

A COMPUTATIONAL STUDY ASSESSING THRESHOLD CRITERIA FOR THE TREATMENT OF LEFT MAIN CORONARY ARTERY BIFURCATIONS CONTAINING MULTIPLE STENOSES

Arash Ghorbanniahassankiadeh MS[1,*], David S. Marks MD MBA[2], John F. LaDisa, Jr. PhD[1,2,3,4]
[1]Department of Biomedical Engineering, Marquette University and the Medical College of Wisconsin;
[2]Division of Cardiovascular Medicine, Department of Medicine, Medical College of Wisconsin,
Departments of [3]Physiology and [4]Pediatrics, Medical College of Wisconsin;
[*]Corresponding Author:
Arash Ghorbanniahassankiadeh
1637 W. Wisconsin Ave, room 334
Milwaukee, WI 53226
E-mail: arash.ghorbannia@marquette.edu

ABSTRACT

An intravascular ultrasound (IVUS)-based minimum lumen area (MLA) of 4.5 mm^2 is being considered as equivalent to fractional flow reserve (FFR) of 0.8, which is the widely accepted standard for percutaneous coronary intervention (PCI) in the left main coronary artery (LMCA). However, there is still clinical debate about whether to use this cut-off value or the prior treatment threshold of 6 mm^2 for complex patients having multiple LMCA lesions. The objective of this investigation is to computationally assess the accuracy of the current threshold criteria in a case consisting of multiple lesions near the LMCA bifurcation. An idealized CAD model of an intermediate LMCA stenosis was integrated with an aorta model using geometrical characteristics of normal adult human arteries. Computational fluid dynamics (CFD) was performed using an open source software package (SimVascular; simtk.org) to solve the time-dependent Navier-Stokes equations. Inflow boundary conditions consisting of a time-varying blood flow waveform were imposed at the aortic inlet. An open-loop iterative approach was used in determining coronary artery outlet boundary conditions at rest and during pharmacological stress (i.e. Adenosine - 140 μg/kg/min) conditions. A threshold criterion of 40 mmHg was used to differentiate autoregulatory and maximum vasodilation responses of the coronary bed to the hemodynamic state of the heart. Results show that an MLA of 4.5 mm^2 underestimates the severity of stenoses in the current LMCA case having multiple lesions. During stress with Adenosine as the pharmacological vasodilator agent, the maximum value of FFR determined from simulations was 0.75, which suggests the current threshold is not an accurate equivalent of FFR threshold in cases involving multiple lesions. However, in models with MLA of 6 mm^2 in the LMCA, the FFR value falls within the range suggesting catherization is not necessary (i.e. >0.8).

Keywords: Computational Fluid Dynamics, Coronary Artery Disease, Percutaneous Coronary Intervention, Fractional Flow Reserve, Minimum Lumen Area

INTRODUCTION

Cardiovascular disease (CVD) is the leading cause of mortality in the U.S. and is associated with ~8M inpatient procedures annually. ~86M Americans have some form of CVD and a substantial portion suffer from coronary artery disease (CAD) [1]. The question of whether or not to treat a particular coronary artery stenosis is frequently debated among interventional cardiologists, with hemodynamic criteria from fractional flow reserve (FFR) [2] and its computational counterpart (FFR_{CT}) [3] growing in popularity over image-based threshold criteria. Left main coronary artery (LMCA) lesions are present in 3-4% of the ~2M coronary catheterizations performed annually [4]. Stenoses in the LMCA have the potential to induce ischemia over a large fraction of the left ventricle and, hence, have a greater potential to result in mortality. Currently an intravascular ultrasound (IVUS)-derived minimal lumen area (MLA) of 4.5 mm^2 is used as