IMPACT OF RESISTANCE DISTRIBUTION AND PRESSURE MEASUREMENT IN THE COMPUTED FFR

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Introduction

Simulating the hemodynamics with the real physiological conditions of each patient has been a challenge in order to help the treatment of cardiovascular diseases (CAD) in the hospital [1,2]. There are several metrics used to assess atherosusceptibility based on the pressure and the wall shear stress. The Fractional Flow Reserve (FFR) is considered to be a gold standard parameter to guide clinical decisions regarding revascularization procedures in coronary lesions. The procedure for its measurement consists of inserting a pressure wire into the stenosis coronary vessel and measuring the aortic pressure value (p_a) and the pressure distal to the stenosis (p_d), along the cardiac cycle. Thus, the FFR value is calculated by the ratio between p_d and p_a [3]. A FFR lower than 0.75 indicates a hemodynamically significant stenosis that induces ischemia and requires revascularization. Recent studies have proved that the Windkessel model is used to implement the outlet pressure boundary conditions specific of each patient [3], in order to obtain an accurate computed FFR instead of the invasive one. The 3-element Windkessel model has three parameters that need to be estimated: the proximal resistance (R_p), the distal resistance (R_d) and the compliance of the vessels (C_a) [4]. Recent studies of Deyranlou et al. (2020) [4] has shown that the distribution of resistances among the proximal (R_p) and the distal (R_d) resistances is 9 and 91%, respectively. However, other recent study of Jonášová et al. (2021) [3] indicates that this distribution of resistances is 3 and 97%, respectively. Thus, it is important to verify if these different distributions influence the hemodynamic results and, consequently, the FFR. Moreover, it is important to analyse the sensibility of the measured blood pressures, systolic pressure ($P_{systolic}$) and diastolic pressure ($P_{diastolic}$), provided by the hospital. As far as we know, no authors in the literature have analysed these two sensibilities in the calculated FFR

Methods

A model of a patient-specific left coronary artery with 40% stenosis was constructed in Mimics® software to be imported in Ansys® software for hemodynamic simulations. CT images of the patient were provided by Vila Nova de Gaia/Espinho Hospital Centre. The invasive FFR measurement was 0.93. User-defined functions in Ansys® were created to define the outlet pressures of the patient, through the 3-element Windkessel model [3]. Moreover, blood was considered as viscoelastic and sPTT model was used [1].

Results

Table 1 presents the computed FFR considering 3 different scenarios. In Scenarios I and II, values for $P_{Systolic}$ and $P_{Diastolic}$ were taken as the average of the invasive pressure measurements made on the patient, at the hospital. In Scenario III, the pressure values were taken in the interval of what the American Heart Association® defines. Moreover, Scenarios I and III consider a resistance distribution different from II.

	Scenario I	Scenario II	Scenario III
$P_{Systolic}$	145 mmHg	145 mmHg	160 mmHg
$P_{Diastolic}$	83.5 mmHg	83.5 mmHg	95 mmHg
R_p	0.09 R_i [4]	0.03 R_i [3]	0.09 R_i [4]
R_d	0.91 R_i [4]	0.97 R_i [3]	0.91 R_i [4]
FFR_{comp}	0.9101	0.9117	0.9094

Table 1: Computed FFR values for the 3 scenarios.

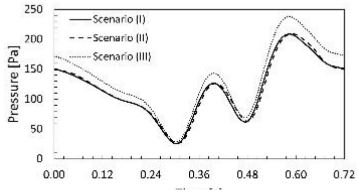

Figure 1: Pressure waveforms, for the 3 different scenarios, for an outlet boundary condition.

Discussion

Although the computed FFR for the 3 scenarios is approximately 0.91, differences in the pressure waveforms can be observed when considering Scenario III. It means that the values of $P_{Systolic}$ and $P_{Diastolic}$ should be patient specific, measured at the hospital, to obtain an accurate computed FFR. No differences are observed between Scenario I and II. Moreover, the code implementation is valid for this patient case - error of 2.15% between comp. and inv. FFR. In the future, we want to validate the software with many patient cases.

References

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