Accuracy and limitations of a quantitative analysis method for 3D MRI data of the shoulder

H. Busse[1], M. Seiwerts[1], T. Kahn[1], G. von Salis-Soglio[2], M. Thomas[2]
[1]Diagnostic Radiology Dept., Leipzig University Hospital, Leipzig, Germany, [2]Orthopedics Dept., Leipzig University Hospital, Leipzig, Germany

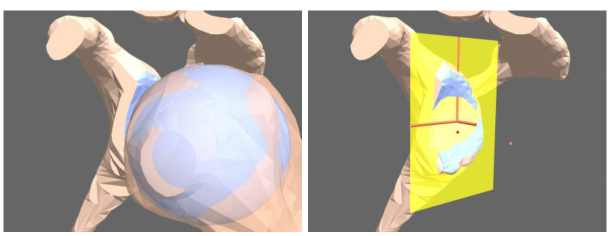
Abstract
The aim of this work was to determine the accuracy and limitations of a novel, quantitative PC-based processing method for 3D MRI scans of the shoulder. Data from 10 healthy subjects in various glenerohumeral joint position, in particular the clinically relevant apprehension position were acquired in a vertically open MRI scanner. Surface model objects rendered after segmentation of the MRI data were available to three observers for further interactive and automatic processing. Despite a limited quality of the underlying model data, a significant difference in the humeral head translation was observed between neutral and apprehension position in 10 healthy volunteers yielding a posterior and caudal shift on average.

Introduction
Due to the lack of bony stability 50 % of all joint dislocations concern the shoulder. The best known conventional procedure for diagnostics of anterior inferior instabilities is the apprehension test [1]. With conventional methods, however, a precise quantitative measurement is not possible. Although MRI is widely accepted for diagnostics of the shoulder, only open MRI scanners allow functional investigations of the shoulder joint in positions relevant for shoulder instabilities, such as the apprehension position (90° abduction, external rotation) [2,3]. We have developed a novel PC-based approach to the analysis of acquired 3D data that will eventually be useful in routine diagnostics. This study addresses the important issues of observer variability and other sources of errors and will discuss some limitations of our processing method.

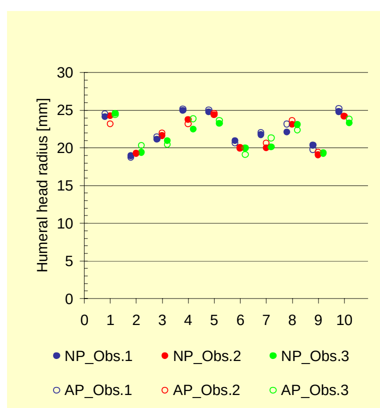
Materials and Methods
MR data (3D FSPGR, TE 10.8, TR 25.1, 256 x 160 matrix, 28 slices, thk 3.0) in the apprehension (AP, 90° abduction, external rotation) and in the neutral position (NP) were acquired in a vertically open 0.5 T scanner (Signa SP/i, GE Medical Systems, Milwaukee, WI) using a special MR-compatible shoulder positioning device. The PC-based data processing was performed in three steps: (1) rendering of a 3D surface model of the shoulder joint after segmentation of the bone structures (2) interactive sphere fit to the the humeral head object and extraction of a glenoid cavity (GC) model using standard modeling software (3ds max, Autodesk, Inc.) and (3) automatic analysis of the exported objects with a self-written tool calculating the projection point of the humeral head onto a patient-based reference plane defined by the principal axes of the GC object (Fig. 1). In this study, the model data of 10 healthy volunteers in AP and in NP were processed by three observers with slightly different experience.

Results
The humeral head radii of a group of 10 volunteers ranged from 18.70 to 25.17 mm (Fig. 2). The average radius of 22.06 ± 2.05 mm was used as a normalization value to account for the natural variation in shoulder size, i.e., all projection positions were scaled according to the ratio of actual radius and reference radius. When comparing the obtained radii of the same humerus imaged in different joint positions, the maximum relative difference in radial size of one observer was 6.0 %. The average variations over all subjects were 1.8 ± 1.2 %, 1.7 ± 1.5, and 3.1 ± 2.0 % for the three observers, respectively, suggesting a good intraobserver reproducibility of the fitting procedure. For the interobserver variability, the standard deviations of the individual radii ranged from 0.45 to 1.02 mm with an average value of 0.65 ± 0.17 mm.

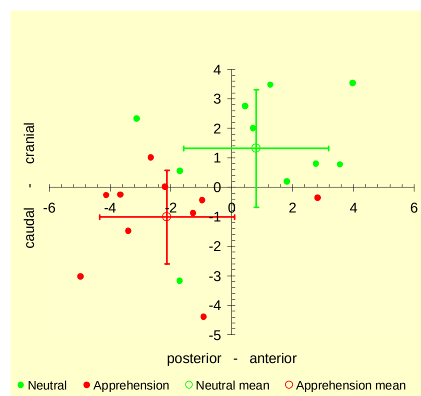
The analysis of the projection coordinates shows the 2D positions (anterior-posterior *ap*, cranial-caudal *cc*) within the calculated GC plane (Fig. 3). The comparable standard deviations in the projection positions obtained by three observers – averaging 1.11 mm in *ap* and 0.81 mm in *cc* direction for NP, and 0.84 mm *ap* and 0.84 mm *cc* for AP – suggest no particular positional dependence of our analysis. The 10 mean values of the humeral head projection in NP showed a clear preference for the anterior-cranial quadrant, while the corresponding values in AP predominantly fell into the posterior-caudal quadrant. A statistical analysis ($p < 0.05$) showed that the mean projection point in AP (2.13 mm post., 1.01 mm caudal) was both significantly more posterior and more caudal than the corresponding point in NP (0.81 mm ant., 1.32 mm cranial).



▲ **Fig. 1** Fit of a sphere to the humeral head and projection of the center point onto a glenoid cavity (GC) plane (yellow) defined by the principal axes (red) of a GC model object (blue).



► **Fig. 2** Humeral head radii of 10 volunteers (random order) in neutral (NP) and apprehension position (AP).



►► **Fig. 3** Humeral head projection onto GC in NP and AP.

Discussion
Using a novel PC-based analysis approach, it was possible to detect significant changes in the humeral head translation between the neutral and the apprehension position in 10 healthy volunteers showing a posterior and caudal shift on average. The variation in the analysis of a given model is produced by two user-dependent steps: (1) manual sphere fit to the humeral head and (2) interactive definition of the glenoid cavity (GC) object. The humeral head radii could be reliably determined on the order of 0.5 mm although the underlying slice thickness of the MR data was only 3 mm. In comparison, the second step is more sensitive to either poor image data, large slice thickness, variable cropping criteria, segmentation errors, as displayed by our interobserver variability of the projection positions. More coherent results are expected by minimizing these error sources.

References
[1] Rowe et al., *J Bone Joint Surg* 63, 863, 1981, **[2]** Graichen et al., *Surg Radiol Anat* 21, 59, 1999, **[3]** von Eisenhart-Rothe et al., *AJSM* 30, 514, 2002.