J Shoulder Elbow Surg (2015) 24, 541-546

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Accuracy of the glenohumeral subluxation index in nonpathologic shoulders

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Background: Correction of posterior humeral subluxation, measured by the humeral subluxation index (HSI) according to Walch, is necessary in total shoulder arthroplasty to prevent early loosening. The 3-dimensional (3D) measurement of the shoulder is becoming well accepted and common practice as it overcomes positional errors to which 2-dimensional (2D) glenohumeral measurements are prone. The first objective was to describe the HSI in a nonpathologic population with the 2D HSI according to Walch and a newly described 3D HSI method. The second objective was to compare both measuring methods with each other.
Methods: In 151 nonpathologic shoulders, the 2D HSI was measured on the midaxial computed tomography scan cut of the scapula. The 3D HSI, based on the native glenoid plane, was defined as $\frac{X+R}{2R}100\%$, in which X is the projection of the center of the humeral head to the anteroposterior axis of the glenoid fossa and R is the radius of the humeral head. Both measuring methods were compared with each other. Correlation was determined. Interobserver and intraobserver reliability of the 3D HSI was measured.
Results: The mean 3D HSI (51.5% ± 2.7%) was significantly ($P < .001$) more posterior than the mean 2D HSI (48.7% ± 5.2%), with a mean difference of 2.9% ± 5.6%. No correlation was found between the 2D and 3D HSI. The interobserver and intraobserver reliability was excellent.
Conclusion: The 2D HSI seems to underestimate the humeral subluxation compared with a 3D reliable equivalent.
Level of evidence: Basic Science, Anatomic Study, Imaging.

Keywords: 3D evaluation; 3D CT scan; 3D reconstruction; glenohumeral subluxation; humeral subluxation index; subluxation index

Ethical approval was obtained from the ethics committee (EC/2010-609). Ethics Committee UZ Gent, Chairman: Prof. Dr. Rubens. Registration number: B67020109674.
Institutional Review Board approval was not applicable for this article.

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A persistent prosthetic humeral head subluxation has been associated with inferior short- and long-term results in total shoulder arthroplasty (TSA).[5,14,31] Therefore, it is necessary to address the glenohumeral subluxation preoperatively, as a preoperative glenohumeral subluxation is associated with prosthetic humeral head subluxation in TSA.[31] The current "gold standard" measurement for

1058-2746/$ - see front matter © 2015 Journal of Shoulder and Elbow Surgery Board of Trustees.
http://dx.doi.org/10.1016/j.jse.2014.07.021

glenohumeral subluxation is the humeral subluxation index (HSI), originally described by Walch et al.[30] On the midaxial computed tomography (CT) scan cut of the scapula, a perpendicular bisecting line on the tangential line through the most anterior and posterior points of the glenoid fossa is drawn. It is the percentage of the humeral head located posterior to this perpendicular bisecting line that defines the HSI.

In primary glenohumeral osteoarthritis, an index of >55% has been originally defined as a humeral posterior subluxation.[30] However, to the best of our knowledge, no studies exist reporting the subluxation index in a large cohort of nonpathologic shoulders.

Current practice consists of measuring the posterior subluxation index on a 2-dimensional (2D) axial CT scan slice. Previous studies have shown that 2D CT scan measurements of the shoulder are often subject to positional errors in the CT scan gantry, leading to an inaccuracy of the measurement.[3,4,6,12] In addition, the posterior subluxation index measurement has been a subject of discussion in the literature as the interobserver and intraobserver reliability measurements seemed not as reliable as initially reported.[18,21]

The 3-dimensional (3D) measurement of the shoulder has been shown to improve the reliability of glenohumeral measurements as it seems to overcome these inherent positional errors of 2D CT scans.[1,8,12,15,16,20,22,25,26] Therefore, a 3D measuring method could improve the reliability of the posterior subluxation index measurement.

In this study, our primary objective was to describe the HSI on 2D axial CT scan slices and 3D reconstructed nonpathologic shoulders with a newly described 3D HSI method.

The secondary objective was to compare the 2D HSI measurement with the 3D measurement technique.

Materials and methods

Patient cohort

Bilateral CT scans were acquired in patients with suspicion of a unilateral shoulder disorder.

The senior author selected the contralateral nonpathologic shoulder on the basis of medical history, clinical examination, and radiographic images. If any suspicion of a pathologic change of the shoulder existed, the patient was excluded. A patient cohort of 151 nonpathologic shoulders with a mean age of 42.02 years (18-80 years) was obtained.

Computed tomography protocols

All patients were positioned in a standardized supine position in the CT scan gantry according to a previously described method in which the arm is adducted to the trunk and the elbow is flexed 90° with the forearm in the anterior direction.[7] All CT scan images were acquired with a Siemens (Somatom Volume Zoom system) scanner (Siemens, Erlangen, Germany) with the following settings: 140/eff kV, 350 mAs; 512 × 512 matrix. A patient-specific field of view was applied, with a maximum of 500 mm for both shoulders and 180 mm for 1 shoulder. A maximum of 1.5-mm interval slices was applied for scanning of the glenohumeral joint.

Two-dimensional humeral subluxation index

Transverse CT scans of the 151 shoulders were evaluated by one orthopedic resident to determine the HSI according to the Walch measuring criteria.[30] On the midaxial CT scan cut, a perpendicular bisecting line was drawn on a tangential line between the anterior and posterior points of the glenoid fossa, so that the humeral head is divided into an anterior and a posterior part. The posterior part of the humeral head in relation to the diameter of the medial third of the humeral head is defined as the HSI. All measurements were acquired with standard measurement tools available on a standard picture archiving and communication system (PACS) workstation.

Three-dimensional reconstruction

The same cohort of 151 CT scans of shoulders were 3D reconstructed and evaluated with a commercially available image analysis software (Mimics; Materialise, Leuven, Belgium). With the use of computer-aided design operations, the native glenoid circle, the scapular plane, and the center of rotation (COR) of the humeral head were reconstructed as previously described.[1,26,27] The native glenoid circle, which has been shown to be the most reliable glenoid plane with the lowest variability, was constructed by the best-fitting circle through a zone marked on the anteroinferior glenoid rim (Fig. 1).[26] The scapular plane was defined by the midpoint (M) of the native glenoid circle, the most medial point and the most inferior point of the scapular blade. The inferior intersection of the scapular plane and the native glenoid was defined as the most inferior point of the glenoid. The humeral head was reconstructed by calculating the best-fitting sphere to the articular surface.[27,32] The center of this sphere, with radius R, was defined as COR (Fig. 2).

To compare the shoulders with each other, a cartesian coordinate system was acquired as previously described. The midpoint of the native glenoid circle is defined as the origin, with the y-axis going through the most inferior point of the glenoid and the origin. The x-axis runs perpendicular to the y-axis through the origin and both the most anterior and most posterior points of the native glenoid circle so that both the x-axis and the y-axis are in the plane determined by the native glenoid circle. The z-axis goes through the origin, perpendicular to the x-axis and y-axis (Fig. 3).[27]

Three-dimensional humeral subluxation index

A new 3D HSI, based on the same landmarks as the 2D HSI according to Walch, was defined and calculated on each 3D reconstructed shoulder. The COR was projected to the native glenoid circle and defined as COR'. As the x-axis connects the most anterior and posterior points of the glenoid fossa, the distance of COR' to the x-axis (X) combined with the radius of the 3D reconstructed humeral head (R) reflects the position of the posterior part of the humeral head in the axial plane. The 3D HSI was defined as $\frac{X+R}{2R}100\%$ (Fig. 4).