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ORIGINAL STUDY

Validation of a CT-based determination of the glenohumeral index

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The amount of bony support by the glenoid can be determined using the glenohumeral index, i.e. the maximum anteroposterior (AP) diameter of the humeral head divided by the maximum AP dimension of the glenoid. This index has been described theoretically, but has never been validated in practice. In this study we used 20 cadaver shoulders to determine the glenohumeral index in two different ways. One method evaluated the glenohumeral index on a CT scan of the shoulders. The second method determined the anatomical glenohumeral index of the same shoulders by direct measurement of anatomical specimens using a digital caliper. All CT and caliper measurements were repeated by three different investigators. We used the Wilcoxon Signed Rank Test, to calculate the statistical significance of intra-observer and inter-observer differences in measurements on CT and with the caliper.

Statistical analysis showed no significant differences between CT scan and caliper measurements for each investigator separately, but we found a statistically significant inter-observer variability concerning the caliper measurements obtained by two different investigators.

This study demonstrates that a two-dimensional CT scan of the shoulder is a reliable and very accurate tool to calculate the glenohumeral index, as the values measured for the AP diameter of the humeral head and the AP dimension of the glenoid compare well with those measured in vitro on anatomical specimens.

Key words : shoulder joint ; glenohumeral index ; CT scan.

INTRODUCTION

Several CT scan studies of the shoulder have described the two-dimensional and three-dimensional anatomy of the glenohumeral joint (*1,2,4,5,6,9, 10,12,14*). Attention is often directed to the version of the glenoid as related to anterior, posterior and multidirectional shoulder instability.

The correlation between measurements obtained by CT scan and measurements obtained by direct measurement with a caliper on anatomical specimens has, however, not been published.

The goal of our study was to obtain a validation of CT measurement of the glenohumeral index against caliper measurement. We therefore compared the recorded anteriorposterior (AP) dimension of the glenoid and the AP diameter of the humeral head on CT scan images with the results of a direct caliper measurement on anatomical specimens.

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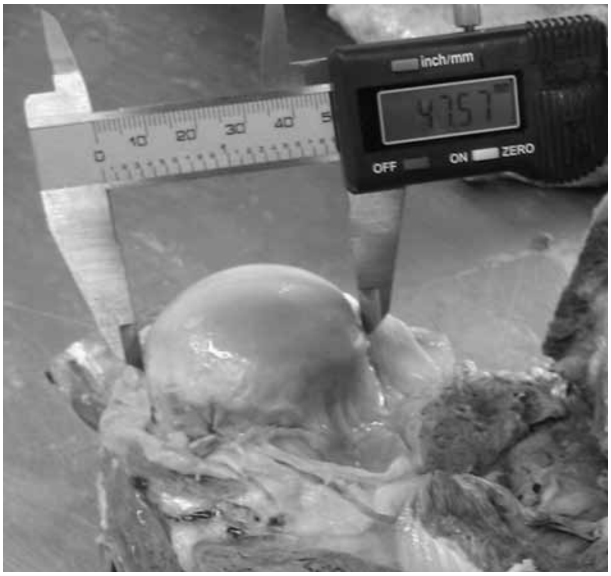

Fig. 1. — Caliper measurement of the AP-diameter of the humeral head.

Fig. 2. — Caliper measurement of the AP dimension of the glenoid.

The glenohumeral index was defined as the maximum AP diameter of the humeral head divided by the maximum AP dimension of the glenoid (*8*).

MATERIALS AND METHODS

For our study we used 20 cadaver shoulders provided by the anatomy laboratory of the University of Antwerp. The investigators were unaware of gender or age.

The 20 cadaver shoulders were first submitted to an i*n vitro* measurement after careful dissection of the glenohumeral joint. The measurements were carried out using a calibrated digital caliper (Digital Caliper, Perel®, contactless linear CAP system ; accuracy 1/100 mm) (Fig. 1 & 2). Some of the shoulders showed a varying degree of osteoarthritic changes with or without osteophytes. When present, osteophytes were included in the measurements without any correction.

In a second stage, a CT scan was obtained of the cadaver shoulders. For the measurements of the AP diameter of humeral head and maximal AP dimension of the glenoid, only axial images were used. The software required for these measurements was supplied by the University Hospital of Antwerp (DICOM Viewer by Codonics Inc.). The method to measure the maximal AP dimension of the glenoid is described by Chuang *et al* (*2*).

The measurements were made by three investigators separately. Two of these investigators were last year trainees in orthopaedic surgery. The third investigator was a last year medical student with special interest in orthopaedic surgery. Each investigator noted his results without informing the other investigators about his results. A spreadsheet was used to write down the measurements and calculate the glenohumeral index.

The results of the three investigators were collected. For each investigator, using the Wilcoxon Signed Rank Test, we looked for statistically significant differences between measurements obtained by CT scan and by caliper. We also used the Wilcoxon Signed Rank Test to determine inter-observer variability in measurements on CT and with caliper. Statistical analysis used the SPSS 17 (Chicago, Illinois, USA) software, because the distribution of differences between measurements was not normal. This test is the non-parametric analogue to the paired T-test.

RESULTS

Results of the statistical analysis are presented in Tables I and II. They show no significant intra-observer difference between the measurements, obtained by the two methods used, for each observer separately. All p-values were greater than 0.05, and thus the Null Hypothesis, which stated there is no difference between two measurements, was not rejected (table I).

Table I. — Wilcoxon Signed Ranks Test (Intra – Observer) Test Statistics

	CT ob 1 – IV Ob 1	CT ob 2 – IV ob 2	CT ob 3 – IV ob 3
Z	-.262	-.363	-.742
Asymp. Sig. (2-tailed)	.793	.717	.458
Exact Sig. (2-tailed) (P*)	0.81	0.73	0.47
Exact Sig. (1-tailed)	.404	.365	.237
Point Probability	.009	.007	.006

*P : P-value (P < 0.05).

Table II. — Wilcoxon Signed Ranks Test (Inter-observer) Test Statistics

	IV ob 2 – IV ob 1	IV ob 3 – IV ob 1	IV ob 3 – IV ob 2	CT ob 2 – CT ob 1	CT ob 3 – CT ob 1	CT ob 3 – CT ob 2
Z	-.736	-2.728	-1.933	-.086	-.710	-.846
Asymp. Sig. (2-tailed)	.462	.006	.053	.931	.478	.398
Exact Sig. (2-tailed) (P*)	0.49	0.01	0.05	0.97	0.51	0.46
Exact Sig. (1-tailed)	.243	.003	.026	.486	.256	.229
Point Probability	.013	.001	.004	.018	.016	.048

*P : P-value (P < 0.05).

When using the same Wilcoxon Signed Rank Test to determine inter-observer variability, we noticed a significant inter-observer variability between observer 1 and 3, with a p-value of 0.01 (table II).

The significant differences between the two observers concern the anatomical caliper measurements. There is also a tendency (p-value 0.05) toward inter-observer variability between the anatomical measurements of observer 2 and 3. The largest differences were measured in osteo-arthritic shoulders.

There is no inter-observer variability (p-value > 0.05) between the three observers concerning the CT measurements.

DISCUSSION

In theory, shoulder stability depends on the amount of bony support provided to the humeral head by the glenoid (*8*). The glenohumeral index reflects the amount of bony glenoid support (*11,13*). The question was whether a CT scan is a reliable tool to determine the glenohumeral index.

Our study has shown that for each individual investigator, the glenohumeral index obtained by CT scan or *in vitro* caliper measurement, was comparable.

Significant differences in caliper results were noted between two observers. This could be due to the fact that one investigator (investigator 3) was a medical student and therefore had less experience with *in vitro* measurements. The largest differences were measured in osteo-arthritic shoulders, probably due to osteophytes.

This study demonstrates that a two-dimensional CT scan of a shoulder is a reliable and very accurate tool to measure the AP diameter of the humeral head and the AP dimension of the glenoid. We can use the index to investigate the difference between stable and unstable shoulders (*3,7*), between shoulders with unidirectional and multidirectional instability and finally between ‘true’ and bony Bankart lesions. The glenohumeral index could help us to better understand possible aetiological factors of shoulder instability.

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