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Is risk-free minimally invasive humeral shaft osteosynthesis possible? A cadaver study (technique and anatomy)

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KEYWORDS
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Abstract
Purpose: To determine the feasibility of using minimally invasive percutaneous plate osteosynthesis (MIPPO) in the treatment of humeral shaft fractures and analyze the anatomical relations of the different bodily structures with the fixation plate.
Introduction: Humeral shaft fractures account for 1.6% of all surgical fractures. Open reduction and compression plate fixation is a universally accepted method, but since it requires an extended dissection it could cause a lesion to the radial nerve. Another alternative is to use intramedullary nails, but the percentage of complications associated to them is similar.
Materials and methods: We conducted a study of 5 cadavers. At the proximal level, we carried out a deltopectoral mini approach; the distal incision was performed at about 5 centimeters proximally to the elbow flexure in the inferomedial region of the arm. Once the two mini approaches were completed, a blunt instrument was used to drive an anterior extraperiosteal sub-brachial tunnel on the anterior aspect of the humerus through which a 10-hole straight narrow plate was introduced from proximal to distal.
Results: Once the osteosynthesis was completed, we identified the relationship of the different anatomical structures with the plate, extending both incisions without finding any significant anatomical structure on the anterior aspect of the humerus that could be damaged.
Conclusions: Even if technically challenging, the MIPPO technique described herein is less invasive or traumatic than open reduction and plate fixation, and it is not associated with any special risks of injury to the radial or musculocutaneous nerves.
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PALABRAS CLAVE
Húmero;
Fractura;
Anatomía;

¿Es posible la osteosíntesis mínimamente invasiva de la diáfisis del húmero sin riesgos? Estudio en el cadáver (técnica y anatomía)

Resumen

Objetivos: Determinar la viabilidad de aplicar la técnica MIPPO (minimally invasive percutaneous plate osteosynthesis, 'osteosíntesis percutánea con placa mínimamente invasiva') en el tratamiento de las fracturas diafisarias de húmero, y observar las relaciones anatómicas de las distintas estructuras nobles con la placa de osteosíntesis.

Introducción: Las fracturas de la diáfisis humeral representan el 1,6% del total de las fracturas quirúrgicas. La reducción abierta y la osteosíntesis con placa a compresión es un método aceptado universalmente pero, al requerir una disección extensa, hay posibilidades de dañar el nervio radial; otra alternativa es el uso de clavos intramedulares, pero el porcentaje de complicaciones es similar.

Material y método: Para esto, se realizó un estudio en 5 cadáveres. Se procedió a realizar un miniabordaje deltopectoral en la zona proximal y se realizó la incisión distal a unos 5 cm, proximal a la flexura del codo en la región inferoexterna del brazo. Una vez realizados los 2 miniabordajes, se procedió a realizar un túnel subraquial anterior extraperióstico con un objeto romo, siempre por la cara anterior del húmero, y se introdujo una placa recta estrecha de 10 orificios de proximal a distal.

Resultados: Una vez realizada la osteosíntesis, se procedió a identificar la relación de las distintas estructuras anatómicas con la placa prolongando ambas incisiones: no se encontró ninguna estructura anatómica noble en la cara anterior del húmero que pudiera dañarse.

Conclusiones: Aunque pueda ser técnicamente difícil, la técnica MIPPO descrita aquí es menos invasiva y traumática que la reducción abierta y la colocación de una placa, además no supone riesgos especiales de lesión en el nervio radial o musculocutáneo.
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Introduction

Humeral shaft fractures account for 1.6% of all operative fractures. In the last few years incidence of these fractures has increased as a result of the higher prevalence of traffic and occupational accidents. Diaphyseal fractures pose radically different problems from those raised by proximal humeral fractures. Apart from healing time differences, reduction o fan epiphyseal fracture requires great accuracy while the aim of diaphyseal reduction is leg length, bone axes and rotational preservation as well as allowing small non-anatomical alterations. For this reason, the majority of diaphyseal fractures can be treated conservatively[1-3]. Nonetheless, in special situations, such as cases where the result of closed reduction is unacceptable (open fractures, post-manipulation radial nerve palsy or multiple fractures) surgical treatment is indicated[4-6]. Moreover, there is growing social pressure to achieve early function and comfort, which means that external immobilization is judged as uncomfortable, insufficient and inefficient, often delaying a surgical procedure that could have been performed immediately. This occurs especially with your problems that have sustained an occupational or Sports-related injury and with obese women for whom conservative treatment constitutes a several weeks- and at times months-long torment.

Open reduction and internal fixation with a compressive plate is a universally accepted method, which has a high incidence of successful healing and allows early motion[4,6], but as it requires extensive dissection, there is a risk of damaging the radial nerve. Intramedullary nailing also induces fast recovery with the advantage that it is a percutaneous procedure that minimizes soft tissue damage[5,7].

The role played by internal fixation in the treatment of these fractures remains controversial. One of the reasons is the high rate of complications related with delayed healing and pseudoarthrosis (7.4%of cases)[12-14], avulsions at the nail insertion site (4.2%of cases)[13] and radial nerve palsy (4.2% of cases)[13].

As a result of the technical advances in the field of minimally invasive devices (MIPPO (minimally invasive percutaneous plate osteosynthesis), these techniques have gained popularity in recent years with satisfactory clinical results[8-10]. Their advantage could lie in the fact that lower blood loss and less soft tissue damage they afford might justify a slight imperfection in the alignment of bone fragments. Although there are several studies of this technique performed in the lower limbs[15], studies of the application of MIPPO in the upper limbs are scarce[16]. The plate is inserted percutaneously, with small incisions in the proximal and distal areas. This methods is more sparing of the soft tissues and preserves the fracture hematoma and the blood circulation of the injured bone fragments.

It could be thought that percutaneous insertion of a fixation plate for the treatment of humeral Shaft fractures could damage the radial nerve. To date, 4 surgical approaches have been described for treating humeral shaft fractures[11]: posterior, anterolateral, anterior and posterolateral. Open reduction and plating is normally performed through an anterolateral or posterior approach. The anterolateral approach is recommended for middle or upper third fractures, while the posterior approach is reserved for lower third fractures[6,11]. The anteromedial approach is less useful given its neurovascular connections and the anterior approach is only rarely used. However, the radial nerve never crosses the anterior aspect of the humerus, which means that the risk to injure this area is minimal.

The purpose of this study is to determine the feasibility to apply the MIPPO technique to the treatment of humeral shaft fractures by placing a fixation plate on the ventral aspect of the humerus through a mini deltopectoral approach in the upper third and an anterior and inferior approach to the arm; another aim was to observe the anatomic relationship between the radial nerve and the fixation plate.

Materials and methods

This study was performed on 10 arms from 5 formol-preserved cadaver. The procedure was carried out with the full specimens in the supine position. We made sure that none of the cadavers had any previous scars in the area indicating some sort of surgery or trauma in the region.

We performed a mini-deltopectoral approach in the proximal area. The incision was 4-5 cm long (fig. 1). A characteristic dissection was carried out between the pectoral muscle and the medial border of the deltoid advancing until the anterior aspect of the humerus was reached. In this case, the main risk was injuring the chephalic vein.

The distal incision, 3-4 cm long, was made 5 cm proximally about 5 cm proximal to the antecubital fossa. As usual, it was made in the inferolateral area of the arm. The interval between the biceps brachii and the brachalis was identified. The biceps was reflected medially in order to identify the musculocutaneous nerve, which runs over the brachialis. Subsequently, the brachialis was divided into 2 portions along its midline until contact was established with the anterior aspect of the humeral shaft. Now, the biceps, the medial portion of the brachialis and the sensory branch of the musculocutaneous were reflected to the medial side. The lateral portion of the brachialis, which protects the radial nerve, was reflected to the lateral side. At this point, the radial nerve perforates the lateral intermuscular wall and runs between the brachioradialis and the brachialis (fig. 2).

Once the 2 mini-approaches were completed, an anterior extraperiosteal sub-brachial tunnel was driven with a blunt instrument, always from the anterior aspect of the humerus (fig. 3). The greatest difficulty may be found in the proximal area because of the intimate relationship between the fibers of the deltoid «V» at its attachment to the humerus. Care must be taken in the distal area so that the radial nerve is not damaged; the humerus should be tunnelized in its anterior or anteromedial aspect.

Following preparation of the subrachialis, a narrow straight 10-hole plate was introduced from distal to proximal. The plate was fixed to the proximal humerus with a screw. The plate was fixed to the proximal humerus with a screw. Next, once the plate was placed on the anterior aspect of the humerus, it was distally fixed with 3 screws and finally stabilized with another 2 proximal screws.

Once the osteosynthesis was completed, the relationship of the different anatomic structures with the plate. A wide deltopectoral approach was made, in order to identify the axillary nerve, the radial nerve, the musculocutaneous nerve and the orientation of the plate. The tunnel was exposed and subsequently bound by the proximal and distal incisions (fig. 4).

Results

Plates were correctly placed on the anterior (extraperiosteal) humeral aspect, under the brachialis muscle, in all specimens, with a relatively thin muscle layer between the plate and the periostium.

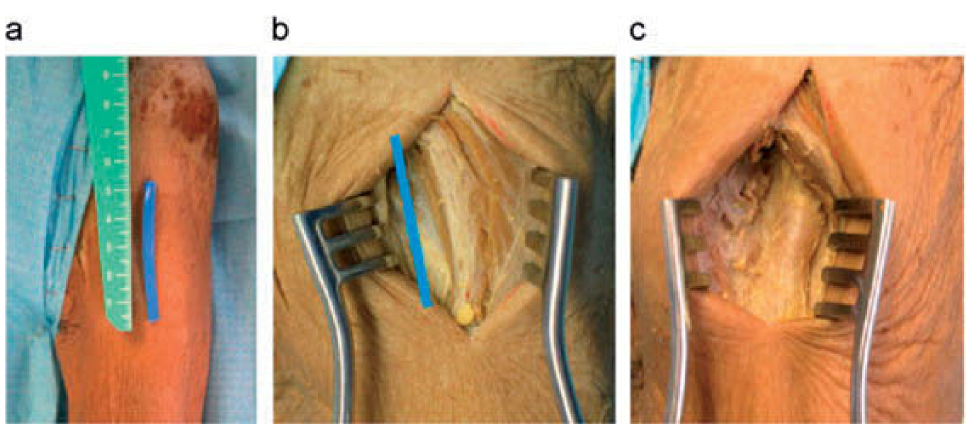

Figure 1 Proximal 4-5 cm long incision (a), blunt dissection that spares the cephalic vein (b) until the anterior aspect of the humerus is reached (c).

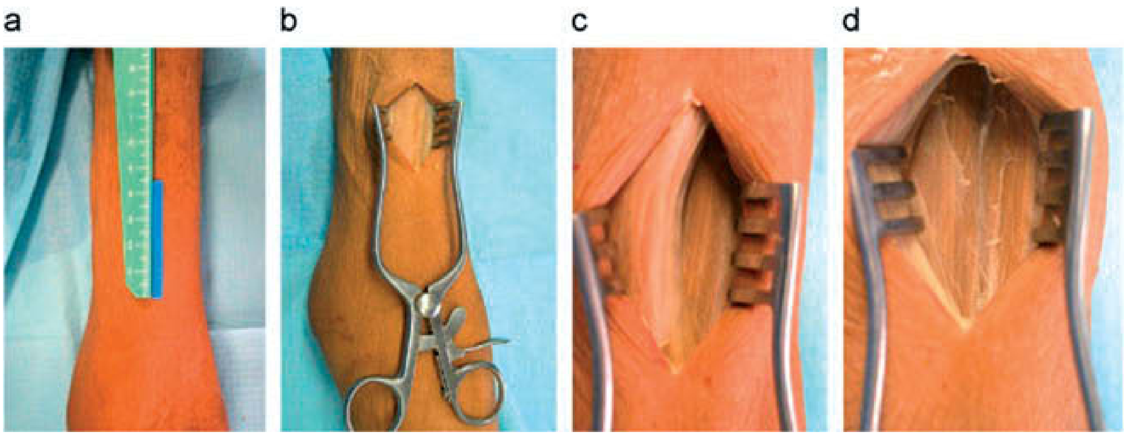

Figure 2 3-4 cm long distal incision (a and b); identification of the plane between the biceps and the brachialis (c); location of the musculocutaneous nerve (sensory branch) (d).

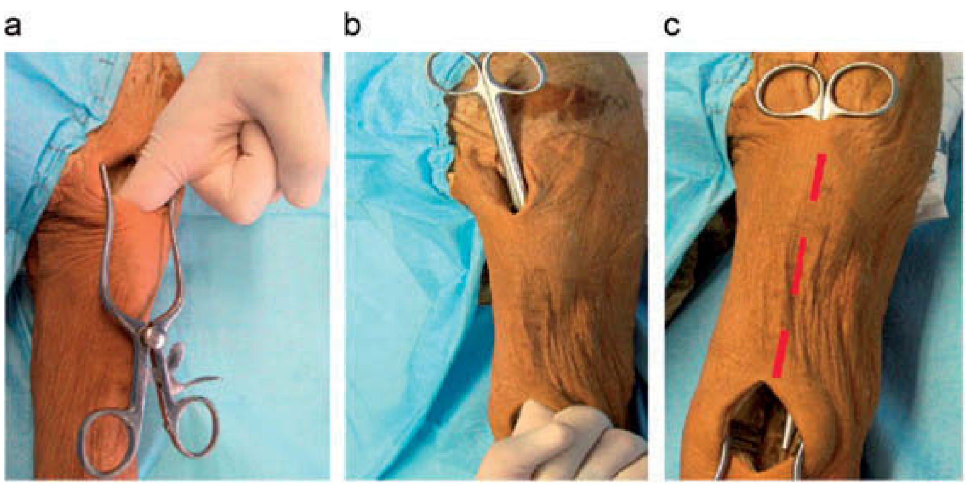

Figure 3 Perforation of a sub-brachial tunnel with a blunt instrument (a, b and c); the straight plate will subsequently be introduced through that tunnel.

When the soft tissues were dilacerated in order to introduce the plate, the brachialis muscle was slightly injured in the area of the tunnel.

The axilliary nerve runs from the posterior aspect of the proximal humerus proximal toward the lateral region; it is not possible to damage it when the anterior deltopectoral approach is used in the proximal incision.

The radial nerve (the branch originating at the posterior secondary trunk of the plexus) runs along the arm from the axilla (posterior to the axillary artery), crosses the humerotricipital sulcus, descends down the posterior aponeurotic cavity (between the posterior aspect of the humerus and the anterior aspect of the triceps) in the radial groove and, at the level of the elbow, runs along the depths of the lateral intertubercular groove, which means that under no circumstances can the radial nerve be damaged. The closest distance between the radial nerve and the lateral aspect of the plate was at least 2.5 cm with the arm in full supination. When the arm was pronated, the distance decreased (fig. 5).

As regards the musculocutaneous nerve, which has an essentially motor component in its upper half and a sensory component in its bottom half, it runs between the biceps brachii and the brachialis and is protected by the medial retractor when a distal approach is used. In none of the specimens dissected did we observe any injury to the musculocutaneous nerve (fig. 6).

Discussion

Several minimally invasive methods have been developed for fracture Management and MIPPO techniques enjoy an increasing level of popularity. The first MIPPO techniques were designed for subtrochanteric and distal fractures of the femur[9]. Subsequently, these methods were modified and adapted to the treatment of other fractures, such as femoral shaft fractures[17], proximal and distal tibial fractures[8,9,17] and fractures of the foot[18]. MIPPO technique for the humerus were previously described by Fernandez[19] and Apivatthakakul[20], who introduced a combined approach technique: a deltoid incision on the lateral aspect of the humerus and another incision in the distal region of the bone. The first author published a report on 20 cases treated chiefly with this technique, with satisfactory results.

Figure 4 Exposure of the tunnel bound by the proximal and distal incisions.

This cadaver study, like others of its kind[20], shows that it is possible to perform a minimally invasive approach to the anterior aspect of the humerus. The course of the radial nerve has been well described in the literature[21] and in textbooks[11,22]. The nerve passes through the triangular space between the long head of the biceps and the humeral axis, below the teres major. It crosses the posterior aspect of the humerus approximately 20.7 ± 1.2 cm proximal to the epicondyle and 14.2 ± 0.6 cm proximal to the epitrochlea.

As in the proximal region the radial nerve is located in the posteromedial humeral shaft; the proximal incision of the MIPPO approach can under no circumstances damage it. In the middle part, the nerve runs posterior to the shaft, which also protects it from any damage since the plate is introduced through the anterior aspect of the humerus. However, in this area care must be taken that the screws fixing the plate are not in a purely anteroposterior direction in order to prevent potential damage to the radial nerve in the spiral groove. Nonetheless, as in these cases the plate is used as an internal strut, as a kind of bridge, screws are rarely used in the middle area[23]. In the distal area, the nerve runs laterally between the brachioradialis and the brachialis muscles. In this area, the lateral portion of the brachialis acts as a buffer between the nerve and the retractor. The Hohmann retractor should not be used on the lateral aspect of the humerus so as not to compress the bone.

The position of the forearm influences the position of the nerve in its distal-most portion. In the dissection carried out for the present study, we found an area of the brachialis muscle between the plate and the radial nerve in all specimens. According to traditional wisdom, the position of the forearm is related to the position of the radial nerve in its distal portion, so that in maximum supination the nerve shifts laterally and in pronation it shifts medially, for which reason in these cases when the tunnel is driven and the plate introduced it is recommended that the forearm should

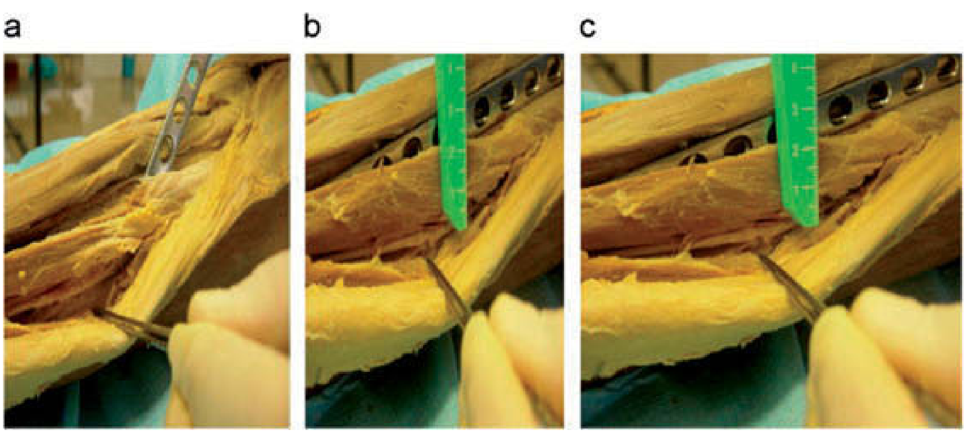

Figure 5 Proximal area (a y b). Note the distance between the plate and the radial nerve, and the safety distance between the radial nerve and the plate distally (c).

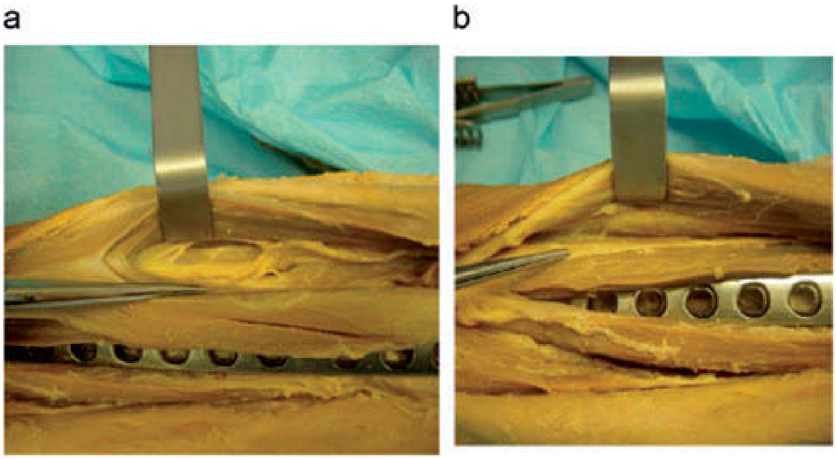

Figure 6 Relationship of the plate with the musculocutaneous nerve in the middle (a) and the distal humerus (b).

be placed in maximum supination to avoid potential damage. This, combined with splitting the brachialis in half and reflecting the medial portion of the muscle together with the nerve, will prevent damage to the distal-most portion of the brachialis.

In the MIPPO technique as described by Fernandez[19], the tunnel begins in the sub-deltoid space and bends 90° towards the anterior aspect of the humerus, in the direction of the sub-brachial space. In this case it is the axillary nerve that could be damaged in the deltoid region when the lateral plate is introduced. In this case, an injury could also occur when dilacerating the deltoid fibers or when the plate is compressed against the bone on proximal screw insertion. This was prevented in the present case since the proximal approach is deltopectoral rather than purely lateral.

Another problem that may arise is interference of the plate with the biceps tendon, as described by Fernandez[19], but in our case the plate was lateral to the biceps and medial to the deltoid so it could not interfere with the course and hence with the function of these tendons. It should be remembered that this study was performed in cadavers with an intact humerus. However, a humeral fracture may disrupt a subject's anatomic landmarks. For this reason it is advisable to restore the alignment of the arm before performing any incisions; this can be done by means of simple traction or in special cases through an external fixator, mainly during the tunneling and plate introduction processes. The authors of this study have not performed a biomechanical study, since that was not the aim of this paper.

To conclude, although technically difficult at times, the MIPPO technique described herein is less invasive and traumatic than open reduction and plate fixation. This technique may be indicated in the treatment of simple or comminuted humeral shaft fractures, which extend around 6 cm from the attachment of the deltoid toward the olecranon fossa. This would make it possible to place at least 3 screws both in the proximal and the distal areas. The technique might also be indicated in humeral fractures that cannot be treated with an intramedullary nail because the diameter of the canal is too small.

Conflict of interests

The authors have declared that they have no conflict of interests.

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