

SELECTION OF PATIENT-SPECIFIC BOUNDARY CONDITIONS WITH APPLICATION TO ANOMALOUS AORTIC ORIGIN OF A CORONARY ARTERY UNDER RESTING AND STRESS CONDITIONS

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ABSTRACT

Anomalous aortic origin of a coronary artery (AAOCA) is a congenital defect where one coronary artery arises from the opposite sinus of Valsalva. Although AAOCA has been associated with sudden cardiac death, local hemodynamics remain largely unexplored. This study applies patient-specific modeling to 1) develop a robust protocol for determining physiologic boundary condition parameters under resting and pharmacological stress (dobutamine ~ 30 mcg/kg/min) states, 2) verify the accuracy of parameters using available data, and 3) quantify local hemodynamics implicated in morbidity before and after surgical intervention. Geometry pre- and postoperatively was generated from cardiac magnetic resonance imaging (MRI) data. The downstream vasculature was modeled by lumped parameter networks (LPN) that include resistance, compliance and intramyocardial pressure. Parameters were determined using a protocol for resting and stress states that considers epicardial vasoconstriction and microvascular vasodilation. Parameter accuracy was assessed by comparing simulated pressure and flow distributions with aimed values measured clinically where possible. Results including flow, pressure and wall shear stress (WSS) were compared preoperatively at rest (PRE_{rest}), and postoperatively under rest ($POST_{rest}$) and stress ($POST_{stress}$). Physiologic phasic behavior of coronary flow, in agreement with the literature, was confirmed by computed contours. Systolic and diastolic blood pressure also matched aimed values. Pressure in the anomalous left coronary artery (LCA) was decreased compared to the aorta during PRE_{rest}. The pressure drop was reduced, and flow improved, in $POST_{rest}$ and $POST_{stress}$ models. WSS in the anomalous LCA of the PRE_{rest} was higher than that of $POST_{rest}$ showing the effect of altered geometry. We conclude that our parameter estimation protocol can successfully reproduce hemodynamics in agreement with available data.

Keywords: coronary arteries, AAOCA, computational modeling, boundary condition, patient-specific, LPN

INTRODUCTION

Anomalous aortic origin of a coronary artery (AAOCA) is a condition where one coronary artery arises from the opposite sinus of Valsalva. AAOCA is a rare congenital defect with the potential for acute ischemia [1]. Isolated intramural AAOCA is the 2nd leading cause of sudden cardiac death (SCD) in young athletes[2]. This risk is highest when the anomalous coronary artery has an intramural course within the aortic wall [3], [4]. This intramural course can be addressed by a surgical procedure called unroofing with creation of a neo-ostium in the appropriate sinus. This eliminates the intramural segment and creates a larger ostium of the coronary that presumably originates perpendicularly, rather than obliquely, from the aorta [5]. There are limited data considering the impact of this surgical procedure on coronary artery morphology and perfusion. These data are important, as any compromise to coronary flow postoperatively may raise questions about the efficacy of the unroofing technique and change the patient's risk for future morbidity and mortality. To date, there has been only one numerical study on an idealized AAOCA geometry that simulated aortic expansion using structural finite element modeling (FEM) in the absence of computational fluid dynamics (CFD) analysis [6]. Results of this prior study indicated that under exercise loading conditions, expansion of the anomalous coronary arteries is impaired, and the ostium has a more oval shape. These data are in agreement with previous hypotheses that lateral compression of the