Unrecognized shoulder joint penetration during fixation of proximal fractures of the humerus

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ABSTRACT – In osteosynthesis of proximal humerus fractures, the screws frequently penetrate the joint. Using orthogonal frontal and lateral radiographs, we found unrecognized pin penetration in 8 of 30 patients during fixation of unstable neck fractures of the humerus.

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It is well recognized that standard radiographs and image intensifier pictures taken at 90 degrees to each other do not always show protrusion of devices into the hip joint (Walters and Simon 1980, Noordeen et al. 1993, Hernigou and Besnard 1997). This is due to the presence of a "blind zone" where a sphere and a cylinder of equal diameters have the same projection (Figure 1). This is also a problem in the shoulder joint, but has not been subject to systematic study.

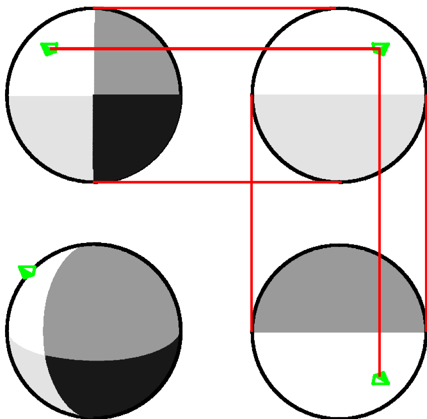

Figure 1. If two beams are orthogonal to a sphere, their projections on two orthogonal planes determine two circles. However, outside of the sphere, the tip of the pin is projected inside two circles representing the orthogonal projections of the sphere.

Several methods are used to operate on neck fractures of the humerus: screws and plate fixation (Kristiansen and Christensen 1986), Ender nailing (Hall and Pankovich 1987, Ogiwara et al. 1996), external fixator (Kristiansen and Kofoed 1988), and Kirschner pins (Svend-Hansen 1974, Post 1980). They all can penetrate the joint and the penetration may not be seen on standard projection radiographs.

Patients and methods

Patients

The series included 30 unstable surgical neck fractures of the humerus. They were treated with various types of osteosyntheses: pin nailing (18), external fixation (4) as well as screws and plate fixation (8). We studied the postoperative radiographs to determine the prevalence of metal penetrating the surface of the humeral head.

At the end of the operation, with the patient still on the fracture table, two exactly orthogonal radiographs were taken. We evaluated the position of the tips of the pins on both films. Our study addressed only one feature of this radiographic analysis: location of the tip of the pin as intra- or extraarticular and, if extraarticular, did the staff fail to detect it during surgery. All the radiographs had been examined and regarded as satisfactory by several members of the orthopedic staff.

Determination of the tip of the pin in relation to the center of the humeral head

The Euclidean co-ordinates of a point in space may be determined from measurements in two planes and related to the center of the humeral head. We

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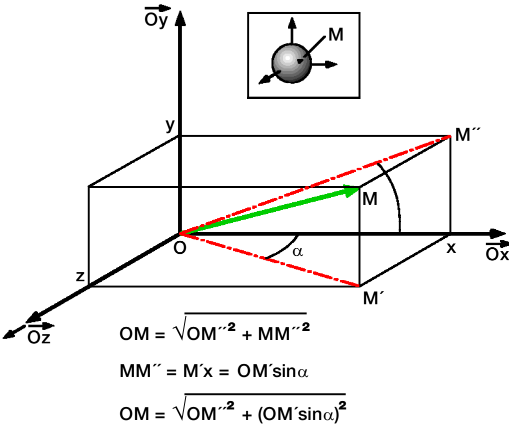

Figure 2. OM = distance between the tip (point M) of the implant and the center (point O) of the humeral head; OM' and OM" are determined on the frontal and lateral views as the projections of point M.

used the frontal and lateral radiographs as the two planes of the Euclidean system. Thus simple measurements on each film (Figure 2) showed the distance between the tip of the implant and the center of the head. The radius of the head was determined from the frontal and lateral images. All measurements were corrected for potential radiographic magnification of one image compared with another. It was therefore possible to determine whether the distance from the tip of the pin to the center of the humeral head was greater or less than this radius, and hence whether the tip (or the screw) was inside or outside the sphere of the humeral head.

This method of calculation is precise, but the humeral head cannot be regarded as a perfect sphere and the radiographic projections of the subchondral bone do not include the articular cartilage. The humeral articular surface (Janotti et al. 1992) is considered as an ellipse (ratio 0.92) and the thickness of the articular cartilage (Soslowsky et al. 1992) is reported to be 1.44 (SD 0.3) mm. We therefore recorded any implant protruding from the subchondral bone by more than 2 mm as entering the joint space.

Results

We found a probable technical imperfection in one third of the shoulders reviewed. In 6 shoulders, our calculations showed that the tip of at least 1 pin might be intraarticular (Figure 3). In 2 other shoulders, 1 screw was thought to be intraarticular. In 2 shoulders, we estimated that the screw tip was in the articular cartilage of the shoulder.

Discussion

When treating humeral neck fractures unrecognized joint penetration may occur. This is because the radiographic beam projects an equatorial dimension of the humeral head onto the film. During the postoperative follow-up, most surgeons review radiographs which show very similar frontal and lateral images of the humeral head. This means that the problem we describe may not be detected. In some suspected cases, intraarticular penetration was confirmed by fluoroscopy with tangential visualization (and at revision operations for removal of pins in 2).

If the screw or the pin is viewed from different angles, or if the humeral head is rotated under an image intensifer, the area of the blind zone becomes smaller. But, once osteosynthesis has been completed, it is difficult with the draping in place to rotate the humeral head under the image intensifier or to rotate the intensifier around the humeral head to examine its contours and prevent blind spots. It may therefore be useful to study the radiographically safe and unsafe zones in the

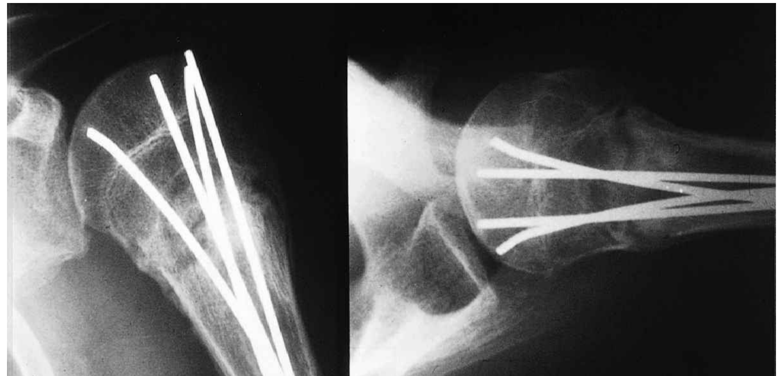

Figure 3. In this example, the calculations showed that 3 pins might be intraarticular.

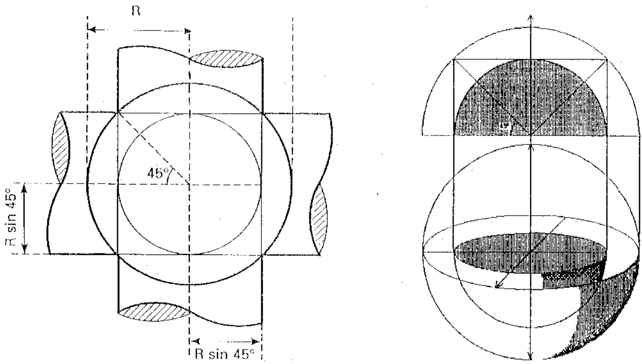

Figure 4. The diagram shows that, for a sphere of radius R sine 45 degrees, the volume determined by the intersection of the two orthogonal cylinders around the sphere of radius R sine 45 degrees lies entirely in the sphere of radius R. In consequence, the "blind" zone of a sphere of radius R sine 45 degrees is situated solely in the sphere of radius R. Therefore, any point projecting on the two orthogonal incidences in a circle of radius R sine 45 degrees is necessarily inside the sphere of radius R.

humeral head. Figure 4 shows that any point projected onto the two orthogonal incidences in a circle of radius R sine 45 degrees ($\approx$ R $\times$ 0.7) is necessarily inside the sphere of radius R, irrespective of the direction of the X-ray's beam. This permits definition of a safety zone on the two orthogonal incidences. For a radius R of 25 mm (average 27 for the humeral head with cartilage (Solowsky et al. 1992)), the safety zone on the frontal and lateral radiological projections has a radius of 18 mm (R sine 45 degrees). Therefore, if the extremity of the implant remains at a distance of at least 8 mm, frontally and laterally, from the subchondral zone, that extremity necessarily lies inside the humeral head.

If the extremity of the implant is very close to the subchondral bone (less than 7 mm) either on the frontal or lateral view (or both), and the image intensifier is not rotated around the femoral head, the probability of not recognizing that the implant is located outside the humeral head may be as high as 21% (Figure 5). Since several implants (pins or screws) are usually placed in the humeral head, the risk may be more than 21% for the patient.

The consequences of intraarticular penetration were small in our patients. We found no evidence of chondrolysis in any shoulder. We diagnosed one rotator cuff injury, but it is uncertain whether this injury was present before the fracture. 2 patients developed pain in their shoulder and had to have the pins removed.

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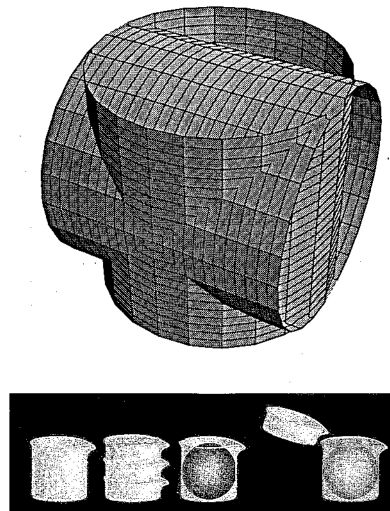

Figure 5. In 200 B.C., Archimedes determined that the volume of a sphere is 2/3 that of the volume of a cylinder of equal diameter and height. It is easy to calculate that the volume of a sphere is 79% of the volume determined by the intersection of two orthogonal cylinders.

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