entry point.

Figure 3. Entrance point with the aid of radiology.

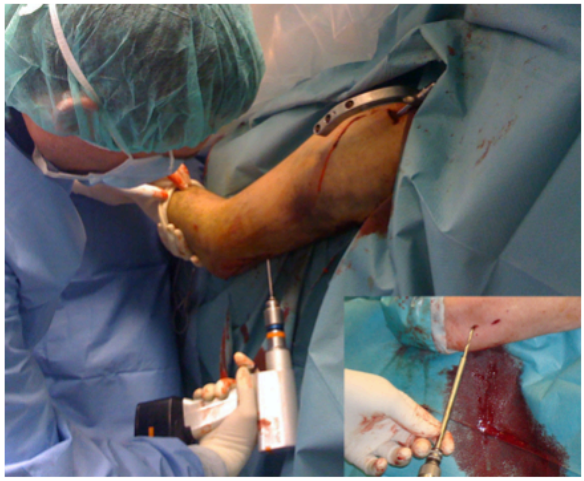

Figure 5. Drilling the holes for the distal locking.

Figure 4. Performing an initial perforation on the cortical bone

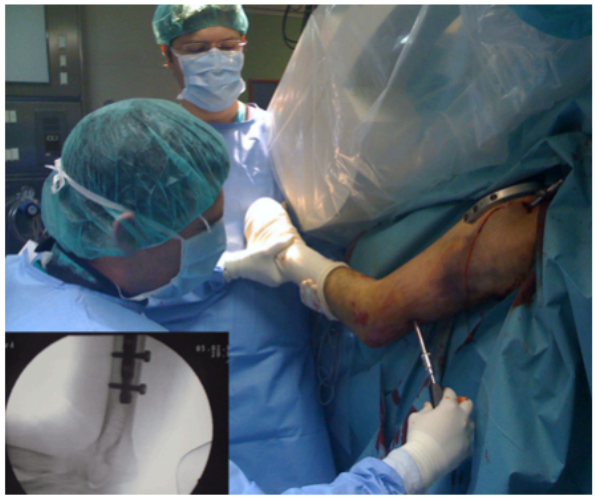

Figure 6. Insertion of the screws

the fluoroscopy emitting source away from the back of the arm so the motor driving mechanism can be manipulated comfortably.

4. Surgeons locate the surgical entrance point at the posterior level of the arm, at its distal end, and make two 1-cm incisions with the scalpel. Incisions are centered in the respective nail entry holes for locking (Fig. 3).
5. As soon as the two entrance points have been located at skin level, and after making a blunt dissection to the bone's level, surgeons proceed to find the right location to drill on the posterior aspect of the distal humerus. A surgical stylet or a 2-mm Kirschner needle may be used to mark the entrance point (Fig. 4).

Advice: It is recommended to use a short diamond-head surgical drill bit. This step can be avoided that way and the entrance site may be located directly with the bit and then drill. The diamond head of the bit allows it to penetrate the bone and avoids loosing the central line during the first seconds of drilling.

In case the available bit is too long, a (proximal locking) cannula may be used to increase stability when drilling (Fig. 5).

6. Once drilling is over, humeral diameters are measured at this level. Advice: It should be remembered that the mean humeral diameter at this level is 24 mm. That is why this step could be omitted.

7. Finally, the following procedure is the distal anteroposterior locking of the humerus endomedullary nail (Fig. 6).

Advice: To secure the screws, and to prevent losing them in the soft-tissue thickness during distal locking, it is recommended to tie them with the help of an

absorbable suture and a simple surgeon's knot that will be cut after finishing the procedure.

Results

The usual incision during anterior approach was centered on the midline of the distal third of the arm's anterior face. Superficial (cephalic and basilic) veins can be found at this level after opening the skin, but their arrangement may vary (Fig. 7). The *biceps brachii* muscle (BB), with a fleshy aspect, may be seen after opening the anterior antebrachial fascia.

It prolongs itself, in a characteristic way, with the *lacertus fibrosus* and its main insertion tendon, which penetrates deep [into the arm] and is fixed to the posterior face of the bicipital tuberosity of the radius. The much wider *brachialis* muscle (B) can be located under the BB muscle and beyond, on both sides, until it inserts itself in the elbow joint capsule and in the *brachialis* ulnar tuberosity just under the coronoid process.

In 100% of cases, the musculocutaneous nerve can be identified between both muscles running obliquely from the medial and superior parts to the lateral and inferior parts to superficially emerge just at the lateral edge of the BB muscle's insertion tendon at a Hueter's line level (Fig. 8). On its lateral aspect, the radial nerve runs at the level of the arm's distal third. It is medially limited by the BB muscle and laterally limited by the *brachioradialis* muscle (BR) in 100% of cases. Medially to the BB muscle, the humerus' neurovascular bundle (the most superficial median nerve, the brachial artery and the two accompanying veins) is wrapped inside a specific aponeurotic triangular space called the "Cruveilhier's canal," which is limited by muscles B and BB, the internal intermuscular septum and the brachial aponeurosis, which cover them (Fig. 9). The superficial tricipital aponeurosis can be found when approaching the posterior compartment [of the forearm] at this level. It has a pearly aspect and is formed at the expense of the long head of the *triceps brachii* muscle (TB). The true tendon of the TB muscle can be seen as soon as it [the superficial tricipital aponeurosis] has been removed. It is sagittally located in the muscle layer's thickness (in a similar way as the intermuscular tendon of the anterior *rectus femoris* muscle). It is formed at the expense of the *vastus medialis* of the TB muscle (Fig. 10).

There are no important neurovascular structures in the midline at posterior and distal levels of the arm that can be damaged during posterior and distal arm approaches (Fig. 11). In the transverse sections, the distal third of the humerus' bone shows a triangular shape with an anterior apex that defines its anteromedial and anterolateral faces, and a leveled surface on its entire distal half called the "posterior face" (Fig. 12). This study found that the posteroanterior diameter of the humerus at the distal third is 24 mm (mean value: 24.2mm (23.4-24.6)).

Figure 7. Superficial veins, anterior view of the elbow.

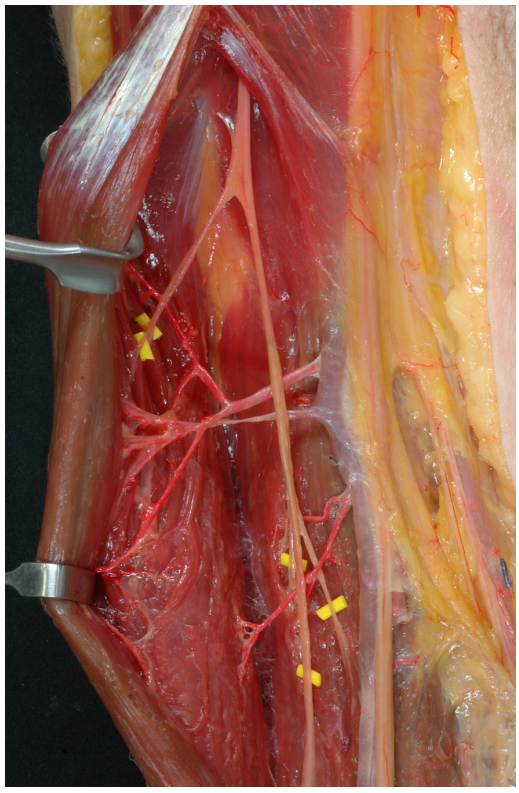

Figure 8. Musculocutaneous nerve branches (yellow marks).

Figure 9. Transverse sectional view of the distal arm.

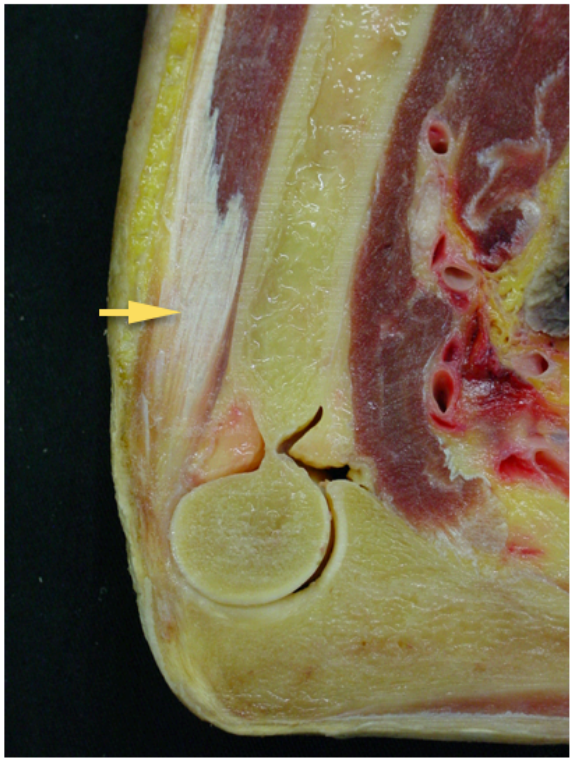

Figure 10. Triceps brachii muscle and tendon.

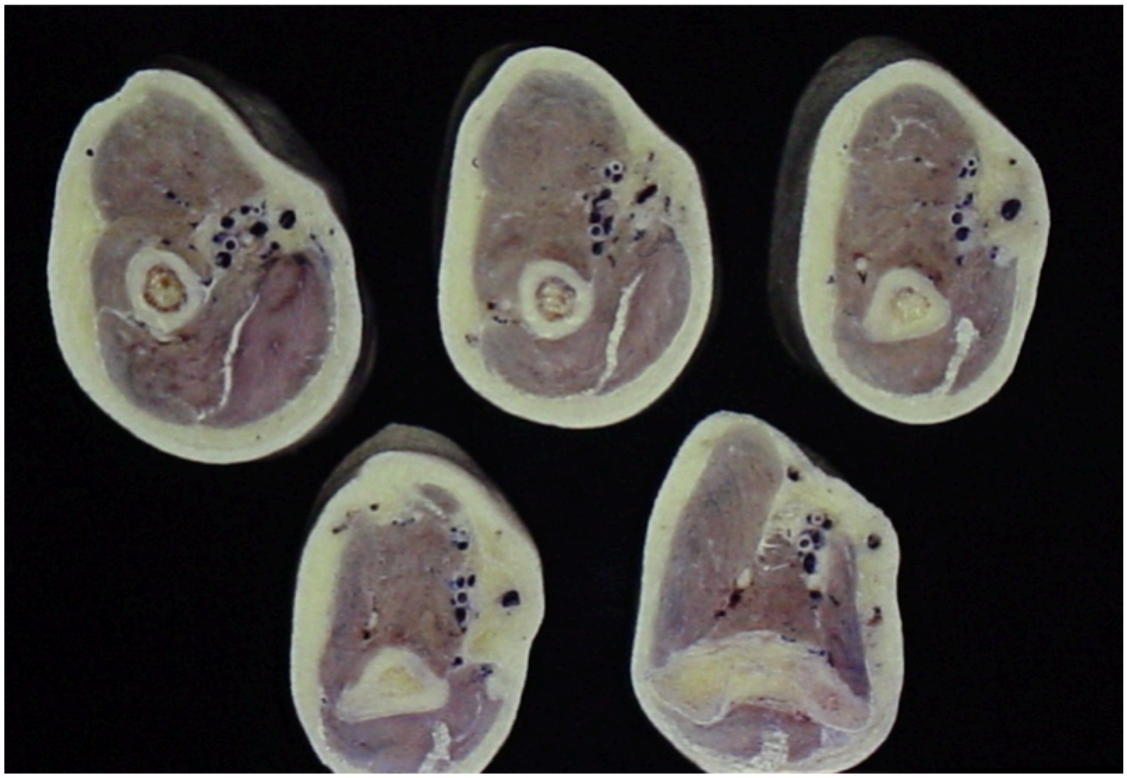

Figure 11. Transverse sections of the distal arm, downwards from left to right. The posterior approach for distal locking proves to be safe, since the neurological and vascular structures remain anterior.

Figure 12. Section of the distal humerus. The triangular shape offers the easiest point of entry from posterior (base of the triangle), and not from anterior, where the drilling can slip easily to lateral or medial.

Discussion

When it is indicated the use of endomedullary nailing in diaphyseal fractures of the humerus with an antegrade technique, the problem of a distal locking has to be faced. It can be carried out with a minimum ("percutaneous") anterior approach for drilling.

However, a 4-5 cm approach, an anterior anatomical plane-to-plane dissection and drilling of the humeral diaphysis under direct visual control are usually recommended both in cases of locking in an anteroposterior direction (since the musculocutaneous nerve obliquely crosses the area where the bit and the screw will be introduced in a possible point of iaotrogenic damage), and in cases of locking in a lateromedial direction (since the presence of the radial nerve is also a possible point of iaotrogenic injury).

The anterior dissection on the distal end of the arm requires advancing carefully due to the presence of important neurovascular structures. Superficial (basilic and cephalic) veins run at that level. The radial nerve lies at a deeper level in the lateral aspect of the arm. The musculocutaneous nerve occupies the space between muscles B and BB.

The median nerve, the humeral artery and accompanying veins, can also be found in the medial aspect of the arm (11,13-16). Besides, although infrequent, there are chances of anatomical variations, like the high division of the humeral artery (14-21).

Finally, and independently from the kind of anterior approach chosen, an added difficulty can be found when drilling in the humerus' anterior vertex or *crista*, since it causes the surgical starter stylet and the bit to constantly slip to one side or the other. This may risk damaging the adjacent neurovascular structures, the radial nerve on the external side, and the neurovascular bundle of the arm on the internal side.

Therefore, choosing an anterior approach risks making cuts on neurovascular structures, implies dissecting large volumes of tissue in BB and B muscles, and also drilling on an angled surface. These are the reasons that cause the need to find a technical solution to minimize those difficulties. A posterior approach, with the intention to carry out a anteroposterior locking, does not cause a problem with large-volume superficial veins, and the volume of muscular tissue to dissect is not important. As a matter of fact, at this level, and just in the midline, only the *vastus medialis* of the TB muscle and the superficial tricipital aponeurosis can be found. This situation will also minimize bleeding.

Finally, and most important, the presence of a flat surface—the posterior distal face of the humerus—can

be counted on. It greatly makes localization of the entrance point with the stylus and posterior drilling much easier. That is why surgical and exposure-to-radiation time may be considerably reduced (14).

Patient positioning continues to be the usual: a beach-chair position. Therefore, it does not represent a change of strategy as far as placing the operating table, the fluoroscope, the surgeons' assistant nurse or the instrument table is concerned. Consequently, work distribution in the operating theater is as usual. It does not need new operating instruments, since the usual will be used.

Besides, it avoids a trend to externally rotate the distal fragment of the humerus that is found during anterior locking. When using this technique, extremities are usually supported on an auxiliary table or on the fluoroscope. To manage the correct projection, it is necessary to abduct the arm and rotate it externally to expose its anterior face and achieve centering of the nail's entry holes for distal locking. However, with posteroanterior distal locking, the arm is kept in the same position as when the nail was introduced, which will not expose the distal fracture fragments to an external rotation or a forced abduction.

Therefore, the authors consider that this technique may be useful during intramedullary nailing of the humerus. A comparative clinical study remains necessary to substantiate these potential advantages

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Conflicts of interest statement

The authors certify that they have no affiliations with or involvement in any organisation or entity with any financial interest, or non-financial interest in the subject matter or materials discussed in this manuscript.

Correspondence

Dr. José R Ballesteros-Betancourt, MD, FEBOT.

Trauma Unit. Orthopaedic and Traumatology Surgery Department, Hospital Clínic Barcelona. Barcelona. Spain. Macro- and Micro-Dissection and Surgical Anatomy Laboratory, Human Anatomy and Embryology Department, Faculty of Medicine, Barcelona University.

Address: C/ Villarroel 170 ICEMEQ. Escalera 4, Planta 4. 08036. Barcelona. Spain. E-mail address: jrballes@clinic.ub.es

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