AXIAL PROJECTION OF THE HUMERUS. PROPOSING A NEW INTRAOPERATIVE RADIOLOGICAL PROJECTION IN THE TREATMENT OF PROXIMAL HUMERAL FRACTURES BY INTRAMEDULLARY NAILING

Panella A 1, Notarnicola A 1, Caiaffa V 2, Maccagnano G 1, Moretti B 1

1 Department of Neuroscience and Organs of Sense, Orthopaedics Units, University of Bari, Italy
2 Orthopaedics Units of Ospedale SS. Annunziata, Taranto, Italy


Key words: proximal humeral fracture, intramedullary nailing, axial radiograph view, Bool-Obata or Velpeau projection

Parole chiave: frattura di omero prossimale, inchiodamento intramidollare, proiezione radiografica assiale, proiezione di Bool-Obata o Velpeau
Abstract

**Background:** To guarantee optimal stabilization of proximal humeral fractures treated by intramedullary nailing, it is essential to position the nail correctly in the humeral head, with the proximal screws reaching pluriaxially into the epiphyseal cortices without protruding into the joint.

**Objectives:** Conventional intraoperative fluoroscopic radiography is used to verify the positioning of these parts from the antero-posterior and trans-thoracic views.

**Methods:** We suggest that these projections should be integrated with an axial view, modified with regard to those proposed by Bool-Obata or Velpeau.

**Results:** We verify it is able to check the correct positioning of the head screws while safeguarding higher bone density areas.

**Conclusions:** After an adequate learning curve, this projection could actually replace the trans-thoracic projection, since it serves to study the relations of the screws with the cortex and any protrusion into the joint.
Introduction

When fractures localized in the proximal humerus are minimally displaced or not displaced, they can be treated conservatively with good results after a period of immobilization of the upper limb. In cases of unstable or displaced fractures, however, non-surgical treatment can lead to delayed consolidation or pseudoarthrosis, resulting in severe functional limitations depending on how long the immobilization period lasts (1). In this scenario, surgical reduction can minimize the functional impairment thanks to the use of valid mechanical stabilization devices. Various types of devices for internal fixation have been proposed, namely plates, wires, intramedullary nails, or a combination of all of these. Intramedullary nailing is widely used to treat this type of fracture because it is less invasive than other tools and the surgical procedure is less technically demanding (2, 3, 4).

During surgery a brilliance amplifier is employed to gain direct vision of the procedure in real-time, and to monitor the positioning of the guidewire and subsequent nail, screws etc. It is fitted on a C-arm and equipped with a primary collimator that emits the X-rays, and a parallel secondary collimator for video or cassette recording. The classic radiographic projections described in literature to verify the correct positioning of the headshaft screws are the antero-posterior (AP) and trans-thoracic (TT) views; these are repeated at postoperative follow-ups and, in cases with a clinical suspicion of articular impediment or instability, CT scanning with 3-D reconstruction may be necessary.

In daily practice, these two projections are used intraoperatively to check the positioning of the screws. However, they may not be enough to ensure a complete view of the spatial relations and may fail to point out the protrusion of a screw or nail into the joint, with the obvious repercussions this will have on the functional outcome.

To reduce this risk, we propose to use an axial cranio-caudal (CC) projection of the humeral headshaft, that allows a further view of the relative positions of the fixation devices on another plane.

Aim of this work was to assess the ease of execution of this new axial radiographic projection during intraoperative monitoring of the nailing procedure, for the purposes of verifying correct positioning of the nail and proximal screws in the headshaft areas, ensuring a lower risk of mobilization.

Methods

During the surgical procedure for intramedullary nailing of proximal humerus fractures we suggest to apply a new axial CC projection in association to the conventional AP and TT ones.

During the surgical procedure, intraoperative radiological control with the aid of the brilliance amplifier is set up to check the successful reduction of the fracture and the insertion of the guidewire and then the nail. The fluoroscope is positioned on the fracture side, near the patient’s head and parallel to the trunk. The patient is placed in the beach-chair position on the operating table, and the support under the affected shoulder was removed. After performing standard AP and TT radiographic projections, we apply axial CC projections according to the following procedure: the C-arm of the fluoroscope was positioned at 90° to the affected arm, in 10° abduction and in retropulsion to the shoulder, with the elbow flexed and the hand in neutral position along the theoretical course of the ray. The primary collimator is placed above the shoulder and the secondary one below the elbow (fig.1). The incident ray would thus cross the humerus longitudinally along the diaphysis.
Axial projection of the humerus. Proposing a new intraoperative radiological projection in the treatment of proximal humeral fractures by intramedullary nailing

Fig. 1- Position of the patient and the brilliance amplifier to achieve the axial projection.

Results

It is possible to execute the axial projection with minimal time wasting, actually prolonging the radiological examination by only about 0.30 minutes. The X-rays by an axial fluoroscopic control provides useful information about the position of the guidewire and nail in the head of the humerus and, above all, about the orientation of the screws on the axial plane (fig.2). This new projection doesn’t cause any invasion of the working field of the anesthetist or other operators, unlike the TT, which requires a greater arm abduction and wider rotation of the C-arm.
Axial projection of the humerus. Proposing a new intraoperative radiological projection in the treatment of proximal humeral fractures by intramedullary nailing

Discussion

Intramedullary nailing has been successfully employed to stabilize proximal humerus fractures. To optimize the stabilization of the fracture, the nail is fitted with 2, 3 or 4 proximal screws positioned in an anteroposterior direction in the humeral head and 2 or 3 oblique screws in the distal site (1). With this method, a frequency of mobilization ranging between 4 and 20% has been reported in literature (2, 3, 5, 6, 7, 8, 9), and the determinant role of the position of the screws in the humeral headshaft, to prevent failure of the implant, has been underlined (3, 6).

Liew and collaborators (9) conducted a study to assess the force necessary to cause mobilization of the fixation of the humeral head, according to the position of the screws. They found that failure occurred more frequently, even with low stress, when the screws were directed toward the supero-anterior quadrant of the humeral head, since the stability of the fixation depends largely on the quality of the trabecular epiphyseal bone.

Tingart et al. (11) studied the distribution of bone density in the head of the humerus and demonstrated that the central area has the greatest density, followed by the infero-anterior, supero-posterior, infero-posterior and supero-anterior areas. For this reason, the mobilization force also varies in proportion to the density. The Authors concluded that to prevent mobilization and improve the results, the nail and screws must be applied in the regions with the highest trabecular density (12). Other studies confirmed that there is a lower risk of mobilization when, as well as correct positioning of the nail, the proximal screws reach within few mm of the epiphyseal cortex (6, 12, 10, 13), owing to the higher bone density of this subchondral bone area. However, this also poses a risk that the screws may protrude into the joint, causing joint damage and functional impediment.

Conventional fluoroscopic radiography is employed intraoperatively to monitor the correct insertion and positioning of the fixation tools (14). Conventional radioscopy relies on AP projections on the scapular (true AP, in extrarotation and intrarotation) and axillary (or trans-thoracic) plane with the patient in beach-chair position on the operating table.

In the antero-posterior projection the shoulder is in neutral position and the arm is abducted (15); the primary collimator is placed anteriorly to the arm and the ray forms a perpendicular angle to the humerus. In the neutral rotation position the palm of the hand lies along the thigh. This allows study of the anterior paramedian zone of the proximal humerus, and yields a good image of the head of the humerus and the supraspinal insertion. In the extrarotation position, the arm is slightly abducted and externally rotated, with the ulnar edge of the hand against the thigh. This projection shows the anterior medial zone of the humerus and gives a particular view of the greater tubercle.
and insertion of the humeral biceps. In the intra-rotation position the arm is internally rotated by 45°, with the back of the hand lying on the thigh, thus providing a view of the lateral region of the humerus, the lesser tubercle, subspinal insertion and the teres minor muscle.

The axillary or trans-thoracic (TT) projection shows a craniocaudal image of the abducted shoulder. The arm is abducted by 45° and the cassette is placed in the armpit; the ray runs vertically at 10° toward the elbow along the longitudinal plane of the arm. This projection is ideal to define the superior, lateral region of the humerus and the relations of the head with the glenoid.

These projections allow a good control of the sagittal trajectory during insertion of the guidewire and then the nail, but their limit is that they are not able to provide an equally good view of the positioning of the nail in the antero-posterior direction, and of the length of the screws in the headshaft. For this reason, the most frequent intraoperative complication (14%) is perforation of the head of the humerus (16).

Our decision to use an axial projection was thus based on the need to verify that successful anatomic reduction of the fracture has occurred, as well as adequate stabilization, and also to improve the sensitivity of intraoperative control imaging. This should also make it easier to reduce the risk of complications (missed poor reduction, secondary dislocations, etc.), and of malpositioning of the screws and nail, that is not always evident intraoperatively with the classic radiological projections (16).

The introduction of a new radiological projection might not seem pertinent, in view of the past proposal by the American College of Radiology to review the projections and eliminate those that do not provide additional information (2). Subsequent works studied whether, among the projections normally used in the trauma series, for instance, some were unnecessary and could be omitted, thus saving on costs and time, as well as reducing patient discomfort and exposure to ionizing radiation (17, 18, 19). The Authors concluded that the most sensitive projection is the AP, that can demonstrate 88% of lesions, as compared to 82% and 60% with the other trauma series projections, namely the apical oblique and the lateral projection. However, the Authors also stressed the need to continue to employ several projections in view of their complementary role in allowing the individuation of pathological signs that might otherwise go unnoticed at a single observation. Up to now, the use of axial projections of the humerus has been described in literature as a means of studying the gleno-humeral joint and identifying instability, recurrent dislocations, Hill-Sachs lesions and calcifications of the acromial os, but this is the first time that this projection has been proposed for intraoperative assessment of the positioning of the intramedullary nail.

Axial projections of the humerus allow caudocranial or craniocaudal assessment at the level of the armpit, showing a free view of the joint with no superimpositions. To study the correct intraoperative positioning of the nail in the proximal humerus the incident ray needs to run longitudinally down the humerus. The projection best suited to this purpose is the Bool-Obata or Velpeau, used largely to identify posterior instability. For this projection the patient is asked to stand or sit leaning against the radiological table, with the elbow flexed and adhering to the body. The cassette is placed on the radiological table with the patient in hyperlordosis to project the shoulder on the cassette, and the ray is directed vertically downward, orthogonally to the clavicle. This projection shows a clear image of the gleno-humeral relations but gives a deformed projection of the humeral headshaft, that appears oblong. To study correct nailing of humeral fractures, we place the patient with the shoulder in retropulsion and abduction by about 10°, so as to centre the projection on the head of the humerus and not on the gleno-humeral joint, and thus to reduce or eliminate the deformed projection of the head and obtain a “true” axial projection of the headshaft. In fact, the projection adopted in this study could therefore be described as a modified Bool-Obata or Velpeau. Use of this axial projection of the proximal humerus has been shown to be a rapid, simple and economic procedure that facilitates the detection or exclusion of technical errors, allowing insertion of the guidewire in the antero-posterior direction to be monitored, and the subsequent positioning of the nail and screws in the headshaft. In our experience, the described technique demonstrates the correct spatial orientation of the nail and screws in the headshaft, respecting the densitometric and biomechanical characteristics of the bone.

Conclusions

We believe that the introduction of an axial projection during nailing of a proximal humerus fracture allows assessment both of the position of the nail in the headshaft and of the direction and length of the proximal screws. In view of this peculiarity, we recommend the performance of this X-ray projection together with the conventional projections, in order to
complete the radiographic picture. We are convinced that after an adequate learning curve, this projection could actually replace the trans-thoracic projection, since it serves to study the relations of the screws with the cortex and any protrusion into the joint. This would facilitate the radiographic procedure for the operators, since it is easier and more time-saving, as well as being more comfortable for the patient.

Performance of the procedure in a larger series of patients is needed to gain further information on the reliability of the procedure, and may also offer new insight into further practical applications.

**Consent Statement**
Written informed consent was obtained from the patient to carry out this radiograph projection and to publish the images.

**Competing interests**
The authors declare that they have no competing interests. We haven’t any economical founding for the realization of this article.

**Acknowledgements**
The authors thank Mrs. Babette for the English translation of the article.

**References**
2. ACR Committee on cost containment. 1979; 35: 11-12.
Axial projection of the humerus. Proposing a new intraoperative radiological projection in the treatment of proximal humeral fractures by intramedullary nailing


**Corresponding Author:** Angela Notarnicola
Department of Neuroscience and Organs of Sense, Orthopaedics Units, University of Bari, Italy
e-mail: info@preventionandresearch.com

**Autore di riferimento:** Angela Notarnicola
Dipartimento di Neuroscienze e Organi di senso, Unità di Ortopedia, Università di Bari
e-mail: info@preventionandresearch.com