Introduction: Shoulder symptoms are thought to be frequently associated with a reduction in subacromial joint space width [1]. Functional parameters such as arm elevation angles and muscle forces are known to influence the width of the subacromial space in vivo [1, 2], but the mechanism is unknown. Since this space is defined by the distance between the acromion and the humeral head, a reduction may be either caused by superior translation of the humeral head or by rotation of the scapula versus the humerus. Understanding the mechanisms of joint space narrowing is particularly important in the context of conservative and postoperative treatment of the impingement syndrome.

The objective of this study was therefore to quantify the subacromial space width, the scapular kinematics (rotation) and the glenohumeral translation during elevation of the arm under different muscle activities (ab- and adduction, respectively) in vivo. The study was designed to test the specific hypotheses that a) adducting muscle activity leads to a widening of the subacromial space in vivo, and that b) the widening is achieved by inferior translation of the humerus (versus the glenoid), but not by scapular rotation.

Methods: 12 shoulder joints of healthy volunteers were investigated using an open MR-system (0.2 T; Siemens Erlangen, Germany) and a 3D GRE-sequence. The pixel size was 0.86 mm x 0.86 mm, the slice thickness 1.86 mm and the acquisition time 4’26 min. The volunteers were placed 30° oblique supine to warrant abduction in the scapular plane. The shoulders were imaged at 30°, 60°, 90°, 120° and 150° of elevation. Oblique coronal images were acquired perpendicular to the glenoid cavity. A weight of 1.5 kg was applied to the distal humerus, once according to isometric contraction of the adductors, and once to contraction of the adductors (10 acquisitions in each subject). Written consent was obtained from all volunteers prior to investigation and the study was approved by the local Ethics Committee.

After image acquisition and interactive segmentation of the humerus and the scapula (including cartilage), trilinear interpolation and 3D reconstruction of relevant anatomical structures was performed. The minimal spatial distances between the humerus and acromion, and between the humerus and clavicle were calculated, independent of the original section plane and orientation. These parameters were used as surrogates of subacromial space width. Moreover, 3D scapular kinematics (scapular rotation and tilting) and 3D glenohumeral position (translation) were determined from these data images.

For determining the scapulo-humeral rhythm the glenoid was separated from the scapula body and a principal axis composition was applied [3]. The ratio between glenohumeral elevation and scapulothoracic elevation was calculated independently of the original section plane and orientation. These parameters were used as surrogates of subacromial space width. Moreover, 3D scapular kinematics (scapular rotation and tilting) and 3D glenohumeral position (translation) were determined from these data images.

Results: Adducting muscle forces led to a significant increase of the acromiohumeral distance in all arm positions (p<0.01), and the magnitude varied from 32% (30°) to 138% (90°) [relative to abducting muscle forces]. The claviculohumeral distance displayed an increase of 9% (30°) to 24% (90°), and this increase was also significant at all positions (p<0.05). The subacromial space width became smaller during arm elevation from 30° to 120° (p=0.001) [-30% under isometric contraction of the adductors, and -53% (p=0.001) under activation of the adductors]. The scapulo-humeral rhythm (2.2-2.5) and the scapula tilting (2°-4°) remained almost constant during elevation of the arm. No significant difference was found between abducting and adducting muscle activity.

Under adducting muscle activity, the humeral head displayed a significant inferior (p<0.05) and anterior (p<0.01) translation versus the glenoid, in comparison with abducting muscle activity at all arm elevation angles (except for 30°). During elevation of the arm, the humeral head translated superiority (p < 0.05) under abducting muscle activity and was positioned (1.3 to 2.3 mm) posterior to the center of the glenoid. During adducting muscle activity, in contrast, the humeral head remained almost constant in superior/inferior direction, while a significant posterior translation of the humeral head was observed between 90° and 150° of elevation. The correlation between the direction of translation and the increase of the subacromial space width during adducting muscle activity was high (r=0.81), while it was low (r = 0.23) for the subacromial space width and scapular kinematics.

Conclusions: In this study we have shown, for the first time that adducting muscle activity leads to a significant increase of the subacromial space width during the entire arm elevation in comparison with abducting muscle activity in vivo. By applying 3D postprocessing techniques we were able to determine both inferior/anterior translation of the humeral head and alterations of the scapula kinematics simultaneously, and we show that the increase of the subacromial space width is caused by humeral head translation and not by alterations of scapular tilt or rotation. The physiologic mechanism of widening of the subacromial space under adduction muscle activity is thus translation of the humeral head, but not scapular rotation. The methods presented here provide an efficient tool for extending these investigations to patients with impingement syndrome, in particular in context of optimizing conservative and postoperative treatment strategies.

References: