An Investigation Of The Subacromial Space During Shoulder Elevation Following Surgical Reconstruction Of The Acromioclavicular Joint

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INTRODUCTION: High-grade disruptions of the acromioclavicular joint (ACJ) have been shown to significantly impair scapular control and positioning, often resulting in scapular dyskinesis.[1] These altered mechanics may reduce the subacromial space, leading to pathological contact between the supraspinatus tendon and the acromion.[2] Given these biomechanical consequences, evaluating changes in the subacromial space may be crucial in patients with ACJ pathology or following surgical reconstruction. This study aimed to quantify the subacromial space between the anterior acromion and the supraspinatus footprint during muscle-driven shoulder motion using dynamic stereo x-ray (DSX). We hypothesized that surgically reconstructed shoulders would show reduced subacromial space and an altered location of minimum spacing than the contralateral limb, indicative of potential alterations in contact mechanics.

METHODS: Informed consent was received from twelve participants (ten males and two females, mean age 39 ± 10 years, mean body mass 92 ± 17kg, mean height 179 ± 10cm) who underwent ACJ reconstruction surgery, 1-3 years before enrollment (IRB code: HSC-MS-20-0585). Each participant underwent 3-D computed tomography, followed by DSX imaging while performing abduction, scaption and flexion movements. Patient-specific bone models were digitized and aligned frame-by-frame within the biplanar X-ray sequences. Regions of interest (ROI) were applied to the inferior surface of the acromion, along with the superior facet of the humeral greater tuberosity. These regions were chosen to provide a more anatomically precise and clinically relevant assessment of subacromial impingement than generalized humeral-acromial spacing. The subacromial space above the supraspinatus footprint was calculated from the smallest 3D Euclidean distance between each respective ROI at every timepoint in the movement cycle for each humeral elevation movement. The anatomical location of the minimum distance was also recorded as a vector with X (medial/lateral), Y (anterior/posterior) and Z (superior/inferior) components relative to the origin of each respective body (Glenoid center for the scapula, and humeral head for the humerus).

RESULTS: Fig. 1 presents the subacromial space above the supraspinatus footprint throughout the entire movement cycle (elevation and depression phases) for abduction, scaption, and flexion. The surgical limb exhibited a reduced minimum space during abduction compared to the contralateral limb (2.67 ± 0.8mm vs 3.48 ± 1.1mm, p = 0.044). It also showed a reduced maximum space during abduction (14.2 ± 1.4mm vs 16.1 ± 2.4mm, p = 0.022), scaption (14.7 ± 1.7mm vs 16.4 ± 1.8mm, p = 0.021), and flexion (13.76 ± 1.1mm vs 16.45 ± 1.7mm, p < 0.001). Additionally, significant differences existed in the location of the minimum subacromial space, with the surgical limb demonstrating more medial locations on the acromion (Fig 2) with respect to the glenoid center during abduction (22.4 ± 2.6mm vs 25.7 ± 3.1mm, p = 0.005), scaption (21.9 ± 2.9mm vs 25.5 ± 2.6mm, p = 0.002), and flexion (22.98 ± 2.8mm vs 26.2 ± 1.5mm, p = 0.001).

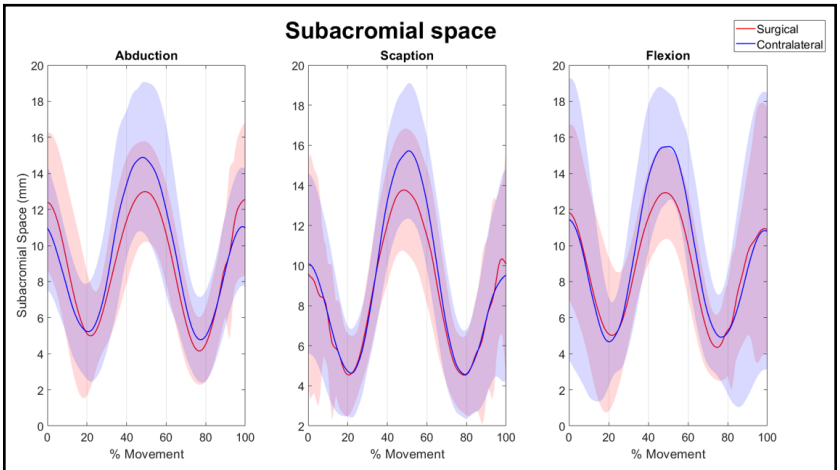

Fig 1: The subacromial space (mean ± std) above the supraspinatus footprint shown throughout the full movement cycle (elevation and depression phase) during abduction, scaption and flexion for the surgical (red) and contralateral (blue) limb.

DISCUSSION: In both limbs, the subacromial space above the supraspinatus footprint consistently decreased with shoulder elevation across all planes of movement, reaching a minimum around 20 to 25% of the movement cycle, followed by an increase as elevation progressed. The surgical limb exhibited a 23% narrower space between the supraspinatus footprint and the anterior third of the acromion during abduction compared to the uninjured contralateral limb. Significant shifts were also observed in the location of the minimum subacromial space across all shoulder elevation planes. These results suggest that internal contact mechanics may be substantially altered following ACJ reconstruction, potentially exacerbating subacromial crowding between the supraspinatus footprint and anterior acromion at lower elevation angles. Repeated compression of the bursal side of the rotator cuff tendon against the undersurface of the acromion may lead to tendon degeneration, with many rotator cuff tears being initiated by impingement wear.[3] This highlights the importance of preserving adequate space between the supraspinatus footprint and anterior acromion, particularly in the context of ACJ disruption. Loss of the ACJ's strut function may reduce acromial elevation, due to the coupled motion of the clavicle and scapula, thereby altering scapular biomechanics and in turn narrowing the subacromial space during arm abduction.

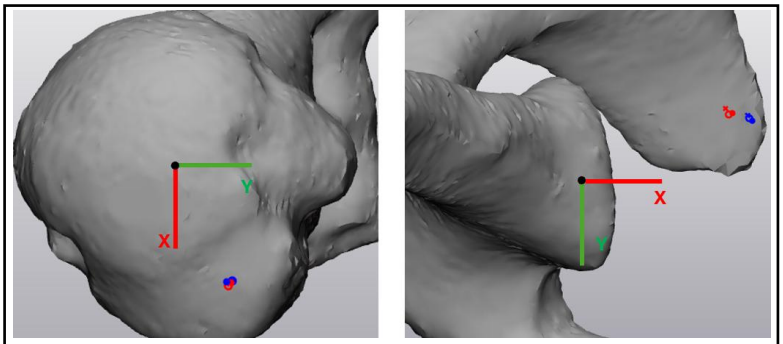

Fig 2: The mean location of the points of minimum subacromial space above the supraspinatus footprint and inferior acromion during abduction (O), scaption (X), and flexion (●), for the surgical (red) and contralateral limb (blue).

SIGNIFICANCE/CLINICAL RELEVANCE:
Subacromial space and internal contact mechanics can be significantly altered following ACJ reconstruction, potentially increasing crowding between the supraspinatus footprint and the anterior acromion. Surgical reconstruction should aim to minimize these changes, in order to mitigate the risk of repetitive shear and compressive forces on the rotator cuff tendon, contributing to potential tendon degeneration.

REFERENCES: [1] Gumina et al. (2009) *J Arth Rel Surg.* 25(1):40-45; [2] Roche et al. (2015) *Shoulder Elb.* 7(4):289-297; [3] Neer. (1983) *Clin Orthop.* 173:70-77.