Deep Learning based Segmentation of the Rotator Cuff from MRI with Accuracy Prediction

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Introduction

Rotator cuff tears (RCT) are associated with pain and decreased shoulder function, effecting almost 10% of the general adult population. Automatic semantic segmentation of the shoulder from magnetic resonance imaging (MRI) is required for three-dimensional (3D) rotator cuff repair prognosis analysis, however, no method or tool for complete 3D shoulder modeling has been reported so far.

Materials and Methods

A network for fully automatic semantic segmentation of the humerus, scapula and the rotator cuff muscles was developed using the nnU-Net framework present by Isensee et al. The network was trained and tested on N=111 diagnostic T1- weighted MRI of 37 rotator cuff tear patients from multiple centres. For automatic identification of inaccurate segmentations during the inference procedure, where no ground truth segmentation is available, the nnU-Net framework was adapted to allow the estimation of the structure-specific network uncertainty. The performance of different metrics at identifying segmentations requiring segmentation verification was evaluated.

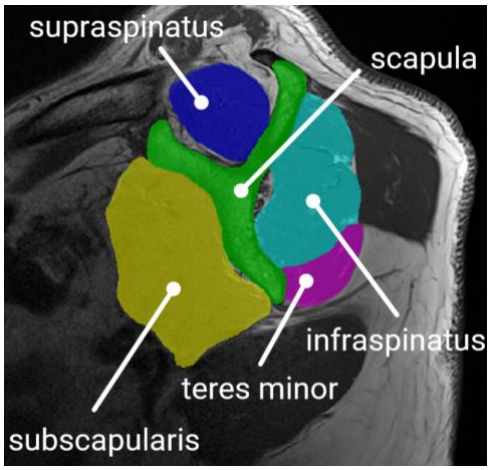

Fig. 1 T1-weighted MRI in sagittal view with overlayed automatic segmentation results.

Results

The shoulder anatomy was segmented by the 3D network with an average dice score of 0.977. Integrated directly into the nn-Unet framework, calculation of the average dice coefficient of results from auxiliary networks to the final segmentation result, demonstrated the best performance in detection of structures requiring segmentation verification. The algorithm detected all failed segmentations with a high specificity of 0.83.

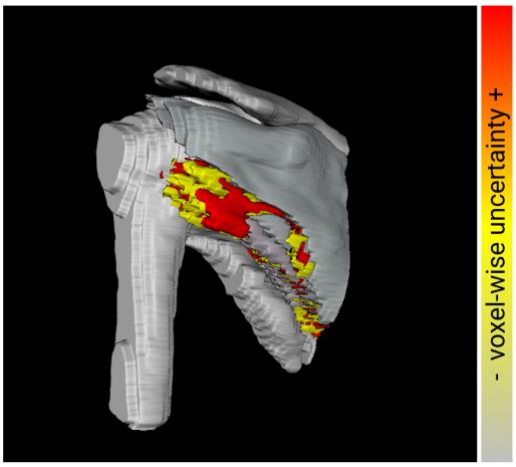

Fig. 2 Automatically generated 3D shoulder model (grey) with overlayed voxel-wise network uncertainty of a failed segmentation of the teres minor muscle with high fatty infiltration. Because the accumulation of this uncertainties exceed the defined threshold the automatic segmentation is correctly detected as insufficiently accurate.

Discussion

In this work, the first fully automatic method for rotator cuff anatomy segmentation from MRI is presented. The deep learning network demonstrated accuracy and robustness across multi-directional and multi-center data. The presented automatic methods for precise detection of failed segmentations eliminates the need for time consuming manual verification, facilitating the use of automatic segmentation methods for 3D diagnosis in the clinical routine.

References

Isensee et al., “nnU-Net: a self-configuring method for deep learning-based biomedical image segmentation,” Nat Methods, vol. 18, no. 2, 203–211, 2021.

Acknowledgements

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