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Multi-class abdominal aortic aneurysm segmentation via 3D neural networks

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Motivation and Aim: In recent years, there has been an increase in the number of patients with atherosclerotic lesions of the aorta and its branches. The most common and clinically significant complications of the course of atherosclerosis are cholesterol and thrombotic emboli. Moreover, the presence of calcinates (calcium deposits in the aortic wall and thrombotic masses) significantly effect on the treatment of another serious disease – aortic aneurysm. Aortic aneurysm is a serious disease, the course of which is accompanied by many adverse consequences for the patient's health and often ends in rupture, leading in many patients to death. The detection rate of aortic aneurysm in different study cohorts ranges from 3.2 to 6 % of the population. Moreover, 98.1 % of the aneurysms were small. The multi-class abdominal aortic aneurysm segmentation task is one of the most challenging segmentation tasks. The aim of the current project is to develop diagnosis approach via deep learning techniques for assessment to aneurysmal lesions of the abdominal aorta.

Methods and Algorithms: The source of clinical cases (clinical base) is the Meshalkin National Medical Research Center (Novosibirsk, RF), which provides high-tech medical care (up to 20000 surgical operations per year). The dataset consists of 30 consecutive study participants who underwent clinically indicated computed tomography angiography (CTA) of the abdominal aorta and iliac arteries. Annotations comprise labels of the aortic lumen, thrombotic masses and calcifications. Segmentation labels were independently approved by three board-certified radiologists experienced in cardiovascular imaging and any label misclassification was manually corrected by an additional expert. All CTA examinations were performed by using a 320-row CT scanner (Aquilion ONE; Toshiba). All images were reconstructed with 1-mm section thickness and 0.8 mm increment by using a CTA-dedicated kernel and adaptive iterative dose reduction algorithm. We perform three different experiments according to the Ground Truth (GT) modification. Within the dataset, not all the presented samples have the equal available annotations. This led to the three following approaches: a) consider only GT from expert #1; b) consider the calcification GT only when 2 experts are agreed; c) consider the calcification GT only when all available experts are agreed. The aorta and thrombotic masses GT remain the same among all experiments.

Firstly, we use nnU-net [2] adapted to our datasets, as a basic architecture for comparison. It has proven to be a strong basic solution for segmenting medical images. In our case, we used the 3D version with a base number of 32 channels and a maximum number of channels in a bottleneck of 320. The model was trained in a 5-fold cross-validation mode for 50 epochs, with patch size of 96x160x160 and a default batch size

equal 2. As an augmentation to the input images were applied: rotations, scaling, Gaussian noise, Gaussian blur, brightness, contrast, simulation of low resolution, gamma and mirroring. Another method that we used is the Modified_3DU-net. This is less adaptive though a more classic and robust approach. In the basic principles it relies on the 3D U-net like network architecture. For this particular task we used the modification consisting of 4 descending encoder context pathway blocks, 1 intermediate block, and 4 decoder localization pathway blocks relatively. In this research we used the modification with a base number of 16 channels in the first encoder block and multiplier of 2 on each descending step. The model was trained in a 5-fold cross-validation mode for 500 epochs with the patches of 320x320x64 and batch size of 4. The patch size was selected of 64 in the Z direction due to the variability of given scans and for correct processing of all volumes. This model was also trained with the use of Cross-entropy loss function. As for the augmentations only Horizontal and Vertical flips were used.
Results:

Method	Dice_Aorta	Dice_Thromb	Dice_Calc
nnUnet_1Exp	0,955	0,765	0,710
nnUnet_2Exp	0,950	0,758	0,672
nnUnet_3Exp	0,951	0,755	0,665
Modified_3DU-net_1Exp	0,928	0,785	0,664
Modified_3DU-net_2Exp	0,873	0,764	0,545
Modified_3DU-net_3Exp	0,909	0,775	0,626

The table shows the results on validation set. We can observe, both methods have good results to segment the aortic lumen and thrombotic masses. One can observe that more strict conditions on the calcification such as agreement of all experts lead to slight reduction in the performance, while the minimum agreement of 2 experts leads to a strong drop in the accuracy. This might be explained the challenging task of the structure's annotations and that the complete agreement within the experts lead to significant reduction in the calcification GT segmentation zones. It becomes very small and so difficult for the processing. The complexity of the task is also due to the fact that usually calcinates are analyzed using a non-contrast CT. But both studies require separate image acquisitions and thus carry radiation burden. We sought to develop and validate a method to segment calcinates using only CT angiography.
Conclusion: The obtained results will make it possible to develop a comprehensive methodology diagnosys of rupture and the occurrence of thromboembolic complications in abdominal aortic aneurysm. One of the most important ways to improve the quality of the proposed methods is to significantly increase and create the reliable training dataset, such that the obtained result could be improved for robustness and stability.
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References

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