A Technique for the Dynamical Evaluation of the Acromiohumeral Distance of the Shoulder in the Seated Position under Open-field MRI

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Introduction
Nowadays, the current understanding is that the shoulder impingement syndrome (SIS) is characterized by impairment and dysfunction of several structures, contained in the subacromial space, which alter normal shoulder movements of flexion and abduction and provoke pain. Currently, the SIS is a clinical diagnosis based on the patient’s history and physical findings which occurs at about 90 degrees of forward flexion and abduction of the arm. Unfortunately, with normal configuration MRI, only indirect signs of this condition can be described [1,2] due to the fact that the examination can not be performed with the patient in the position in which the SIB occurs.

New open-configuration MRI systems, now offer an opportunity to investigate the variation of the acromiohumeral distance (AHD) during active shoulder motions of controlled and large amplitude. To that end, we have developed an MRI examination protocol designed to consider the subject in a sitting position and executing controlled movements. The open-field MRI technique is conceived to allow for a standardized evaluation of the dynamical behavior of the shoulder in normal conditions. We have tested the technique with a group of normal volunteers and present here the results obtained on a population of thirteen normal subjects. We substantiate measurements of the dynamical behavior of the AHD during forward flexion as extracted from a typical case of our population of normal subjects. We further quantify the inter-reader and inter-trial uncertainties on measurements of the acromiohumeral distance hence acquired.

Methods
Asymptomatic candidates considered for this study were first scheduled for a standardized clinical evaluation in order to ensure the integrity of the glenohumeral joint. Candidates showing normal results to the physical and clinical tests were then directed to undergo a radiograph of the shoulder. Subsequently, only those subjects for which the glenohumeral joint was diagnosed as normal were retained for the study. We could recruit a group of 13 volunteers with whom to pursue the entire study; 7 men and 6 women between 20 and 46 years of age.

Our imaging protocol exploits the unique features of a 0.5T SIGNA-SP open-field MRI unit from General Electric Medical Systems [3]. The so-called vertical “double donut” configuration and near-real-time imaging capacity of this interventional MRI system is particularly well suited for dynamical studies of the shoulder in the seated position. An hydrogoniometer was strapped to the subject’s upper arm to allow for a direct measurement of the flexion or abduction angle with respect to the starting position (0° of flexion) of the dynamical examination of the shoulder joint. The subject was instructed to perform two consecutive trials of a movement of anterior flexion and to maintain successive angles of 15°, 50°, 70°, 90°, 110° and 130°. Subsequently, the subject executed two consecutive trials of a movement of abduction maintaining angles of 50°, 70°, 80°, 90° and 110° respectively. The AHD was measured as the smallest vertical distance between the acromion and the humeral head on the MR image. The best of all three images collected in a given position and movement trial was considered. The AHD measurement was carried out by two independent radiologists, each reading the image at two different times. As a result, 8 measurements (2 trials x 2 readers x 2 reading times) of the AHD were collected for each flexion or abduction position.

The technique uses a miniature active coil[4] to actively localize the acromion during the dynamical examination. The device was taped to the skin over the acromioclavicular joint line. Images, actively registered by the miniature localizer coil, were acquired in near-real-time mode using a fast 2D-Gradient Recalled Echo sequence. A near-T1W contrast was selected from using a 70° flip angle along with a TE/TR of 7.2/19.0 m sec. A single slice per image was acquired in a coronal oblique plane, 7 mm thick and on axis with the supraspinatus tendon. The slice spanned a FOV of 30X30 cm² sampled with a matrix of 256x128 pixels and 1 NEX. The resulting image refresh rate was of 2.5 sec/image, including active slice registration by the miniature localizer coil.

Results
Figure 1 demonstrates the capacity of the technique to monitor the dynamical behaviour of the AHD under open-field MRI.

Further considering our full data set, the observed inter-reader uncertainty is of ±0.5 mm for a confidence level of 91%. Similarly, independent trials of flexion or abduction movements are found to yield measurements of the AHD agreeing to ±1.5 mm for the same confidence interval.

Conclusion
This new technique specifically exploits the vertical opening of the SIGNA-SP magnet which has been found to be particularly well suited in accommodating the natural motion of the arm. Our results demonstrate the feasibility and capacity of the technique to monitor variations of the AHD under open-field MRI with healthy subjects. They also confirm that measurements of the AHD, using this approach are accurate. The study demonstrated an excellent control of the inter-reader uncertainty for forward flexion and abduction movements. With the methodology and proof-of-principle being established, one may now undertake clinical investigations with a specific focus on comparing the dynamical variations of the AHD in healthy subjects and symptomatic patients. This should eventually lead to a radio-clinical correlation and better understanding of the pathogenesis of the SIS.

References