11 Instrumental Evaluation: X-Ray and CT

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The first step in the evaluation of a fracture is represented by the exact definition deriving from the instrumental examinations that, allowing us to classify, represents a useful guide for the therapeutic decision [1].

In the proximal humerus, as in other anatomical districts, conventional radiology plays a major role as it is a readily available, fast and low-cost exam.

The simple radiographic examination (X-ray) is a useful tool in the diagnosis of the proximal humerus fractures, providing important information regarding the extent of the fracture, the number of fragments, their possible decomposition and the articular surface's involvement. Indirect signs such as the presence, in an anteroposterior radiogram performed in an upright position, of adipose tissue and blood in the articular capsule with the characteristic FBI (fat-blood interface) sign indicating an intra-articular extension of the fracture (Fig. 11.1) can help [2].

Fig. 11.1 An anteroposterior radiogram performed in an upright position with the characteristic *FBI* (fat-blood interface) *sign*, indicating an intra-articular extension of the fracture

However, there are several studies that highlight the difficulty in repeatability and reproducibility of a radiogram reading among different observers. Moreover, the quality of the slabs carried out under emergency conditions is often poor, both due to the poor collaboration of the patient suffering from the fractured event and to

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the difficulty in obtaining an accurate execution of standardized series of shoulder radiographs always under emergency conditions (trauma series). Furthermore, performing a correct radiographic examination cannot disregard an adequate knowledge of the shoulder's anatomy. It must be remembered that the scapula does not lie on the frontal plane of the chest but is inclined about 45° with respect to it; it follows that the anteroposterior radiographs on the frontal plane of the chest provide oblique images of the glenohumeral joint (Fig. 11.2a). An incomplete and inadequate X-ray examination because of the non-execution of some radiographic projections or a poor execution of the same can prevent a correct classification of the fracture and therefore induce to undertake a treatment, conservative or surgical, which is not the most suitable for that determined fracture or even, at worst, to make a fracture or a glenohumeral dislocation misunderstood [3]. Today, the trauma series remains the gold standard as a first-level examination when there is shoulder trauma [1]. It includes a true anteroposterior radiograph on the scapula plane which provides us with a real anteroposterior image of the glenohumeral joint, a lateral projection onto the scapula plane or a Y-projection of the scapula and an axial projection. The goal is to carry out an examination that altogether describes the fracture picture through the three floors of the space at best in order to obtain a description that is the most realistic and complete.

The two projections onto the scapula plane, anteroposterior and Y-lateral, can be performed keeping the traumatized limb in the bandage, thus avoiding its mobilization. This is a considerable advantage in particular for the patient, who avoids an accentuation of the algic

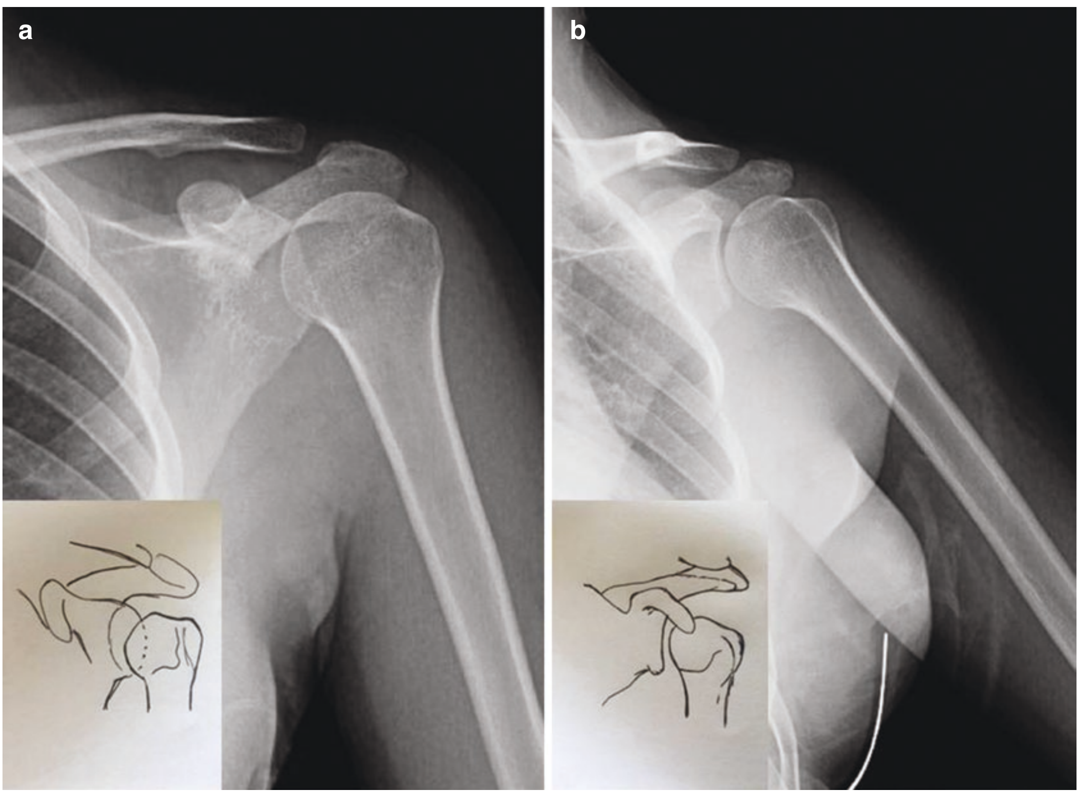

Fig. 11.2 (**a**) The anteroposterior radiograph on the frontal plane of the chest provides oblique images of the glenohumeral joint. (**b**) The anteroposterior projection on the scapula plane allows a visualization of the glenoid profile and thus allows the two articular components, the humeral head and the glenoid cavity, to be clearly seen at least in physiological conditions

symptomatology, and consequently also for the radiographic examination correct execution requiring a minor collaboration of the patient himself. The anteroposterior projection on the scapula plane can be performed in orthostatics or in supine position and in particular is carried out positioning the radiographic cassette posteriorly to the shoulder to be examined and inclining the contralateral shoulder with a forward angle of about 35°–45° so that the body of the scapula is positioned parallel to the sensitive plane. The radiating beam will thus be orthogonal to the sensitive plane and to the body of the scapula, inclined about 40° from the frontal plane in the mid-lateral direction and aimed at the centre of the scapula itself, approximately 5 cm below the coracoid process (Fig. 11.3). This allows a visualization of the glenoid profile and thus allows the two articular components, the humeral head and the glenoid cavity, to be clearly seen at least in physiological conditions (Fig. 11.2b).

On the contrary, if there is an anterior or posterior glenohumeral dislocation, the two structures will appear overlapped. However, the evaluation of the acromion, of the acromion-clavicular joint and of the clavicle's lateral portion appears more difficult with this projection rather than with the standard anteroposterior one.

The Y-lateral projection of the scapula [4] also known as projection of the defile of the supraspinatus, trans-scapular or lateral tangential can be performed with patient in orthostatics or sitting and, as the previous projection, can be performed without mobilizing the limb and maintaining it in the bandage or in the support. To perform the examination, the anterior region of the shoulder affected by the trauma lies on the X-ray cassette, while the contralateral shoulder is inclined forward approximately by 30°–45°. The radiating beam transits tangentially through the posterolateral chest wall and parallel with the spine of the scapula up to the radiographic cassette. The central ray's point of incidence must coincide with the centre of the median edge of the scapula. The radiological image must show the two median and lateral margins of the scapula perfectly overlapped to represent the stem of a "Y", whose arms are instead represented anteriorly by the

Fig. 11.3 The anteroposterior projection on the scapula plane is carried out, positioning the radiographic cassette posteriorly to the shoulder to be examined and inclining the contralateral shoulder with a forward angle of about 35°–45° so that the body of the scapula is positioned parallel to the sensitive plane

base of the coracoid process and posteriorly by the base of the acromial process. This projection is crucial to the study of the articular relationships between the humeral head and the glena. In physiological conditions, the head of the humerus is at the centre of the so-formed "Y", while it is forward or backward in the case of anterior or posterior dislocation, respectively. The Y-lateral projection is also particularly useful for the evaluation of the decomposition of the trochitis's possible fracture. It can help in the diagnosis of fractures of the coracoid process and of the acromial process and for the evaluation of the acromion's inferior margin, while it does not allow a careful study of the glena's anterior and posterior edges (Fig. 11.4).

The lateral axillary projection was first described by Lawrence [5], and it involves the 90° abduction, and it is a great method for the assessment of the anterior or posterior glenohumeral dislocation and for the detection of Bony Bankart involving the anterior glenoid fissure. The lateral axillary projection can be performed by the patient to a supine or upright position. The X-ray cassette is placed on the patient's shoulder and as close to the neck as possible, while the X-ray tube is placed slightly below the patient with the radiogenic beam directed inferior-superiorly and centred at the axillary cavity. Compared to the original projection, some variants in the literature have been described, providing a lower abduction angle so that this projection could be carried out even in traumatized patients, unable to reach that degree of abduction due to pain symptoms. In the technique described by Cleaves, the patient's limb, supine or seated, is abducted just enough to allow placement of the X-ray cassette below the shoulder [6]. If, because of the algic symptoms reported by the patient for the fracture, it's impossible to abduct the limb for correct execution of the axial, or in any case it is preferred not to remove the bandage to avoid any decomposition of the fracture, it is possible to make a Velpeau's axial [3, 7] (Fig. 11.5).

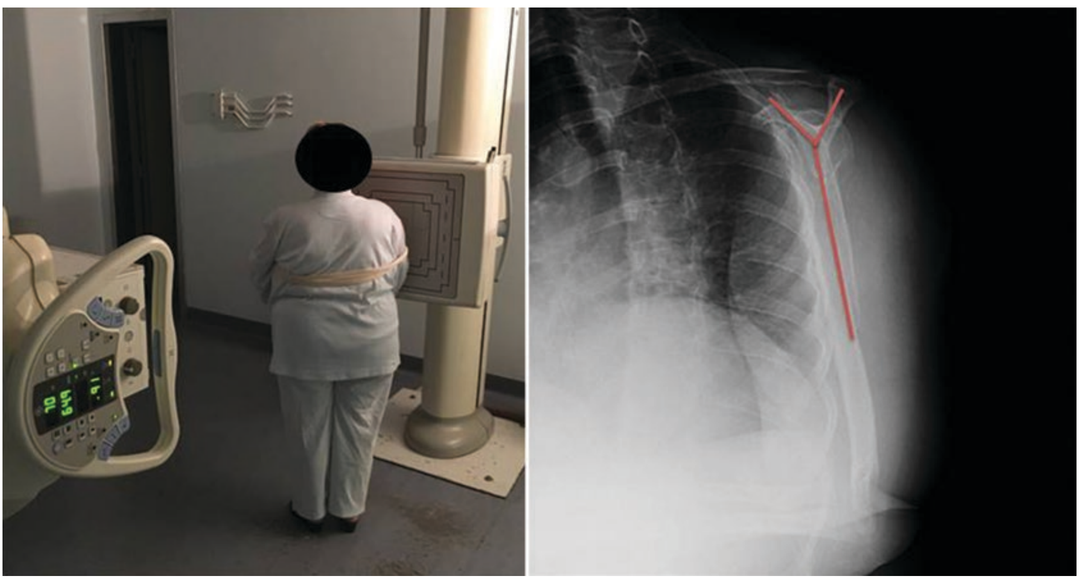

Fig. 11.4 In the Y-lateral projection of the scapula, the anterior region of the shoulder affected by the trauma lies on the X-ray cassette, while the contralateral shoulder is inclined forward approximately by 30°–45°. The radiating beam transits tangentially through the posterolateral chest wall and parallel with the spine of the scapula up to the radiographic cassette. The radiological image must show the two median and lateral margins of the scapula perfectly overlapped to represent the stem of a "Y", whose arms are instead represented anteriorly by the base of the coracoid process and posteriorly by the base of the acromial process. In physiological conditions, the head of the humerus is at the centre of the so-formed "Y", while it is forward or backward in the case of anterior or posterior dislocation, respectively

Fig. 11.5 In Velpeau's axial projection, the joint relationships can be assessed, although the glenohumeral joint appears enlarged and the humeral diaphysis shortened

Fig. 11.6 Velpeau's axial projection allows maintaining the limb immobilized and adducted to the chest. The patient positions himself at the end of the radiological table by bending the thorax backwards by about 20°–30°. The X-ray cassette is placed directly below the shoulder, while the X-ray tube is placed above

This projection allows maintaining the limb immobilized and adducted to the chest and can be performed by the patient into an upright or sitting position. Specifically, the patient positions himself at the end of the radiological table by bending the thorax backwards by about 20–30°. The X-ray cassette is placed directly below the shoulder, while the X-ray tube is placed above. It follows that the X-ray beam is vertical and perpendicular to the table in the cranio-caudal sense, with incidence on the clavicle's lateral end (Fig. 11.6). Although the glenohumeral joint appears enlarged and the humeral diaphysis shortened, the joint relationships can be assessed. Further axillary projections have been described such as the trans-humeral axillary projection described by Tietge and Ciullo in 1982 [8], which can be carried out by keeping the immobilized arm in the bandage, like the previous ones, but it can be performed by the patient into a supine position.

The upper limb is anteriorly flexed by about 20° by placing a support below the elbow, and the radiological cassette is placed on the shoulder, perpendicular to the table. The X-ray beam will be horizontally directed following the cauda-cranial sense and incident towards the armpit. The axillary projections allow to evaluate the glenohumeral joint relationships, the glenoid's articular surface and the presence of potential Bony Bankart and glenoid fractures and allow an accurate study of the tuberosities and in particular of the decomposition degree of their potential fracture [9].

It is not always possible with simple radiographic examination to come to a correct classification of the fracture in order to plan the most suitable therapy. In recent years, thanks also to the technological development of diagnostic equipment, it is more and more frequent to resort to computed tomography (CT) for the assessment of proximal humerus fractures, especially when we decide to undertake the surgical treatment in such a way to carry out a pre-planning operation as accurately as possible and to have an idea as realistic as possible about what the intraoperative situation to be faced will be [10, 11]. As the common radiographic investigations, the CT is based upon the production by an X-ray tube of an X-ray beam whose attenuation is measured by some fixed detectors placed upon the stand at the machine that is named "gantry". During the rotation of the X-ray tube, the bed where the patient is placed moves along the horizontal axis, thus determining the reproduction by a software of the selected body volume, obtaining body sections of less than a millimetre (in modern equipment) which will allow us to have in addition to the traditional axial plane images some 2D multiplanar reconstructions (MPR, multiplanar reformation) on the coronal, sagittal and axial plane of the space and some 3D reconstructions (VR, volume rendering), thanks also to the contribution of modern equipment that allow us to obtain an isotropic voxel or an element characterized by the same dimensions on the three planes of the space with consequent, equal, spatial resolution in the

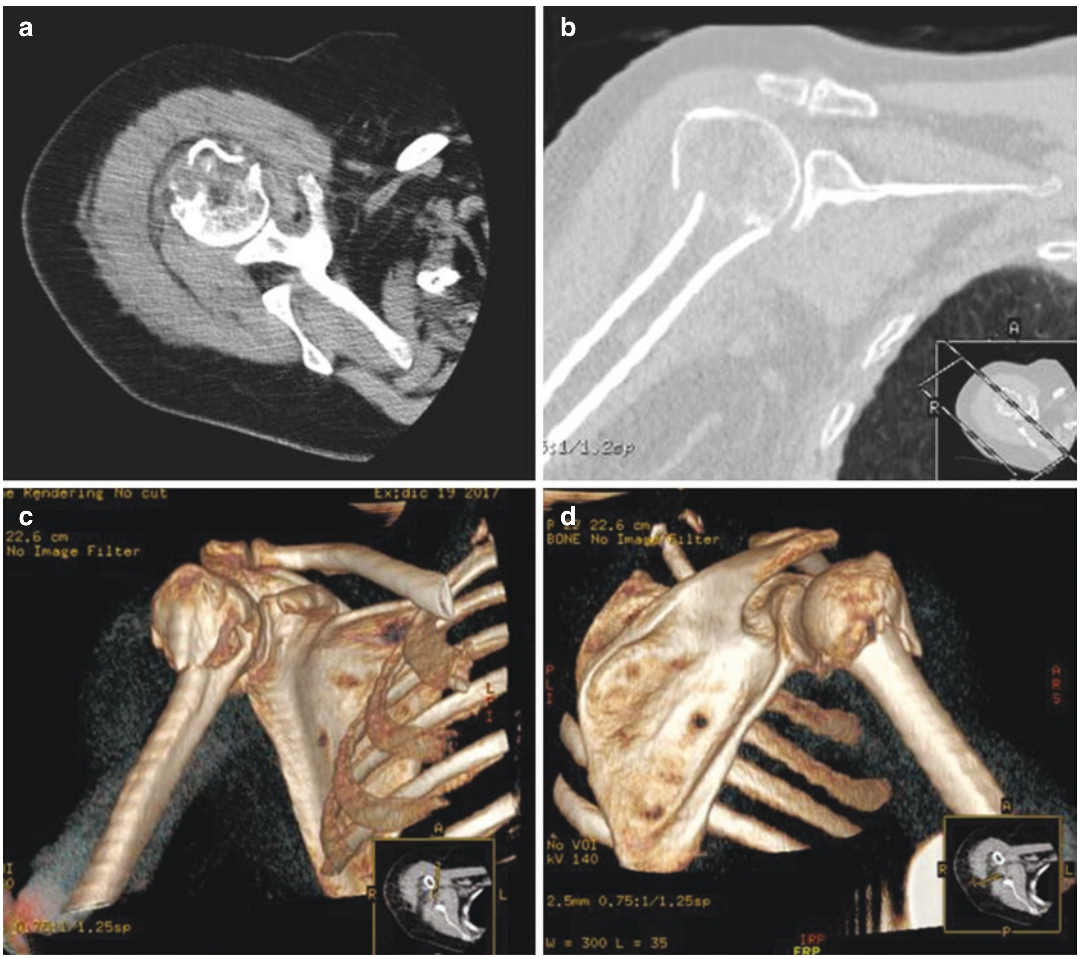

Fig. 11.7 CT scan: 2D multiplanar reconstructions (MPR, multiplanar reformation) on the axial (**a**) and coronal (**b**) plane of the space; 3D reconstructions (VR, volume rendering) (**c**–**d**)

reconstructions that we will carry out [12–14] (Fig.11.7).

The different X-rays' attenuation by the various anatomical structures will allow us to differentiate them within the images obtained [15]. The latest generation equipment (multidetector) allows us to acquire large body volumes in a few seconds, thus drastically reducing the time required to perform the examination and, therefore, any technical motion artefacts that affect it.

In the traumatic pathology of the proximal humerus, CT is extremely useful to define the presence and extent of the fracture or of a dislocation, to evaluate various intra-articular anomalies, to define the number and exact location of the fragments and to evaluate the adjacent soft tissues, in order to plan a conservative or, in alternative, a surgical treatment [16, 17].

CT is of particular importance in detecting small bone fragments located at the joint due to a trauma. The CT's advantage compared to conventional radiology is its ability to exceed the radiographic limits due to the overlap of several anatomical structures, providing great contrast resolution, to measure accurately the tissue attenuation coefficient and to obtain direct axial images. Multiplanar reconstructions (MPR) can be carried out on all floors of the space, thus offering greater diagnostic accuracy and adequate preoperative planning [18]. The three-dimensional images (VR) processed by the routinely used post-processing software allow the creation of a plastic model to the area in question, thus facilitating the operative planning and allowing a trial for complex reconstructive procedures' surgery [1, 19, 20]. The CT's disadvantages are related to the high radiant dose compared to common radiographic investigations and to a lower contrast resolution to the study of muscle-tendon structures compared with other imaging methods such as magnetic resonance, which, however, does not provide further information with respect to the TC for the bone study, and it is not usually indicated for patients with fracture of the proximal epiphysis of the humerus [21, 22].

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