Radiological Criteria for Rotational Reduction in Humeral Shaft Fractures

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ABSTRACT

Introduction: Humeral shaft fractures are frequent and surgical treatment is currently favored. Consolidation in malrotation is a complication that can lead to impaired function and long-term osteoarthritis. In minimally invasive techniques, it is difficult to manage intraoperative rotation as there is no direct view of the fracture reduction. **Objective:** To describe radiological criteria for rotational reduction in humeral shaft fractures. **Materials and Methods:** Retrospective study of humerus radiographs comparing radiological criteria of the distal humerus between radiographs with internal rotation (without proximal retroversion) and radiographs with external rotation (with physiological retroversion). Criteria studied: Overprojection of the lateral epicondyle over the *capitellum* of more than 50%; sclerosis of the lower border of the olecranon fossa (OF); sclerosis of the lateral border of the OF; and asymmetry of the OF. **Results:** 200 radiographs were studied; 97% met the inclusion and exclusion criteria. Overprojection of the epicondyle over the *capitellum* was found in 83.3% of the cases. Sclerosis of the inferior border of the OF in 30%, sclerosis of the lateral border of the OF in 86.6%, and asymmetry of the OF in 80%. All criteria were statistically significant (p<0.001). When analyzing the 3 positive signs, we found a sensitivity of 70% and a specificity of 98%. The positive predictive value was 95.5% and the negative predictive value was 84.5%. **Conclusions:** Correct humeral rotation is difficult to reproduce when performing minimally invasive surgeries in patients with a diaphyseal fracture. We describe 4 radiological criteria that allow inferring a correct humeral rotation.

Keywords: Humerus fracture; diaphyseal fracture; intramedullary nail; radiological criteria; humeral retroversion; humerus surgery.
Level of Evidence: III

Criterios radiográficos para la reducción rotatoria en fracturas diafisarias de húmero

RESUMEN

Introducción: La fractura diafisaria de húmero es frecuente y, en la actualidad, se privilegia el tratamiento quirúrgico. La consolidación en mala rotación puede causar un deterioro de la función y artrosis a largo plazo. Con las técnicas mínimamente invasivas, es difícil manejar la rotación intraoperatoria al no tener una visión directa de la reducción fracturaria. **Objetivo:** Describir criterios radiográficos para la reducción rotatoria en las fracturas diafisarias de húmero. **Materiales y Métodos:** Estudio retrospectivo de radiografías de húmero comparando criterios radiográficos del húmero distal entre radiografías con rotación interna (sin retroversión proximal) y rotación externa (con retroversión fisiológica). Criterios estudiados: sobreproyección del epicóndilo lateral por sobre el *capitellum* >50%, esclerosis del borde inferior de la fosa olecraneana, esclerosis del borde lateral de la fosa olecraneana y asimetría de la fosa olecraneana. **Resultados:** El 97% de las 200 radiografías estudiadas cumplió con los criterios de inclusión y exclusión. Sobreproyección del epicóndilo por sobre el *capitellum:* 83,3% de los casos; esclerosis del borde inferior de la fosa olecraneana: 30%, esclerosis del borde lateral de la fosa olecraneana: 86,6% y asimetría: 80% de ellas. Todos los criterios con significancia estadística (p <0,001). Al analizar los tres signos positivos en conjunto, la sensibilidad fue del 70% y la especificidad, del 98%; valor predictivo positivo 95,5% y valor predictivo negativo 84,5%. **Conclusiones:** La rotación humeral correcta es difícil de reproducir en las cirugías mínimamente invasivas, en pacientes con una fractura diafisaria. Describimos cuatro criterios radiográficos que permiten inferir una correcta rotación humeral.

Palabras clave: Fractura de húmero; fractura diafisaria; clavo endomedular; criterios radiológicos; retroversión humeral; cirugía de húmero.
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INTRODUCTION

Humeral shaft fractures represent 1-3% of all adult fractures[1,2] and their incidence has a bimodal distribution with an increase between 20 and 30 years of age in men, associated with medium and high energy trauma, and a second rise in women between the ages of 60 and 70, frequently by low-energy mechanisms.[3]

Functional immobilizers (braces) are the orthopedic treatment of choice for the management of humeral shaft fractures.[4,5] However, at present, there are prospective studies and randomized clinical trials that have detected a higher rate of complications associated with this treatment and a tendency has been noted to favor surgical treatment of these fractures over conservative management.[6]

Surgical treatment alternatives include open reduction and internal plate fixation, either through an open approach or with minimally invasive techniques, or fixation with intramedullary implants that can be antegrade or retrograde.[7-11] Both techniques have achieved good outcomes; however, there is no consensus on which is the best treatment for this type of fracture.[7-11]

In humerus fractures, intramedullary nails require proximal and distal locks to fixate the functional reduction (length, angle, and rotation), so the fracture line should be located under the surgical neck of the humerus and about 5 cm from the olecranon fossa to ensure proper positioning of both locks.[12] The stability obtained is relative, with the exception of those transverse fractures where, depending on the implant used, the focus of the fracture can be compressed, giving it absolute stability.[13] In general, it is desirable to achieve the indirect consolidation of the fracture without the need to open the focus of the fracture, allowing the preservation of the fracture hematoma, and favoring the stages of consolidation.

For adequate consolidation, restoration of length, axis (or angle) and rotation are required, the latter being more difficult to achieve when dealing with comminuted fractures.[12]

A complication of intramedullary nailing—and plating with a minimally invasive technique—in humeral shaft fractures is the consolidation in excessive internal malrotation (without retroversion or anteversion of the proximal humerus), which can occur in up to 27% of cases and is associated with poor functional outcomes.[14] This is difficult to control during surgery due to the lack of direct vision of the reduction and the presence of comminution. Additionally, many times, fluoroscopy is insufficient and does not allow us to obtain a complete image of the humerus. Excessive internal malrotation results from aligning a strict anteroposterior fluoroscopic image of the proximal humerus with the distal humerus without considering the normal retroversion of the latter.

Some studies have shown that a consolidation of the humeral head in excessive internal malrotation can cause severe impairment of the patient's function and lead to osteoarthritis in the long term.[15]

There are no criteria available to infer correct humeral rotation using fluoroscopy during surgery.

The objective of this study was to describe fluoroscopic criteria that indirectly allow determining a correct retroversion of the humeral head.

MATERIALS AND METHODS

200 humerus radiographs taken during 2015 and 2016 were reviewed. We included studies that allowed complete visualization of both proximal and distal humerus joints from patients >18 years of age (skeletal maturity) with no surgical or traumatic history.

One hundred of these radiographs showed the humeral head in external rotation, simulating a true anteroposterior radiograph of the proximal humerus without retroversion. In these, a clear difference between both articular surfaces could be appreciated and the humeral head was observed with its largest radius. The remaining 100 radiographs showed a true anteroposterior position of the distal humerus. They showed a profile projection of the capitellum and trochlea, with both epicondyles viewed in profile with the greatest distance between them (Figure 1).

Radiographs that did not include the entire humerus in the projection, and those that showed osteosynthesis material, previous fractures, tumor, inflammatory lesions, or bone diseases were excluded.

Based on our experience, we describe four radiological criteria that allow predicting the correct rotation of the distal humerus while maintaining a true anteroposterior image of the proximal humerus. In the surgery for humeral shaft fracture with antegrade intramedullary nailing, after blocking the distal or proximal area, the respective block is prepared with a true anteroposterior image of the proximal humerus. The distal humerus should be externally rotated with fluoroscopic support to achieve correct retroversion.

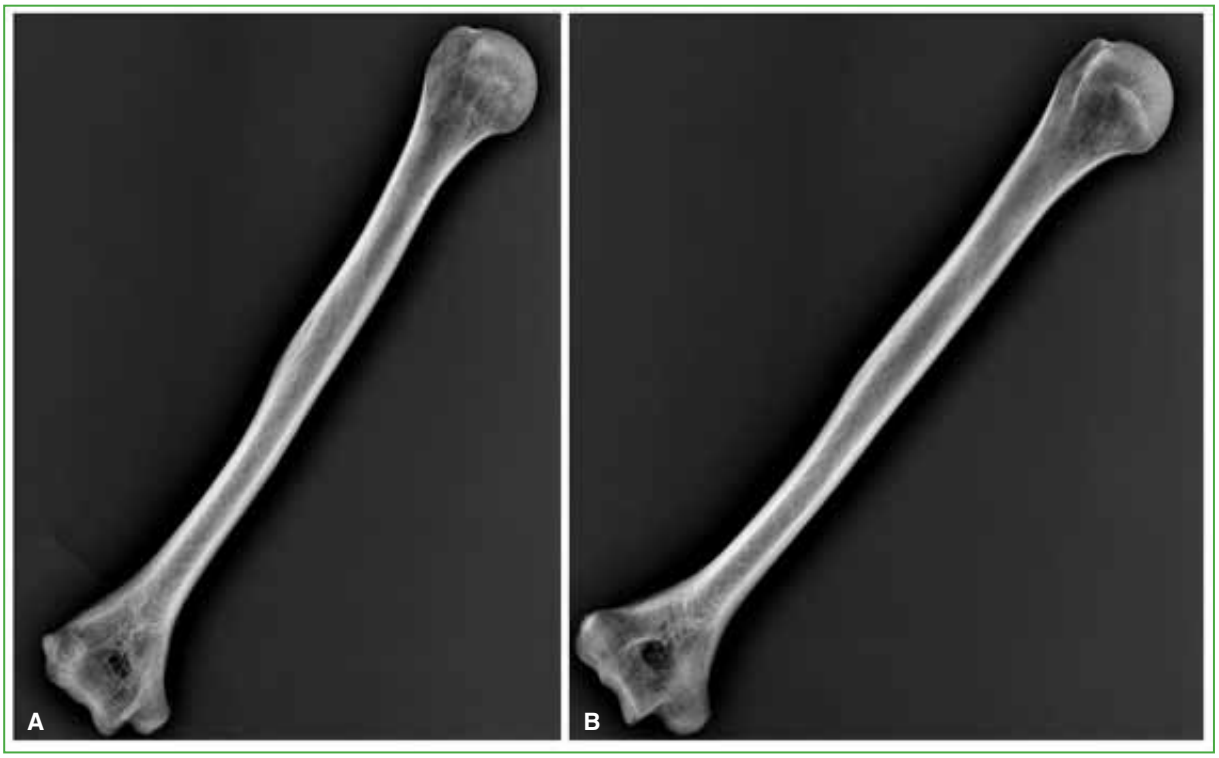

Figure 1. Humerus radiographs (cadaveric piece). **A.** Real anteroposterior view of the proximal humerus segment with the distal segment in rotation according to anatomical retroversion. **B.** Retroverted view of the proximal humerus with a true anteroposterior view of the distal humerus.

To describe the criteria, the 100 radiographs of the humerus with external rotation which achieved an anteroposterior view of the proximal humerus were compared with the 100 radiographs with internal rotation which achieved an anteroposterior view of the distal humerus.

Radiological criteria (Figure 2):

- Overprojection of the lateral epicondyle over the capitellum > 50%
- Sclerosis of the lower ridge of the olecranon fossa
- Sclerosis of the lateral ridge of the olecranon fossa
- Asymmetry of the olecranon fossa (difference between the medial and lateral ridges of the olecranon fossa)

The evaluation of the radiographs was performed by four independent investigators (two traumatologists specialized in shoulder surgery with more than 5 years of experience and two second-year traumatology residents). All were obtained using a digital imaging system (DigiRAD-FP (ST-5000C), Gyeonggi-do, Korea). A commercial imaging program (Vue PACS, Carestream) was used to analyze the images. The interobserver correlation was measured by the kappa coefficient. The strength of agreement was considered poor for a kappa between 0.21 and 0.4; moderate between 0.41 and 0.6; good between 0.61 and 0.8; and excellent between 0.81 and 1. The chi-square test and the STATA IC 16® program were used for statistical analysis.

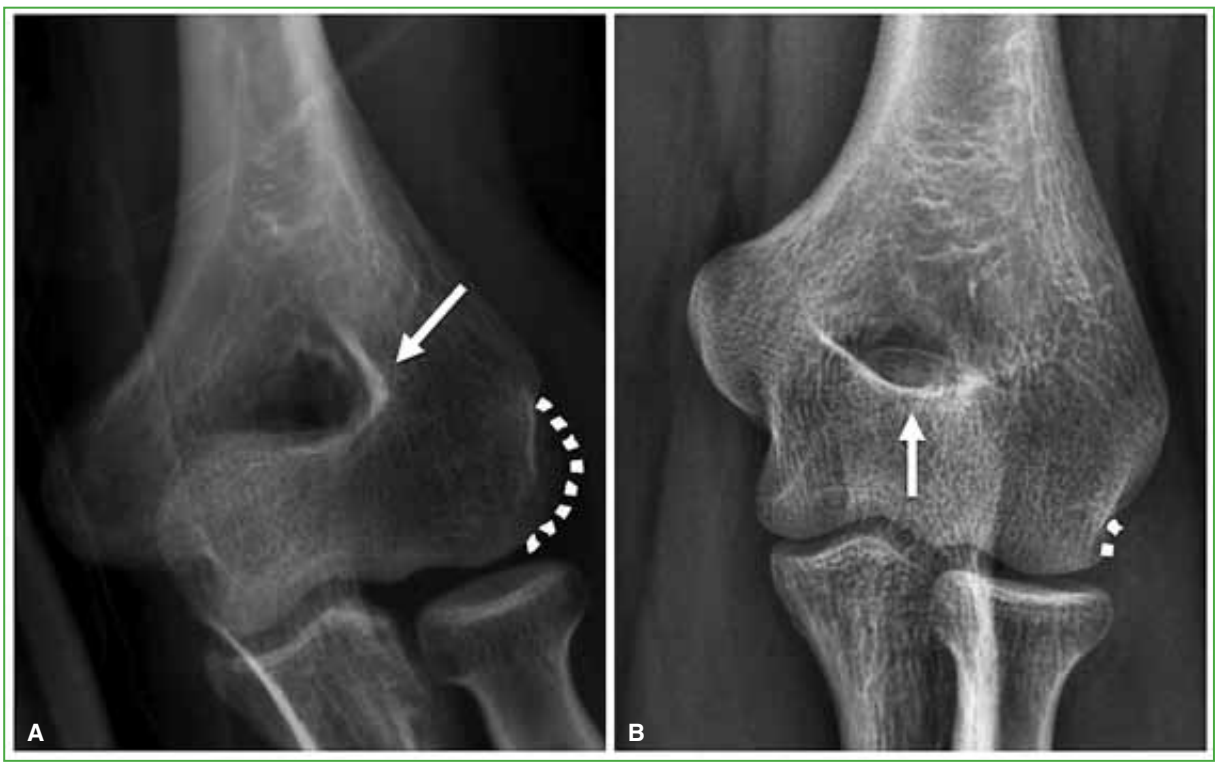

Figure 2. Radiological criteria. **A.** Anteroposterior radiograph of the distal humerus. The distal segment of the humerus is visualized with rotation according to anatomical retroversion. The arrow shows the sclerosis of the lateral border of the olecranon fossa. The asymmetry of the olecranon fossa can be appreciated. The dotted line shows the overprojection of the epicondyle over the capitellum of more than 50%. **B.** Anteroposterior radiograph of the distal humerus. The symmetry of the olecranon fossa is observed. The arrow indicates the sclerosis of the lower border of the olecranon fossa and the dotted line shows the absence of overprojection of the epicondyle over the capitellum.

RESULTS

97.5% of the 200 radiographs reviewed met the inclusion and exclusion criteria. In 83.3% of the anteroposterior radiographs of the proximal humerus, an overprojection of the epicondyle over the capitellum was found; in 30%, there was sclerosis of the lower ridge of the olecranon fossa and, in 86.6%, sclerosis of the lateral ridge of the olecranon fossa. In 80% of the radiographs, there was asymmetry of the olecranon fossa.

In the anteroposterior radiographs of the distal humerus, there was an overprojection of the epicondyle over the capitellum in 9% of cases, and sclerosis of the inferior and lateral ridges of the olecranon fossa in 69.8% and 22.6%, respectively. In 26.5%, olecranon fossa asymmetry was found.

When comparing the anteroposterior radiographs of the proximal and distal humerus, significant differences were found in the presence of the four criteria ($p < 0.001$).

The diagnostic performance of the radiological signs was calculated on the 195 selected radiographs. When analyzing the three signs with the best performance (sclerosis of the lateral border of the olecranon fossa, overprojection of the epicondyle over the capitellum, asymmetry of the fossa), the combined sensitivity was 70%; the specificity, 98%; the positive predictive value, 95.5% and the negative predictive value, 84.5% (Table).

The kappa correlation coefficient for the researchers was 0.85, corresponding to the "excellent" category.[16]

Table. Sensitivity, Specificity, and Predictive Values of Radiological Criteria

	Lower sclerosis	Lateral sclerosis	Overprojection of the epicondyle	Asymmetry of the fossa	Three positive signs
Sensitivity	80%	86.67%	83.33%	80.00%	70.00%
Specificity	57%	77.36%	90.57%	77.36%	98.00%
Positive predictive value	70%	68.42%	83.33%	66.67%	95.45%
Negative predictive value	70%	91.11%	90.57%	87.23%	84.48%

DISCUSSION

The humerus is a long bone that intrinsically has a degree of torsion that determines a retroversion of the humeral head.[17,18] The sequela of consolidation in internal after a humeral shaft fracture can cause a functional deficit with worse outcomes in functional scales, decreased articular ranges and long-term glenohumeral osteoarthritis.[14,15,19]

Flury et al.[15] performed humeral derotation osteotomies to manage instability by bringing the humeral head to a position of internal rotation and found that 88% of the patients developed some degree of osteoarthritis within 14 years.

Fjalestad et al.[19] described a loss of external rotation in 38% of patients with orthopedically-treated humeral shaft fractures as a consequence of the management of the shoulder with a sling in internal rotation during the first weeks. Similar outcomes have been published in other series and the deficit of clinical rotations is correlated with a consolidation in malrotation by imaging.[14,20,21]

At present, it is difficult to achieve correct rotation of the fragments in surgery for humeral shaft fractures with intramedullary nailing, since intraoperative fluoroscopy does not allow a complete visualization of the humerus and topographic anatomical parameters are not precise. In addition, this becomes even more difficult when it comes to complex or comminuted fractures where the edges of the fracture do not allow the anatomical position of these to be inferred.

The aim of this study was to describe radiological criteria that indirectly predict correct humeral retroversion based on the visualization of a true anteroposterior image of the distal humerus aimed at solving the difficulties mentioned during intramedullary nailing surgery for humeral shaft fractures. Three of the four criteria described, if present, significantly guide a correct retroversion of the humeral head: overprojection of the epicondyle over the capitellum >50%, sclerosis of the lateral border of the olecranon fossa and asymmetry of the olecranon fossa. Although the criterion for sclerosis of the inferior border of the olecranon fossa was statistically significant, its presence was not as high as the other criteria, so we suggest using the other three criteria to be more certain.

During surgery, after the distal or proximal block, a real anteroposterior image of the proximal humerus is sought in order to perform the proximal or distal block, respectively. While keeping the same axis of rotation, the fluoroscopy is transferred distally and the distal humerus is rotated externally until the three radiological criteria described are met. Then, the focus is compressed (if necessary) and the respective block is made. This maneuver allows the humerus to consolidate in retroversion avoiding excessive internal malrotation and all the functional and long-term complications described.

This study has a large number of evaluated studies and describes three criteria that are easy to search for and with a high interobserver correlation. As it is a retrospective imaging study, it lacks clinical evaluation and, therefore, the real impact on surgery is unknown and the benefit is theoretical. It would be important to carry out prospective clinical studies to evaluate the real usefulness of these criteria.

CONCLUSIONS

There are radiological criteria at the elbow level that indirectly determine a correct humeral retroversion with a high degree of interobserver correlation. These can be useful tools when performing intramedullary nailing surgery for humeral shaft fractures in order to reduce residual malrotation, but prospective clinical studies are required to be able to issue a recommendation in this regard.

Conflict of interest: The authors declare they do not have any conflict of interest.

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