# MODELLING HEMODYNAMICS WITH REAL PHYSIOLOGICAL CONDITIONS OF PATIENT-SPECIFIC CORONARIES

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## Introduction

Modelling haemodynamics with real physiological conditions specific to each patient, using principles of physics, mathematics and engineering, is still a challenge [1-3]. Achieving a supporting tool which helps in clinical decision may help cardiologists and surgeons to better manage coronary artery diseases (CADs). Recent research works of the authors, with experience in hemodynamic modelling in patient-specific coronary arteries, have considered pulsatile flow, the viscoelastic property of blood [1,2], and arteries with rigid walls [3]. The well-known viscoelastic property of blood should be considered since it has a significant impact on hemodynamic results [1,2]. Blood flow is pulsatile and, thus, deformable walls of the arteries should be considered. However, hemodynamic results considering deformable walls or rigid walls are almost the same. Moreover, the computational time of assuming rigid walls is significantly lower [3], which is beneficial for hospital applications. In this way, the authors of the present study have used rigid walls. In the past, outlet pressure profiles defined in the literature, as typical boundary conditions of the arteries, were considered by the authors [1,3]. The imposition of pressure profiles as boundary conditions in the artery outlets means the creation of a pressure gradient along the artery, which is not physiologically correct and accurate when the distribution of flow and pressure is the desired solution, such the Fractional Flow Reserve (FFR) [4]. Lumped-parameter models (Windkessel) solve this issue. This model finds the accurate pressures in the coronary branches, based on the resistance of blood flow [4]. The main goal of the present research project (PTDC/EMD-EMD/0980/2020) is to obtain a non-invasive computed FFR and CT-derived coronary hemodynamic descriptors, on-site and minimizing costs for the hospital, through a software with the most accurate conditions as possible, assuming pressure profiles specific for each patient artery (Windkessel model) [4] and the viscoelastic property of blood (simplified Phan-Thien-Tanner model, sPTT) [1]. To our knowledge, no other authors have considered these two accurate properties simultaneously.

## Methods

A patient-specific left coronary artery model with 40% stenosis was constructed through a semi-automatic method in Mimics®. The CT images were provided by the Vila Nova de Gaia/Espinho Hospital Centre, which also measured an invasive FFR of 0.93 for this patient, through a coronary angiography procedure. User-defined functions (UDFs) in ANSYS® software were created to define outlet pressures, specific for the patient, through a 3-element Windkessel model [4], and for the sPTT model [1]. The computed FFR and the descriptors - Oscillatory Shear Index (OSI), Relative Residence Time (RRT) and Time Averaged Wall Shear Stress (TAWSS) – were achieved.

## Results

The computed FFR was equal to 0.910, having a 2.15% relative error when compared to the invasive measurement. Moreover, the descriptors OSI, RRT, and TAWSS, for a cardiac cycle, are presented in Figure 1.

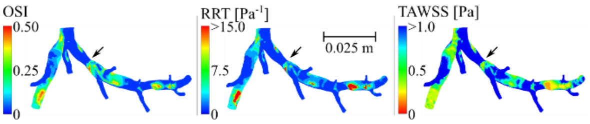


*Figure 1: OSI, RRT and TAWSS fields in the coronary artery (stenosis is flagged with a black arrow).*

## Discussion

The obtained hemodynamic descriptors, for this patient, are accurate and physiologically correct for clinical observation since the relative error between the computed and invasive FFR is very small, meaning that the validation of the software is promising. However, this study is a proof of concept. The software will be completely validated with many patient-specific cases with different stenosis degrees and positions, and considering different Windkessel models (5 and 7 parameters). After validation, a software for clinical routine use in hospitals will be created. This tool would make it possible to assess CAD in a more accessible, quick, and non-invasive manner, improving the diagnostic efficiency and safety as well as cost savings.

## References

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