Left main Stenosis Stenting Normalizes Wall Shear Stress of Ascending Aorta in Bicuspid Aortic Valve

Running Head: WSS in bicuspid aortic valve and Left main Stenosis

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Abstract

Introduction: Bicuspid aortic valve (BAV) is associated with dilation and dissection of the ascending aorta. The high shear forces within the ascending aorta lumen seem to have a pivotal role on the development of such complications. We describe the Time-Averaged Wall Shear Stress (TAWSS) forces in a patient with normally functioning BAV and significant ostial/mid-shaft left main (LM) stenosis using computational fluid dynamic analysis (CFD).

Case report: A 47-year-old female patient, with normally functioning BAV with fusion of right and noncoronary cusps was investigated for unstable angina. CFD and stress mapping of the ascending aorta before LM stenting showed a mean TAWSS of 9.4 Pa and was associated with higher TAWSS values at the site of LM stenosis. The LM lesion was treated by stent implantation of an a Orsiro 4.0 × 12 mm at 18 atm preceded with a pre-dilation with noncompliant Euphora (Medtronic Inc, USA) balloon 3.0 × 12 mm at 16 atm and followed by an over-dilation with 4.5 × 12 mm non-compliant Euphora (Medtronic Inc, USA) balloon at 20 atm. The reconstructed post-procedural model revealed a decrease of the mean ascending aorta TAWSS to 5.6 Pa.

Conclusions: As suggested by our case, stenting of LM lesion in BAV patient has the potential to improve the TAWSS in the ascending aorta protecting ascending aorta from the well-known complications of BAV.

Key words: Bicuspid aorta, Left Main; Stenting; Angioplasty; Wall shear stress.

Bicuspid aortic valve (BAV) represents the most common congenital cardiac anomaly with a prevalence ranging between 1% to 2% in the general populations.[1] BAV are known to be associated with dilation and dissection of the ascending aorta and the significantly higher shear forces seem to have a pivotal role on the development of such complications.[2] BAV patients are

nowadays frequently encountered in clinical practice presenting coronary artery disease or other comorbidities due to the increasing survival age of the congenital heart disease population.[3] While some recent investigations have characterized the aortic flow patterns as well as the Time-Averaged Wall Shear Stress (TAWSS),[4,5] the aortic arch flow pattern in BAV patients with a coexisting ostial/mid-shaft left main (LM) stenosis have not been analysed yet. We describe the TAWSS in a patient with normally functioning BAV and significant ostial/mid-shaft LM stenosis before and after LM stenting using computational fluid dynamic analysis (CFD). Informed consent was obtained by the patient and the approval by the local ethic committee was waived due the type of study.

Case report

A 47-year-old female patient, with normally functioning BAV with fusion of right and non-coronary cusps was investigated for unstable angina. Proximal arteries and aortic arch were reconstructed using coronary computed tomography angiography (CCTA) with a 64-slice multi-detector computed tomography scanner (64-detector row Lightspeed VCT scanner, GE Healthcare, Milwaukee, WI, USA) to define the morphology and degree of dilation of ascending aorta.

The acquired images were then segmented to reconstruct the vascular anatomy in 3D. Coronary artery stenosis and minimal lumen area have been calculated considering the reconstructed coronary artery model. Specifically, the severity of the LM stenosis has been computed as 100% minus the percentage of minimal lumen area to the reference lumen area. Blood has been modelled as a laminar non-Newtonian and incompressible fluid. Reconstruction and CFD analysis of coronary arteries TAWSS have been trunked to the proximal segment of the vessels. The aortic

wall was assumed to be elastic with a radial dilation of the proximal aorta of 8% (physiological value around 10%) and a total arterial compliance of 1.75 ml/mmHg (physiological value 1.84 ± 0.76 ml/mmHg).[3] To estimate the patient-specific flow rate, the patient-specific stroke volume was calculated from the difference between the end-diastolic (EDV) and end-systolic volumes (ESV), and then combined with the measured heart rate to obtain their time-averaged flow rate. Then the calculated velocity was applied as an inlet boundary condition at the LVOT.

Stress mapping of the ascending aorta before LM stenting showed a mean TAWSS of 9.4 Pa, and was associated with higher TAWSS values in the site of LM stenosis (*Figure 1*, Panel A). The LM lesion was treated by stent implantation treating the target lesion with a Orsiro 4.0 × 12 mm at 18 atm. Stent implantation was preceded by pre-dilation with non-compliant Euphora (Medtronic Inc, USA) balloon 3.0 × 12 mm at 16 atm and followed by a over-dilation with 4.5 × 12 mm non-compliant Euphora (Medtronic Inc, Fridley, MN, USA) balloon at 20 atm. The reconstructed post-procedural model revealed a decrease of the mean ascending aorta TAWSS to 5.6 Pa.

Discussion

Our case demonstrated that the treatment of LM lesion in our BAV patient improved the TAWSS in the ascending aorta potentially protecting ascending aorta from the well-known complications of BAV.

Although the association between BAV and LM disease remains probably very rare in young subject, the increasing percentage of patients with congenital heart disease reaching the middle and older ages[3] makes the association between BAV and coronary artery disease, more likely to be clinically relevant.

Barker et al. demonstrated using 4-dimensional (4D) flow-sensitive magnetic resonance imaging an increased and asymmetric WSS at the aorta wall related to ascending aortic flow jet patterns, which were influenced by the BAV fusion pattern.[6]

Similarly, Guzzardi et al observed that regions of increased WSS correlated with extracellular matrix dysregulation and elastic fibre degeneration in the ascending aorta of BAV patients, suggesting that valve-related haemodynamics may be a contributing factor in the development of aortopathy.[7]

Our group already demonstrated in LM disease using CFD analysis that not only a concomitant LM lesion but also the type of stenting significant modify the WSS over the ascending aorta:[5] extending the stent coverage up to the ostium, when the ostial region is not diseased, might induce unfavourable alterations of flow not only at level of LM lesion and ostium, but also in the ascending aorta and aortic arch, potentially predisposing the aortic wall to long-term damage. In the case of BAV, which already perturbates the aortic arch flow, we hypothesised that the increased thickness of the vessel at the atherosclerotic lesion site may create an additional rigidity point into the aortic wall at the LM site worsening even more the aortic arch flow. This condition, as suggested by our case, can be ameliorated by LM stenting, especially in middle-aged patients where BAV and coronary atherosclerosis can be more frequently associated.

Conclusions

The treatment of LM lesion in BAV patients have the potential to improve TAWSS in the ascending aorta protecting ascending aorta from the well-known complications of BAV.

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Legend

Figure 1. 3D reconstruction of the patient-specific anatomy with Time-Averaged Wall Shear Stress (TAWSS) showing the higher stress level in the ascending aorta before (A) and after the left main stenting (magnification) (B).