COMPUTATIONAL FLOW ANALYSIS IN BIOVALSALVA PORCINE AORTIC VALVED CONDUIT

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Introduction

Aortic valve diseases affect many people worldwide with an increasing number of cases in recent years. They are often associated with diseased ascending aorta including aortic dilatation and dissection. For the majority of patients, surgical aortic valve replacement is still a preferred treatment. BioValsalva is the world's first pre-sewn composite biological porcine aortic valved conduit for aortic heart valve replacement and the associated repair or replacement of diseased ascending aorta. It has demonstrated satisfactory initial results with low mortality and acceptable low morbidity rates [Kaya, 2012], but changes in blood flow patterns after aortic root replacement with the newly formed conduit is unknown. In this study, the effects of the BioValsalva conduit on aortic blood flow are examined by combined MR imaging and computational flow analysis. Reconstructed flow patterns in the replaced aorta are compared with those in normal ones.

Methods

Four patients with aortic valve diseases and two healthy volunteers were recruited in this study with matching age, gender and race. 4D phase-contrast MR scans were carried out on all the patients and volunteers. The patients were scanned six weeks after surgical aortic valve replacement with the BioValsalva conduit. The blood flow velocity was captured in the sinus just above the aortic valve in foot-head, right-left and anterior-posterior directions, as well as in the descending aorta at the level of the main pulmonary artery. The former is utilized as the inlet boundary conditions by mapping the velocity profiles in all three directions, while the latter is used to estimate the flow loss through the arch branches and also for the purpose of validation. The central aortic pressure of each subject was measured a short time before each scan by using a noninvasive device, the PulseCor, and the measured aortic pressure is applied at the model outlet in the descending aorta. Patient-specific models of the aorta are reconstructed from sagittal MR images. The Shear Stress Transport model [Menter, 2006] is utilized to predict possible disturbed blood flow patterns in the aorta. The blood is treated as a Newtonian and incompressible fluid and the vessel wall is assumed to be rigid with no-slip condition.

Results

The spatial flow velocity profiles at the aortic root are compared between the patients after aortic valve replacement and normal subjects. Figure 1 demonstrates that flow patterns through the valve in the conduit are similar to those seen in a normal aorta, with a triangular shape of effective orifice area and comparable maximum velocity. Similar aortic root morphology can also be observed between the patients and normal controls (Figure 2). The haemodynamic parameters including wall shear stress and turbulence intensity, as well as flow patterns in the aorta are also examined.

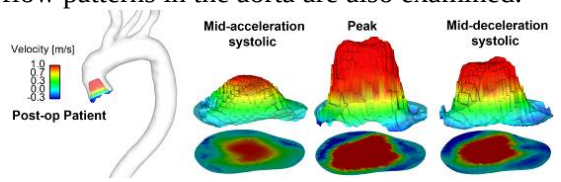

Figure 1: Spatiotemporal flow patterns of patient in foot-head direction.

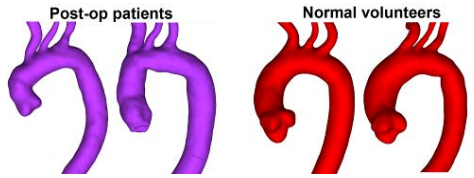

Figure 2: Aorta geometry of patients vs. normal.

Discussion

The results show similarities in blood flow profiles at the aortic root between patients and normal subjects, suggesting that the BioValsalva conduit is capable to improving blood flow conditions after aortic valve replacement.

References

Kaya et al, Ann Thorac Surg., 94:72-7, 2012.

Menter et al, Flow Turbulence Combust, 77:277-303,2006