CORONARY ARTERY SEGMENTATION IN HYPEREMIA CONDITIONS FOR COMPUTED FFR ANALYSIS

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Introduction

Cardiovascular disease (CVD) is the leading cause of death worldwide. It is caused by the deposition of lipid tissue on the artery wall, resulting in the constriction of circulatory channels (stenosis). High mortality rates and difficult diagnosis, increase the need of rapid and effective detection. One functional assessment of hemodynamic behavior is calculating the Fractional Flow Reserve (FFR). Authors of this work have used conventional coronary artery segmentation for FFR achievement. This type of segmentation relies on manual procedures being inherently linked with long execution times where human error is also probable. A commercial software was used [1]. Ma et al. (2020) [2] developed an effective semi-automatic segmentation method based on region growing and section area using coronary angiography examinations, an invasive procedure associated with rare but serious complications. Computed Tomography (CT) is a non-invasive alternative. Pan et al. (2021) [3] created an automatic technique based on machine learning. However, this method requires a great amount of data to create the training dataset. As far as we know, there are no works in the literature purposely focused on coronary artery segmentation for hemodynamic simulations and FFR analysis. Thus, the scope of this project is to develop an in-house Python software to obtain a rapid and precise segmentation of coronary arteries from CT scans. In hospital, FFR is obtained in hyperemia condition. Thus, the computed processing steps to obtain these conditions should be automated to have an instant response time and eliminate the need to rely on costly commercial software. Also, the advantage of Python code is to be made available as open source.

Methods

Python code is used to obtain the coronary artery model of a male patient with 40% stenosis. The process only requires a manual input of an aortic point and a coronary artery starting point. In first place, a smoothing operation is conducted to reduce image noise and minimize under or over segmentation issues. The software then separates the coronary artery and the aorta by identifying significant increases in section area and defining the boundary using a probabilistic random walks method [4]. Region-growing algorithm segments the artery and a 3D model, in resting conditions, is created. To create the hyperemia model for FFR achievement, the centerline of the coronary model is computed by removing pixels from the border and comparing adjacent layers, continuously. Then, to define the various branches, the points closest to each other are computed, and the tangent to each point is derived through interpolation. For each point and the corresponding tangent, a cutting plane is defined so that cross-sectional area of the artery can be obtained.

Results

Figure 1 shows the 3D model after segmentation and smoothing, also the respective centerline and the identification of the cross-section.

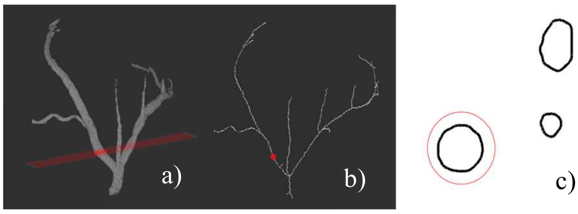

Figure 1: a) 3D model of the artery in resting conditions and cutting plane for a given point; b) centreline of the segmented model and definition of the given point; c) section created by the cutting plane and selection of the proper cross section from proximity to the point.

Discussion

This research is a proof of concept showing promising results in segmenting the 3D model and automatic computing both the centerline and cross-sections. These are tasks that were otherwise performed manually and are necessary to obtain the model in hyperemia conditions. In a near future, the model must undergo additional processing operations towards this end. Therefore, the inlet and the various outlet sections must be defined, and the cross-section area must be increased by a factor of 2.04 due to hyperemia conditions. The in-house code will be validated by computing many patients' data, allowing rapid image processing and contributing to more efficient CVD detection.

References

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