Automatic segmentation and 3D reconstruction of plaque components in carotid artery from ultrasound images

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Abstract— **Automatic segmentation of the carotid artery wall from ultrasound images and three-dimensional reconstruction of carotid artery are important for the improvement of clinical diagnostics. The main aim of this study is to present the identification and classification of the atherosclerotic plaque components (lipid core, fibrous and calcified tissue), by segmenting the US images using a deep learning model and to use the information gathered from this segmentation to include the three mentioned plaque components within the arterial wall of the reconstructed carotid artery. In this study, the segmentation is defined as multiclass segmentation model, where four classes should be detected in images: background (area outside the ring), fibrous, lipid and calcified atherosclerotic plaque components. The UNet architecture was used for this task, with weighted categorical cross entropy loss function for training. After 3D reconstruction of the entire geometry, plaque elements are labelled and an overlap of these elements with the data obtained from segmentation for the appropriate cross-section is performed to determine the elements of the mesh belonging to each plaque component. The obtained detailed and complex 3D geometrical model of the carotid artery can be used to pre-estimate the risk of cardiovascular disease and stratify patients as a high/low risk. These models can also be used for further computational examinations, using numerical simulations such as plaque progression or stenting implantation simulations.**

I. Introduction

Automatic segmentation of the carotid artery wall from two-dimensional (2D) ultrasound images and three-dimensional (3D) carotid artery reconstruction is a crucial task towards fully automating the diagnosis procedure and patient's risk stratification. In order to determine the correct patient-specific diagnosis that also considers the individual anatomy of the particular patient, it is necessary to perform simulations using a patient-specific geometry. There are several methods that mostly addressed the arterial plaque-free wall [1]. The 3D carotid artery reconstruction from US images has been presented in [2]. This approach consists of two steps: i) training and deploying a deep learning model (U-net) for the image segmentation and ii) computer-based automated 3D reconstruction method. In this study, this approach has been improved to include the identification and 3D reconstruction of atherosclerotic plaque components.

II. Results and Conclusion

The results of the 3D reconstruction of the plaque components are presented in Fig. 1. The fibrous plaque is colored in yellow, the lipid plaque is colored in blue and the calcified plaque is colored in green.

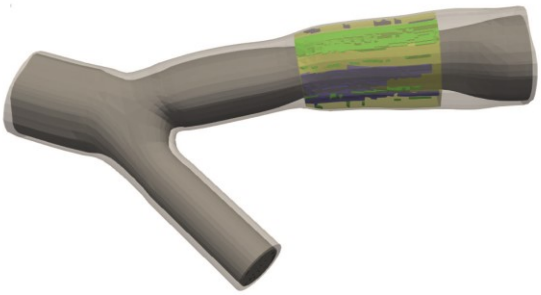

Figure 1. The reconstructed 3D geometry for a specific patient, with transparent walls and colored plaque components.

The presented approach and methodology which combine data mining and computer-based 3D reconstruction of carotid artery enable efficient segmentation, extraction of the morphological parameters (plaque characterization, geometrical features) and creation of 3D meshed volume models that can be used to analyze in detail the state of patient'a carotid artery and can also be used for further computational examinations, such as plaque progression or stenting implantation numerical simulations.

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