DCNN-based aortic aneurysm segmentation and volume quantification from CTA images

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1. Motivation

Accurate assessment of the volume of Abdominal Aortic Aneurysms treated with Endovascular Aneurysm Repair is essential to evaluate the risk of aneurysm rupture and the progress of the disease. However, a good evaluation is hindered by the lack of automatic, robust and reproducible aneurysm segmentation algorithms. Previous intensity and shape prior based segmentation methods are semi-automatic, requiring additional inputs and user interaction. We propose a new approach based on Deep Convolutional Neural Networks (DCNN) for robust, reproducible and fully automatic thrombus segmentation and we evaluate the ability of directly utilizing this segmentation in the clinical practice for aneurysm volume quantification.

2. Methods

In this work, we propose an automatic approach to aneurysm segmentation and volume quantification. For the segmentation task, we have designed a DCNN leveraging the advantages from Fully Convolutional Networks [1] and a Holistically-Nested Edge Detection network [2], which combines low-level features with coarser representations that ensure the smooth contour of the thrombus is kept. The schema of the proposed network is depicted in Figure 1.

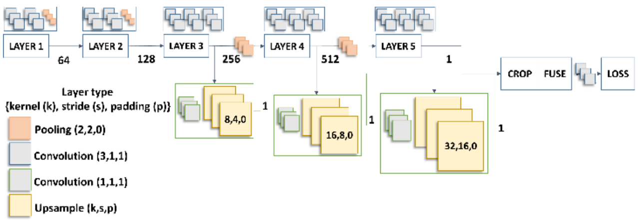

Figure 1. *Deep convolutional neural network architecture for thrombus segmentation.*

We train and test the network with 2D slices of preoperative and postoperative Computerized Tomography Angiography volumes, for which ground truth segmentations done by an expert vascular surgeon are available. Training data consists in 2D slices of 11 postoperative datasets and 2D slices of 9 pre-operative datasets. None of the datasets correspond to the same patient. Data augmentation is applied as 90º rotations and mirroring. For testing, datasets of 18 new patients are employed, 9 preoperative and 9 postoperative. We minimize the Softmax loss, using a learning rate of 1e-3, with a batch size of 4 images and no batch accumulation. The Stochastic Gradient Descent solver is employed and training is done during 100 epochs. From the output probability maps provided by the network, a reconstructed 3D binary segmentation is obtained with 3D Gaussian filtering in z direction, K-means clustering and a connected component analysis. This segmentation is compared with the ground truth in terms of total overlap (TO), Dice coefficient, false positive (FP) and false negative (FN) rates and the aneurysm volume difference, computed using the Divergence Theorem Algorithm.

3. Results and conclusions

Table 1 summarizes the testing results of the automatic segmentation for both the preoperative and postoperative data.

Data	TO	Dice	FP	FN	Volume Diff
Pre	0.784	0.790	0.216	0.193	0.134
Post	0.817	0.837	0.183	0.133	0.121
All	0.801	0.814	0.199	0.163	0.128

Table 1. *Quantitative segmentation results*

Automatic segmentation results show a good agreement with the ground truth, with a mean Dice similarity coefficient of 81.4%. To the best of our knowledge, this is the first approach to automatic aneurysm segmentation based on DCNN and the results notably exceed the state-of-the-art. To use the segmentation directly in the clinical practice for disease progression assessment, it should be further refined, since the volume difference is above the 5% considered as relevant in the clinical practice.

References

[1] Jonathan Long, Evan Shelhamer, and Trevor Darrell. Fully convolutional networks for semantic segmentation in Proceedings CVPR, June 2015.

[2] Saining Xie and Zhuowen Tu. Holistically-nested edge detection. CoRR, abs/1504.06375, 2015.