Humerus axial projection. New intraoperative radiological projection proposal for proximal humeral fractures treatment by intramedullary nailing

Antonio Panella
Angela Notarnicola
Vincenzo Caiaffa
Giuseppe Maccagnano
Biagio Moretti

Corresponding author:
Angela Notarnicola
UO Ortopedia e Traumatologia, Piazza G. Cesare 11, 70124 Bari
E-mail: angelanotarnicola@yahoo.it

Abstract

Background: guaranteeing humeral proximal fracture stabilization by intramedullary nailing is essential to correctly position the nail in the humeral head, being careful that proximal screws reach pluriaxially epiphysis cortices without protruding into the joint.

Objectives: conventional intraoperative fluoroscopic radiography is used to verify positioning of these parts from the antero-posterior and trans-thoracic views. We suggest to integrate projections with an axial view, modified with regard to those proposed by Bool-Obata or Velpeau.

Methods: we performed a clinical observational study in which we tested the effectiveness of this new projection. The primary endpoint was to assess the feasibility of performing this new projection. We also monitored the need for additional time. The secondary endpoint was to assess the reliability of this new projection, monitoring in how many patients the screws were in joint and were not visible to the two standard projections.

Results: twenty patients undergoing intramedullary nailing surgery for proximal humeral fractures were monitored. This new projection did not cause any invasion of the working field of the other operators. Its execution required on average additional 30 seconds. It showed that a screw was in a joint in 6 patients, which was not visible with AP and TT projections (p=0.005).

Discussion: we verified that it was possible to check the correct positioning of the head screws while safeguarding higher bone density areas. After an adequate learning curve, this projection could actually integrate the previous projections, since it is necessary to study the relations of the screws with the cortex and any protrusions into the joint.

KEY WORDS: shoulder fracture; fracture fixation; intramedullary; technology; radiologic.

Introduction

When fractures localized in proximal humerus are both minimally or not displaced, after a period of immobilization of the upper limb, they can be treated conservatively with good results. In cases of unstable or displaced fractures, however, non surgical treatment can delay consolidation also leading to pseudoarthrosis, resulting in severe functional limitations depending on how long the immobilization period lasts (1). In this scenario, surgical reduction can minimize 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 combination from all of these. Intramedullary nailing is widely used to treat this type of fractures because it is less invasive than other tools and surgical procedure is less technically demanding (2-6). On the other hand, this surgical procedure can cause failure in the case of wrong positioning of the nail and release of the screws in the joint (7-9). The intra-operative X-ray control is a valuable aid (5). During surgery, a brilliance amplifier is used to have real-time direct view, monitoring guidewire and nail positioning, screws etc. It is fitted on a C-arm and equipped with a primary collimator emitting 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 of clinical suspicion of articular impediment or instability, CT scanning with 3-D reconstruction may be necessary. However, even the combined application of different imaging modalities, such as CT scans, CT and 3D reconstructions could be useless (10-12). In addition, CT methods are used post-operatively and repositioning of the nail requires a new surgery, increasing costs and complications. Up to now, only two projections are normally used intraoperatively to check screw positioning. By the way, it may be possible those are not enough to ensure a complete.
view of spatial relations and may fail to point out the protrusion of a screw or nail into the joint, driving to a negative final outcome. For this reason, we decided to study the utility of inserting a new radiographic projection, in addition to standard ones. We propose to use an axial craniocaudal (CC) projection of the humeral headshaft, allowing a further view of the relative positions of the fixation devices on another plane. Thus, to the best of our knowledge, no one has yet proposed this new projection to monitor screw placement during the surgical treatment of the fracture of the humerus. Our first endpoint is to verify the feasibility of the execution of this new projection. The secondary endpoint is to observe if this new projection provides additional information. During the surgical procedure, the X-ray control should verify correct positioning of the nail and proximal screws in the headshaft areas and ensuring a lower risk of mobilization.

Materials and Methods

We designed a prospective observational clinical study. From May 2010 to May 2011, all consecutive patients that were treated in our institution for stabilization of fractures of the proximal humerus were evaluated to be recruited into study. Institutional board approval was obtained. The patients read and signed the informed consent. The fractures were classified according to AO classification (13). Inclusion criteria for this study were: (2) AO type 11-A2/3 or type 11-B1/2/3 humerus fractures; (3) acute fractures; (4) satisfactory reduction in fluoroscopy; (1) satisfactory reduction possible with a nail (Citieffe, Italy). Exclusion criteria were: (2) nonunion or pathological fractures; (3) fracture-dislocation; (4) age under 30 years old; (1) severe osteoporosis.

During surgery, we applied the new axial CC projection in association to the conventional AP and TT ones. Intraoperative radiological control was set up with the aid of the brilliance amplifier to check the successful repositioning of the nail and the insertion of the guidewire and then the nail. The fluoroscope was positioned on the fracture side, near the patient’s head and parallel to the trunk. The patient was placed on the operating table in beach-chair position, and the support under the affected shoulder was removed. After performing standard AP and TT radiographic projections, we applied 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 was placed above the shoulder and the secondary one below the elbow (Fig. 1). The incident ray crossed the humerus longitudinally along the diaphysis.

Outcome measures

Epidemiological data of patients and classification of the fracture were recorded. The surgical procedure was carried out by the same surgeon. The radiographic projection was performed by the same radiologist. The axial CC, AP and TT projections were examined to evaluate postoperative reduction and to control screw placement in joint. The same radiologist and the same orthopaedic examined all the X-rays. During the follow up at 3 months an independent orthopaedic performed the functional assessment of each patient, using the Constant shoulder score (14).

Statistical analysis

Data are expressed as mean +/- Standard Deviation (SD) and range. Student’s t-test for independent samples was used and the level of significance was set at p <0.05. Data processing was done with Epi-Info 6.00 software (public domain software-CDC Atlanta, Georgia; WHO Geneva, Switzerland).

Results

Twenty patients met the inclusion criteria. They underwent intramedullary nailing surgery for proximal humeral fractures and were monitored with the new projection. There were 9 male and 11 female patients aged between 34 and 78 years old, with an average age of 51 (SD +/-14). According to AO classification (13), in 3 cases the fracture was A2, in 2 cases A3, in 5 cases B1, and in 10 cases B2. The X-rays by an axial fluoroscopic control provided 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 did not cause any invasion of the working field of the anesthetist or other operators, unlike the TT, which required a greater arm abduction and wider rotation of the C-arm. It was possible to execute the axial projection with minimal time wasting, actually prolonging the radiological examination by only about a mean of 30 seconds (SD=25; range=25-40 seconds).
The new axial projection (CC) has shown that a screw was in a joint in 6 patients, which was not visible with the other two standard projections. Intraoperative control screw placement was statistically more careful by the axial CC projection than by AP and TT projections (p=0.005). At the end of the surgery, the reduction was satisfactory in all the patients. None was lost to follow up at 3 months. There were no wound complications, no postoperative neurovascular problems, no morbidities and the average Constant shoulder score was 64.2 (SD=7.54; range= 55-80).

Discussion

Intramedullary nailing has been successfully employed to stabilize proximal humerus fractures. To optimize fracture stabilization, nail is fitted with 2, 3 or 4 proximal screws positioned in an anteroposterior direction towards humeral head and 2 or 3 oblique screws in the distal site (1). Using this method, a frequency of mobilization ranging between 4 and 20% has been reported in literature (2, 4, 15-19), and the determinant role of the position of the screws in the humeral head, to prevent failure of the implant, has been underlined (4, 17). Liew et al. (20) had already run a study to assess necessary force to fix and mobilize humeral head, according to screws position. 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 largely depends on the quality of the trabecular epiphyseal bone. Tingart et al. (21) studied bone density distribution of humerus head and demonstrated that the central area has the greatest density, followed by infero-anterior, supero-posterior, infero-posterior and supero-anterior areas. For this reason, the mobilization force also varies in proportion to density. Authors concluded that to prevent mobilization and improve results, nail and screws must be applied in the regions with the highest trabecular density (22). Other studies confirmed that there is a lower risk of mobilization, as well as correct positioning of the nail, when the proximal screws reach within few mm of the epiphyseal cortex (17, 20, 22, 23), owing to the higher bone density of this subchondral bone area. However, this is also a risk because screws may protrude into the joint, causing joint damage and functional impediment. Conventional fluoroscopic radiography is employed intraoperatively to monitor fixation tools correct insertion and positioning (24). Conventional radiography relies on AP projections on the scapular (true AP, in extrarotation and intrarotation) and axillary (or trans-thoracic) plane with patient in beach-chair position on the operating table.

In the antero-posterior projection, shoulder is in neutral position and the arm is abducted (25); 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 the study of proximal humerus anterio-paramedian zone, yields a good humerus head and supraspinal insertion image. 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 anterior medial zone of the humerus and gives a particular view of the greater tubercle and insertion of the humeral biceps. In the intrarotation position the arm is internally rotated by 45°, back of the hand lying on the thigh, providing a view of: lateral region of the humerus, lesser tubercle, subspinal insertion and 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 is an ideal projection to define humerus superior and lateral region and relations of the headshaft with the glenoid. These projections allow a good control on sagittal trajectory during insertion of guidewire and nail, unfortunately its limit is that it cannot provide also a good view for nail positioning in antero-posterior direction and/or screws length in the headshaft. Due to this reason, for example, the most frequent intraoperative complication (14%) is humerus head perforation (26). We chose to use an axial projection because in our opinion, we needed to verify if a fracture anatomic reduction was successful, stabilization is adequate as well as to improve intraoperative control imaging sensitivity. This should also make it easier to reduce complication risks (missed poor reduction, secondary dislocations, etc.), and screws and nail malpositioning – sometimes it is not possible to see it intraoperatively from classical radiological projections (26). The introduction of a new radiological projection may seem not acceptable according to the American College of Radiology past proposal to review projections eliminating those that do not provide additional information (2). As a matter of fact subsequent studies have shown that among normally used projections in trauma series some were unnecessary and could be omitted saving costs and time, as well as reducing pa-
Humerus axial projection. New intraoperative radiological projection proposal for proximal humeral fractures treatment by intramedullary nailing

tient discomfort and exposure to ionizing radiation (27, 28). In this case, the Authors concluded that the most sensitive projection is the AP, demonstrating how 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 underline that it is important to continue to employ several projections in view of their complementary role to allow the identification of pathological signs that might otherwise go unnoticed at a single observation. Up to now, axial projections of the humerus has been only used and described in literature as a tool to study gleno-humeral joint, identifying instability, recurrent dislocations, Hill-Sachs lesions and calcifications of the acromial os. 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. Best projection suitable for this purpose is the Bool-Obata or Velpeau, widely used to identify posterior instability. For this projection, the patient is asked to stand or sit leaning against the radiological table, flexed elbow adhering 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 shoulder in retropulsion and about 10° abducted, to centre projection on humerus head instead gleno-humeral joint, 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 detection or exclusion of technical errors, allowing insertion of the guidewire in the antero-posterior direction to be monitored, as well as subsequent positioning of nail and screws in the epiphysis. In our experience, the technique described demonstrates correct spatial orientation of nail and screws in the headshaft, respecting densitometric and biomechanical characteristics of the bone.

We believe that the introduction of this 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 operators’ radiographic procedure since it is easier and time-saving, as well as being more comfortable for patients. Performance of the procedure in a larger series of patients is needed to gain further information on its reliability, also offering new insight for further practical applications.

In conclusion, the axial projection is recommended due to its simplicity and efficacy. The introduction of this projection shall have important clinical implications. It should improve the nailing of humerus fractures and reduce the costs for other diagnostic procedures as well as manage possible complications. It will be interesting to investigate the efficacy of this new projection also in other surgical procedures, for example in stabilization with plates.

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. They have not received any economical funding for the preparation of this article.

Acknowledgements

Authors thanks Mrs. Babette for the English version for this article.

References


2. ACR. Committee on cost containment. 1979; 35:11-12.


Prevention & Research 2014; 3(3):116-120


