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ORIGINAL ARTICLE

Guidelines for humeral subluxation cutoff values: a comparative study between conventional, reoriented, and three-dimensional computed tomography scans of healthy shoulders

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Background: The humeral subluxation index (HSI) is frequently assessed on computed tomography (CT) scans in conditions of the shoulder characterized by humeral displacement. An arbitrarily set HSI cutoff value of 45% for anterior subluxation and 55% for posterior subluxation has been widely accepted. We studied whether mean values and thresholds of humeral subluxation, in relation to the glenoid and scapula, were influenced by different imaging modalities.

Methods: The HSIs referenced to the scapula (SHSI) and glenoid (GHSI) were compared between conventional CT scans, CT scans reoriented into the corresponding reference plane (ie, scapular plane for the SHSI and glenoid center plane for the GHSI), and 3-dimensional (3D) CT reconstructions of 120 healthy shoulders. The 95% normal range determined the cutoff values of humeral subluxation.

Results: The SHSI thresholds for conventional, reoriented, and 3D CT scans were 33%-61%, 44%-68%, and 49%-61%, respectively. A different mean SHSI was found for each imaging modality (conventional, 47%; reoriented, 56%; 3D, 55%; $P \leq .014$), with the conventional SHSI showing an underestimation in 89% of the cases. GHSI thresholds for conventional, reoriented, and 3D CT scans were 40%-61%, 44%-56%, and 46%-54%, respectively. The mean GHSI did not differ between each imaging modality (conventional, 51%; reoriented, 50%; 3D, 50%; $P = .146$).

Conclusions: The SHSI and GHSI are susceptible to different imaging modalities with consequently different cutoff values. The redefined HSI cutoff values guide physicians in the evaluation of humeral subluxation in conditions characterized by humeral displacement, depending on the available image data.

Level of evidence: Level III; Diagnosis Study

Keywords: Humeral head displacement; humeral subluxation; glenohumeral relationship; CT scan; glenohumeral osteoarthritis; total shoulder arthroplasty; glenoid dysplasia; shoulder instability

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Static posterior humeral head displacement has been associated with several pathologic shoulder conditions, including glenohumeral dysplasia secondary to brachial plexus palsy,[3,9,32] glenoid rim fractures,[26] and primary glenohumeral osteoarthritis (GHOA).[15,24] In these conditions, radiographic evaluation of the static position of the humeral head is of interest for the assessment of the pathoanatomy,[3,9,15,32] guidance of treatment decision-making,[19,26,31] preoperative planning,[11] outcome prediction,[30] and evaluation for realignment procedures.[11,20,31]

Posterior humeral head displacement is typically measured as the posterior offset of the center of the humeral head in relation to the center line of the glenoid or the scapular body.[22] When the segment posterior to the reference line is normalized to the humeral head diameter, the resulting ratio represents the static posterior humeral head subluxation index (HSI).[11] This measurement, originally described by Badet et al[1] as a static measurement determined on computed tomography (CT) scans, was used by Walch et al[29] to characterize humeral head displacement in GHOA and was adapted to a classification of glenoid morphology of primary GHOA.[28] Glenoid wear was classified on the basis of the position of the humeral head, with type A representing a well-centered humeral head, type B defined by a posteriorly subluxated humeral head, and type C a true dysplasia with a retroverted glenoid. In this classification of glenoid morphology, anterior and posterior subluxation with respect to the glenoid has been arbitrarily set at an HSI of 45% and 55%, respectively. Clinical studies emphasize the importance of an accurate assessment of the subluxation index in GHOA as the posteriorly subluxated type (type B) is a risk factor for accelerated glenoid component loosening of total shoulder arthroplasty and worse clinical outcomes compared with well-centered type A glenoids.[14,18,19,30] Therefore, the HSI is generally assessed in GHOA before considering an anatomic total shoulder arthroplasty.

Whereas the original HSI referenced the glenoid center line,[1,28,29] more recent studies reference the scapular body as it is independent of acquired bone loss and glenoid deformity.[19,24,32] In the proposed modification of the original Walch classification, the HSI was assessed with respect to the scapula without changing the cutoff values of subluxation.[2] Given that the glenoid has an average retroversion of approximately 3°-5° to the plane of the scapula,[5,10,16,25] a difference between the posterior HSI in relation to the glenoid (GHSI) and scapula (SHSI), with subsequently different cutoff values, has recently been proven.[16]

With the introduction of 3-dimensional (3D) reconstructed CT scans, conventional 2-dimensional (2D) measures of glenoid version, inclination, and the HSI have been converted to 3D.[5,8,13,17,22] These 3D measures are more accurate and reproducible than the corresponding 2D measures because they provide a standardized orientation of the scapula with a more global evaluation of the anatomy, independent of slice selection.[5,8,13,17] Similarly, measurements on axial 2D CT scan slices reoriented into the plane of the scapula proved to be more accurate and reproducible than the corresponding conventional 2D measures.[4,8]

The 95% prediction interval, or normal range, has been described as the range within which the HSI of a healthy person is expected to lie.[21] Because the normal range depends on the standard deviation (SD), and different imaging modalities have been proven to have different variances,[4,5] cutoff values might also differ between imaging modalities. Therefore, the aim of this study was to determine whether mean values and cutoff thresholds of humeral subluxation in relation to the glenoid and scapula are influenced by different imaging modalities in healthy shoulders. The null hypothesis was that each imaging modality would have the same mean HSI with the same cutoff thresholds for subluxation.

Materials and methods

In this retrospective diagnostic study, electronic medical records were reviewed to select a normal population based on medical history, clinical examination, and radiographic findings. Skeletally mature patients with unilateral disease of the shoulder and an available bilateral CT scan obtained between 2006 and 2008 were included. The CT scan of the healthy side was used for further analysis. Patients with shoulder instability were excluded.

The CT scans (Siemens, Erlangen, Germany; 140 kVp tube voltage, 512 × 512 acquisition matrix, ≤1.5-mm slice thickness, 500-mm field of view, 0.97-mm pixel size) were taken in a standardized supine position by use of an orthosis with the upper arm fixed to the trunk and the forearm pointing forward (Fig. 1) and were

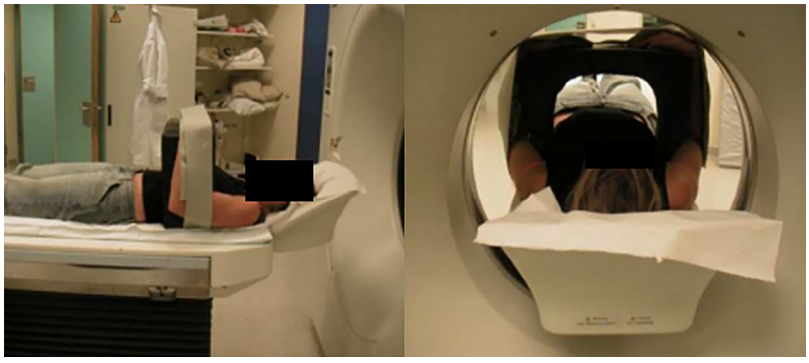

Figure 1 Standardized supine position for computed tomography scanning of the shoulder.