IMPACT OF INTEROBSERVER LUMEN SEGMENTATION UNCERTAINTY IN FFR_{CT}: THE LOCATION OF THE STENOSIS MATTERS

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Introduction

Coronary stenoses are the main cause of severe heart failure as they can reduce or even stop the blood supply to the myocardium. Fractional Flow Reserve derived from computed tomography (FFR_{CT}) is a computational non-invasive procedure for evaluating the hemodynamic significance of those stenoses [1].
Quantitative assessment of the variability of FFR_{CT} due to input uncertainties is essential for its integration into a clinical setting, especially when FFR is near the cutoff (FFR = 0.80) [2]. In this work, we present a hybrid invasive and in-silico study that aims to analyze the impact of interobserver segmentation uncertainty on a wide range of patient-specific coronary models.

Methods

Eight anonymous patients with moderate coronary lesions were enrolled (FFR = 0.815±0.03). The location of the patient´s stenosis varies among them: 60% located along one of the epicardial arteries, close to the ostium, and 40% in a 2nd or 3rd generation vessel, far from the ostium. 64-bit CCTA images were collected and segmented to reconstruct the coronary tree and the left ventricle (LV) using a threshold-based segmentation method [3], under the supervision of an experienced radiologist. The side branch truncation level was set at 1 mm. Interobserver variations (11±7%) [4] on the segmentation threshold were performed to obtain 2 variants of each patient´s anatomy, as shown in Figure 1. It is worth noting that these lumen variations are more pronounced as the vessel diameter decreases, i.e., at bifurcations and side branches.

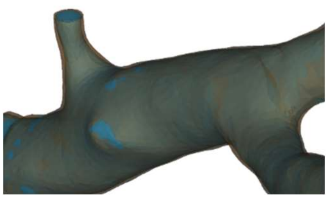

Figure 1: Lumen diameter corresponding to two different thresholds. Blue: 230 HU, gray: 200 HU.

Patient-specific coronary lumped parameter models were tuned and coupled to the 3D simulation to mimic the pulsatile and diastolic-predominant flow present in coronary arteries [5]. Simulations of the optimal segmented fluid domain and its variants were performed until the results matched those obtained by invasive catheterization, measured 2 cm distal to the stenosis.

Results

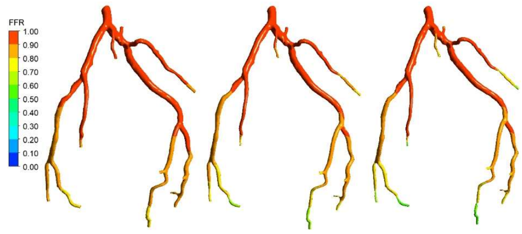

Figure 2: FFR_{CT} for each threshold. Left: 170 HU, center: 200 HU, right: 230 HU.

Mean contour plots show that along the larger vessel sections, there are no obvious variations in FFR_{CT}. On the other hand, segmentation accuracy seems to be crucial on the smallest vessels to avoid a mismatch in FFR_{CT}. Table 1 summarizes the mean FFR_{CT} variation found as a function of stenosis location.

	1st gen branch	2nd and 3rd gen branch
ΔFFR_{CT}	0.006	0.034

Table 1: Mean FFR_{CT} variation.

Discussion

Pressure drops in coronary stenosis depend on both stenosis geometry and flow rate [6]. If the segmentation threshold is increased (smaller lumen), the inlet flow rate will be reduced. Thus, despite the smaller lumen diameter, the lower inlet flow rate will compensate pressure losses through the localized stenosis in larger vessels. This compensation is insufficient in smaller vessels, where the larger geometric variations dominate against the reduced flow rate. Therefore, we can conclude that the impact of interobserver segmentation uncertainty on FFR_{CT} will be greater as the stenosis is located in smaller vessels.

References

1. Taylor et al, J Am Coll Cardiol, 61(22):2233-41, 2013.
2. Seo et al, Int J Numer Meth Biomed Engng, 36:e3351, 2020.
3. Dueñas-Pamplona et al, Comput Biol Med. 133:104423, 2021.
4. Schepis et al, Heart, 96(8):610-5, 2010.
5. Kim et al, Ann Biomed Eng. 38(10):3195-209, 2010.
6. Gamage et al, Appl. Sci. 12, 5573, 2022.

Acknowledgments

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