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ORIGINAL ARTICLE

Coronal displacement in proximal humeral fractures: correlation between shoulder radiographic and computed tomography scan measurements

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Background: The purpose of this study was to analyze if there is a correlation in displacement measurements in coronal projections between shoulder radiographs and computed tomography (CT) scans in patients with proximal humeral fractures (PHFs).
Methods: A comparative, retrospective analysis of images from our database was performed. Ninety-seven cases with PHFs with radiographs and CT scans were included. Four evaluators measured PHF displacement using the following: metaphyseal extension (ME), medial calcar (MC) medialization, apex-tuberosity distance (ATD), and cervicodiaphyseal (CD) angle. Measurement reliability was evaluated with a pilot sample by performing intraclass coefficient correlation analysis. Surgery indication according to displacement (CD angle <105° or >155° and ATD <3 mm) and agreement analysis were assessed by κ tests.
Results: All evaluated parameters presented correlations among methods for intrarater and inter-rater reliability. All measurements showed significant differences (ME of 1.2 ± 6 mm, $P = .034$; MC of 1 ± 5 mm, $P = .041$; ATD of 2.6 ± 5 mm, $P = .001$; and CD angle of 9° ± 16°, $P = .001$). Regarding indications for treatment type relating to ATD and CD angle, there was agreement between CT scans and radiographs in 66 of 97 cases ($\kappa = 0.351$, $P < .001$). Twelve cases with surgical indications by CT scans had conservative indications by radiographs, whereas in 19 cases with conservative indications by CT scans, radiographic measurements suggested surgical treatment.
Conclusion: This study documented regular concordance between radiographs and CT scans for coronal displacement measurements in PHFs. Statistical differences were documented for all measurements. We

Hospital de Trabajador Ethical Committee Approval was obtained before initiation of the study.

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believe that ATD and CD angle differences are clinically relevant (mean, 3 mm and 9°, respectively) because these differences might change the type of treatment.
Level of evidence: Level III; Diagnostic Study

Keywords: Proximal humeral fractures; X-rays; computed tomography scan; coronal displacement; conservative treatment; surgical treatment

Proximal humeral fractures (PHFs) represent 5% of all fractures, with the incidence increasing over time, growing 3-fold in the United States in the past 3 decades.[6,10] Multiple variables are relevant when deciding on the appropriate PHF treatment (conservative or surgical): patient age, injury mechanism, patient function and demand, vascular prognosis of the proximal humeral bone after the fracture, bone quality, and initial displacement of the fracture. These variables are frequently determined by measurements of different anatomic parameters on radiographs or computed tomography (CT) scans.[11]

There is sufficient evidence to support conservative treatment of nondisplaced PHFs, given that bone healing and off-work time are similar in different groups treated with conservative or surgical management, with similar functional results.[12-14] These points are relevant if we account for final costs or complications associated with surgical treatment.

Different studies have documented low interobserver and intraobserver agreement for different imaging measurements on radiographs or CT scans that classify the fracture or recommend specific treatments, with moderate concordance when determining surgical treatment among different shoulder surgeons.[8,12] Resch[11] has explained that any classification should be easy to understand, should include at least 2 orthogonal projections, and should describe relevant findings that could guide the surgeon when defining treatment, such as varus or valgus deformities, metaphyseal extension (ME), and medial hinge displacement of the fracture. Generally, these are measured on anteroposterior (AP) shoulder radiographs. These varus or valgus deformities, evaluated in the coronal plane (eg, varus >20° or valgus displacement that predisposes an apex-tuberosity distance [ATD] >3 mm or >5 mm), can define surgical treatment of the fracture because the ATD correlates with a displacement of the greater tuberosity (GT) greater than 5 mm.

Many factors can alter the correct evaluation of the aforementioned parameters, such as an appropriate technique for obtaining radiographs, patient obesity, use of shoulder slings, or antalgic positions. Sometimes, when these factors are present, they can cause variability among radiographic measurements that can influence definitive treatment, diverging in some cases from the appropriate management.

The purpose of this study is to analyze if there is displacement measurement correlation in coronal projections between shoulder radiographs and CT scans in patients with PHFs. Our hypothesis is that there is relevant variability in these measurements when we compare results evaluated on radiographs or CT scans in the coronal plane.

Methods

A retrospective analysis of radiographic images saved in our database (Impax; Agfa, Greenville, SC, USA) was performed. The images of patients with the diagnosis of PHF between the years 2010 and 2014 were retrieved. Of 381 cases, only 97 met the following inclusion criteria and were subsequently used for analysis: (1) PHF with fracture lines that included at least the surgical neck and the GT and (2) true AP shoulder radiographs and CT images obtained within a period of no longer than 5 days.

The exclusion criteria were fracture-dislocations, splitting of humeral head, isolated tuberosity fractures, incomplete imaging, and CT scan obtained 5 days after the initial radiograph.

We analyzed the following displacement measurements of the proximal humeral anatomy:

- ME of the fracture is defined by the metaphysis length attached to the humeral head after the fracture, expressed in millimeters. Hertel et al[5] analyzed vascularity of the humeral head after fracture and determined that an ME shorter than 8 mm is one factor associated with proximal humeral avascular necrosis after a fracture (Fig. 1).
- Medial calcar (MC) medialization is defined by medial displacement of the diaphysis at the level of the surgical neck. Hertel et al[5] showed that a medial displacement greater than 2 mm is another factor associated with proximal avascular necrosis after a fracture (Fig. 1).
- Measurement of ATD determines the final position of the GT, measured from the most apical segment of the humeral head to the most apical segment of the GT and expressed in millimeters (Fig. 2). Normal values range from 8 to 12 mm.[9,15] When the ATD is shorter than 3 mm, we consider that the odds of subacromial compression rise significantly.
- Measurement of the cervicodiaphyseal (CD) angle represents varus or valgus displacement of the humeral head. It is measured by tracing a mid-diaphysis line that intersects with a perpendicular line traced in the middle of a third line that crosses from the most cephalic area of the articular segment of the humeral head to the most caudal area of the articular segment (Fig. 3). The normal value of this measurement is 130° ± 15°.[9]

Three independent observers conducted radiographic and CT scan measurements: a shoulder surgery fellow, an orthopedic surgeon, and an orthopedic surgery resident. For CT measurements, evaluators were instructed to choose the image frame in which the greatest CD angle displacement was observed in the coronal plane.

In a pilot sample, the 3 observers analyzed 18 cases (chosen at random); the reliability of the measurements was analyzed with intraclass correlation coefficients (ICCs) assessing intraobserver and interobserver correlation (measuring the same images within a 3-week