Assessment of length variations of the coracoclavicular ligaments during arm movement from MRI data

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Introduction

The anatomic reconstruction of the coracoclavicular ligaments (CCL) is important for the treatment of acromioclavicular joint disruption [1]. The length variations of the conoid ligament and the trapezoid ligament during arm movement may be important for their restoration. To date they have not been studied in vivo. The manual assessment of these variations from MRI data is difficult and not reproducible due to the complex morphology of the bones and the complex course of the CCL. This study introduces a semi-automatic method to reproducibly obtain distance variations between the ligament insertion regions at the clavicle and the coracoid process during different arm abductions.

Methods

Data from 15 healthy volunteers were acquired on a 0.25T open bore scanner with rotatable patient bed (G-Scan, Esaote, Genova, Italy) during different arm abductions in lying position (abductions of 0°, 30°, 60°, 90°, 120°) and sitting position (abductions of 0°, 90°, 120°) yielding 8 datasets per volunteer. A 3D gradient-echo sequence with TR = 28ms, TE = 14ms, voxel size = 0.95x0.95x2.14mm^3, flip angle = 50° and an acquisition time of 6:18min per data set was used for the measurement. In each dataset the scapula and the clavicle were segmented manually. For the insertion regions of the conoid ligament and the trapezoid ligament at the clavicle and the coracoid process points on the lateral and medial borders as well as the central point (in total 4 insertion regions with 3 points each) were identified manually for one reference data set (lying, arm abduction of 60°) per volunteer. For the remaining data sets these points were propagated automatically as follows. The segmented bones from all data sets were rigidly registered to the corresponding bones of the reference data set using FSL [2] resulting in transformation matrices T^a_{scap} and T^a_{clav} for the scapula and the clavicula during the different arm abductions a. These matrices were then used to propagate the points from the different insertion regions of the reference arm abduction to the other arm abductions (Fig. 1). After the point propagation, the distances between points can be measured for the different arm abductions to assess the changes in ligament length.

The proposed methodology was evaluated using ratings from two experts. Each expert marked the considered points for the 120° arm abduction in lying position for three volunteers where he had already defined the points for the reference position, i.e. 60° arm abduction in lying position. The evaluation of the points for a data set was then performed by the expert who had not marked the points for that data set to avoid a subjective bias. The origin of the points at the 120° arm abduction (automatically mapped or manually marked) was blinded for the evaluating expert. For each point triplet consisting of the manually marked points at the 60° and the 120° abduction and the automatically mapped points at the 120° abduction (Fig. 1) two different criteria were considered: **(1)** The agreement regarding the position in the insertion region between the point at the 60° abduction and each of the two points at the 120° abduction. **(2)** The anatomical correctness of the location of each point (regardless of the positional agreement between points).

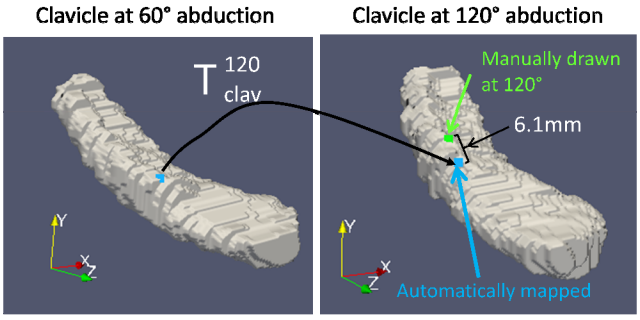

Fig. 1: Manually marked points at 60° abduction (blue) and 120° abduction (green) and automatically mapped point at 120° abduction (blue).

Results

In total 72 point triplets (4 insertion regions with 3 points each in 6 volunteers) were evaluated. The analysis of evaluation criterion **(1)** yielded an agreement between the points at the 60° abduction and the automatically mapped points at the 120° abduction in 66 cases (92%). A positional agreement between the points at the 60° abduction and the manually marked points at the 120° abduction was found only in 26 cases (36%). According to evaluation criterion **(2)** 63 (98%) of the manually marked points at the 60° abduction, 59 (92%) of the manually marked points at the 120° abduction and 62 (97%) of the automatically mapped points at the 120° abduction were anatomically correct. The distances between the automatically mapped and the manually marked points at the 120° abduction (Fig. 2) are considerable as the expected ligament length variations for the different arm abductions range approximately within the same order of magnitude.

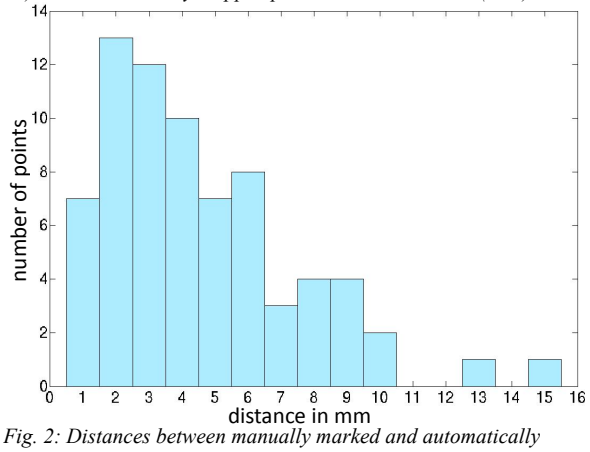

Fig. 2: Distances between manually marked and automatically mapped points at 120°.

Discussion

The good agreement between the manually marked points in the reference data and the automatically mapped points at the 120° arm abduction indicates a high accuracy of the proposed method. In the rare cases where these points do not agree according to the experts, their positional difference is likely to be small since the rigid registration has only a limited number of degrees of freedom and all points marked for one bone are mapped with the same transformation matrix. The intraindividual reproducibility for marking points in the ligament insertion regions at different arm abductions is low. This seems to be due to the flattened medial and lateral borders of the ligament insertion regions. Thus their unique description with single points is difficult as there exists more than one anatomically correct point. The (not necessarily reproducible) identification of an anatomically correct point seems however possible in MRI data following evaluation criterion **(2)**. Hence, the proposed method provides a valuable semi-automatic tool to improve the required reproducibility for accurate distance measurements.

References

[1]Mazzocca, A.D., et al., Am J Sports Med, 2006. **34**(2): p. 236-46. [2]Jenkinson, M., et al., Med Image Anal, 2001. **5**(2): p. 143-56.