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Preoperative planning in shoulder arthroplasty: what about the soft tissue?

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Abstract

The primary objective of this study was to obtain a reliable method of automatic segmentation of shoulder muscles. The secondary objective of this study was to define a new computed tomography (CT)-based quantitative 3-dimensional (3D) measure of muscle loss (3DML) based on the rationale of the 2-dimensional (2D) qualitative Goutallier score. 102 CT scans were manually segmented and an algorithm of automated segmentation of the muscles was created. The volume of muscle fibers without intramuscular fat was then calculated for each rotator cuff muscle and normalized to the patient's scapular volume to account for the effect of body size (NV_{fibers}). 3D muscle mass (3DMM) was calculated by dividing the NV_{fibers} value of a given muscle by the mean expected volume in healthy shoulders. 3D muscle loss (3DML) was defined as 1 - (3DMM). Automated segmentation of the muscles was possible with a mean Dice of 0.904 ± 0.01 for the deltoid, 0.887 ± 0.014 for the infraspinatus (ISP), 0.892 ± 0.008 for the subscapularis (SSC), 0.885 for the supraspinatus (SSP) and 0.796 ± 0.006 for the teres minor (TM). The mean values of 3DFI and 3DML were 0.9% and 5.3% for Goutallier 0, 2.9% and 25.6% for Goutallier 1, 11.4% and 49.5% for Goutallier 2, 20.7% and 59.7% for Goutallier 3, and 29.3% and 70.2% for Goutallier 4, respectively. 3DML measurements obtained automatically incorporate both atrophy and fatty infiltration, thus they could become a very reliable index for assessing shoulder muscle function which could help in the decision process in shoulder surgery

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1 Introduction

Several softwares have been developed to execute a preoperative plan before shoulder arthroplasty[3]. All the softwares allow three-dimensional (3D) reconstruction of the humerus and scapula but do not take the shoulder muscles into account[1]. Rotator cuff and deltoid status and fatty infiltration (FI) are known to be very important parameters to predictoutcome after shoulder arthroplasty[2]. Goutallier et al first reported a method to subjectively and qualitatively stage intramuscular FI into 5 grades using computed tomography (CT) on axial views. The primary objective of this study was to obtain a reliable method of automatic segmentation of shoulder muscles. The secondary objective of this study was to define a new computed tomography (CT)-based quantitative 3-dimensional(3D) measure of muscle loss (3DML) based on the rationale of the 2-dimensional (2D) qualitative Goutallier score.

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2 Methodology

102 CT scans from healthy shoulders (46) and shoulders with cuff tear arthropathy (21), irreparable rotator cuff tears (18), and primary osteoarthritis (17) were manually segmented. A convolutional neural network (CNN) was used with a U-Net 3D architecture using the Monai Project to create an algorithm of automated segmentation of themuscles. Quantitative 3D measurements of fatty infiltration (3DFI) were completed. The volume of muscle fibers without intramuscular fat was then calculated for each rotator cuff muscle and normalized to the patient's scapular volume to account for the effect of body size(NV_{fibers}). 3D muscle mass (3DMM) was calculated by dividing the NV_{fibers} value of a given muscle by the mean expected volume in healthy shoulders. 3D muscle loss (3DML) was defined as 1 - (3DMM).

3 Results

Automated segmentation of the muscles (Figure 1) was possible with a mean Dice of0.904 ± 0.01 for the deltoid, 0.887 ± 0.014 for the infraspinatus (ISP), 0.892 ± 0.008 for the subscapularis (SSC), 0.885 for the supraspinatus (SSP) and 0.796 ± 0.006 for the teres minor (TM). These results are detailed in Table 1. The mean values of 3DFI and 3DML were 0.9% and 5.3% for Goutallier 0, 2.9% and 25.6% for Goutallier 1, 11.4% and 49.5% for Goutallier 2, 20.7% and 59.7% for Goutallier 3, and 29.3% and 70.2% for Goutallier 4, respectively.

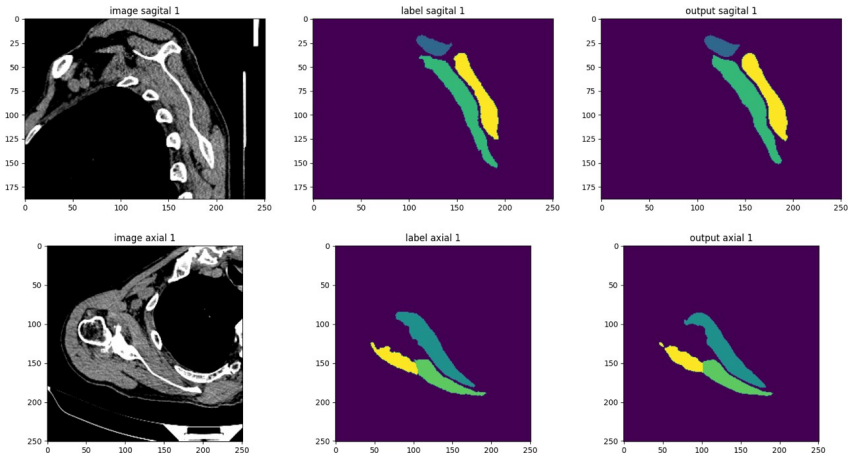

Figure 1: Example of segmentation from CT images of healthy shoulders *Top: sagittal view (supraspinatus in blue, subscapularis in green and infraspinatus in yellow)*
Bottom: axial view (subscapularis in blue, teres minor in yellow, infraspinatus in green)
Left: manual segmentation
Right: automated segmentation

Table 1: Accuracy of automated segmentations before and after data augmentation (DA).DICE: DICE coefficient is a statistical indicator that measures the similarity of two samples

	Back	Delto	ISP	SSC	SSP	TM
Dice without DA	$0,987 \pm 0,001$	$0,896 \pm 0,010$	$0,871 \pm 0,007$	$0,870 \pm 0,009$	$0,881 \pm 0,007$	$0,747 \pm 0,012$
Dice with DA	$0,987 \pm 0,001$	$0,904 \pm 0,010$	$0,887 \pm 0,014$	$0,892 \pm 0,008$	$0,885 \pm 0,004$	$0,796 \pm 0,006$
Dice with DA and bones	$0,986 \pm 0,001$	$0,871 \pm 0,001$	$0,861 \pm 0,003$	$0,871 \pm 0,003$	$0,869 \pm 0,002$	$0,777 \pm 0,003$

	CTA	Healthy	PGHOA	MRCT	Bones	Tissues
Dice without DA	$0,838 \pm 0,011$	$0,856 \pm 0,009$	$0,844 \pm 0,005$	$0,841 \pm 0,008$		
Dice with DA	$0,856 \pm 0,009$	$0,895 \pm 0,007$	$0,848 \pm 0,009$	$0,842 \pm 0,006$		
Dice with DA and bones	$0,756 \pm 0,006$	$0,895 \pm 0,004$	$0,843 \pm 0,004$	$0,862 \pm 0,007$	$0,814 \pm 0,003$	$0,876 \pm 0,002$

	Without DA	with DA	with DA and bones
Overlapping	$0,090 \pm 0,016$	$0,081 \pm 0,013$	$0,085 \pm 0,001$

4 Conclusion

Automated segmentation of the shoulder muscles can be achieved using machine learning. This allows fully automatic calculation of the 3DML of the cuff. The Goutallier score has been helping surgeons by using 2D CT scan slices. However, this gradingis associated with suboptimal interobserver agreement. The new measures we propose providea more consistent assessment that correlates well with the expected Goutallier values of fatty infiltration (where Grade 0 corresponds to normal muscle without fat, Grade 1 to few fatty streaks within the muscle, Grade 2 to less fat than muscle, Grade 3 to the same amount of fat as muscle and Grade 4 to more fat than muscle)[4; 5]. As 3DML measurements incorporate atrophy and fatty infiltration, they could become a very reliable index for assessing shoulder muscle function which could help in the decision process for cuffrepair and the choice of anatomic or reverse shoulder arthroplasty.In order to cross-reference a figure or table in your text, go to Insert->Cross-reference… (or Insert->Reference->Cross-reference… in earlier versions) from the Word menu. Select the type of object you are referencing in the "Reference type" drop-down list, and then select which object you are referencing under "For which caption". Ensure that the "Insert as hyperlink" box is ticked. You can choose how much of the caption is inserted in the "Insert reference to" drop-menu. For example, to generate this cross-reference for Figure 1, "Only label and number" was selected.

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