CFD Analysis of Pulsatile Flow in Aortic Heart Valves: Investigating Hemodynamics under Transient Conditions.

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INTRODUCTION

Worldwide, more than 28 million people are affected by heart valve diseases [1]. The main function of heart valves is to ensure that blood flow is unidirectional. A popular treatment option is aortic valve replacement [2]. Aortic valves come in different sizes and can be placed at different angles, both of which affect blood flow and hemodynamics [3]. The aim is to investigate aortic valve models under transient conditions in different sizes and angles, to analyze the hemodynamic effect.

METHODS

Using computational fluid dynamics, the Medtronic Avalus bioprosthetic heart valve is evaluated at diameters of 23 mm, 25 mm, and 27 mm, with the latter two having tilt angles of 11.84° and 25.58°, respectively, in the Sinuses of Valsalva, as displayed in Figure 1. Two cases with asymmetric valve leaflet openings are examined. Case 1 is moderately restricted, while Case 2 is fully open except for a single leaflet, which is shown in figure 2. Transient pulsatile flow is replicated with a pulse of 80 beats per minute and a glycerin-water mixture. Data and visualizations of wall shear stress, shear stress, turbulent kinetic energy and the velocity magnitude are analyzed. The area of wall shear stress and shear stress over a threshold of 16 Pa and 10 Pa respectively are analyzed.

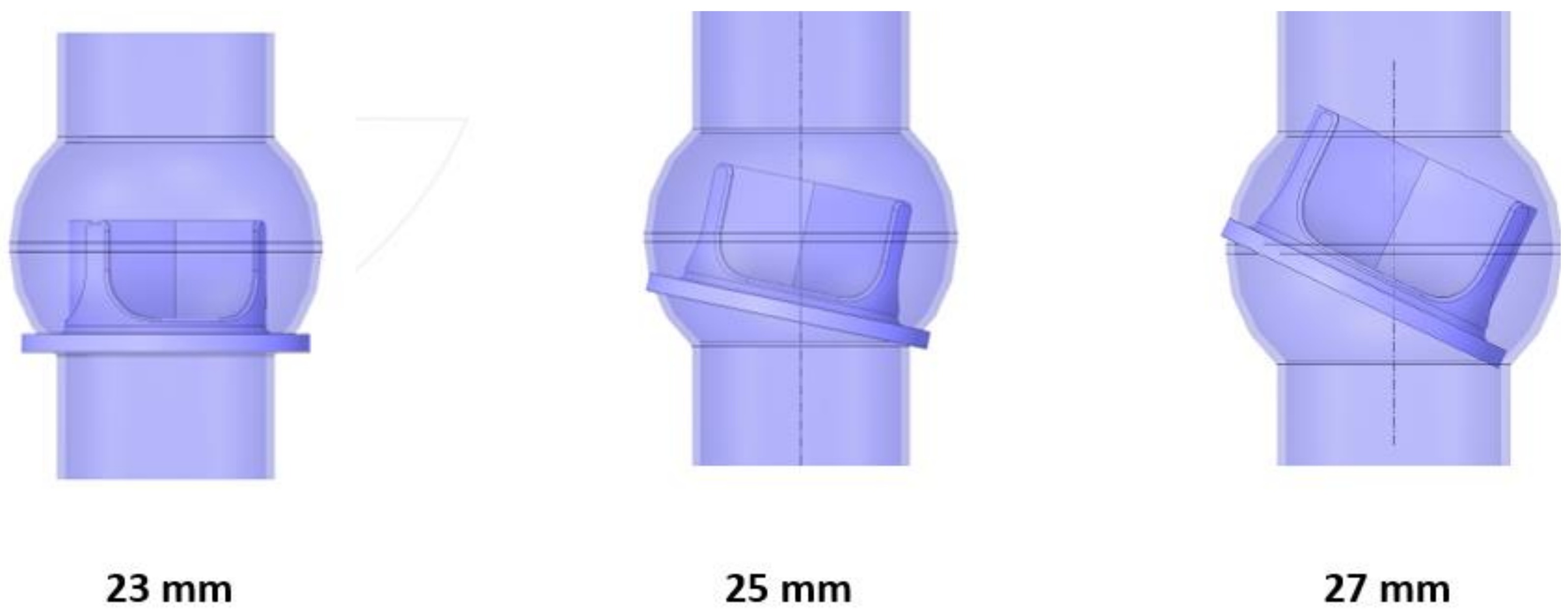

Fig. 1: Visualization of different valve sizes positioned with tilt.

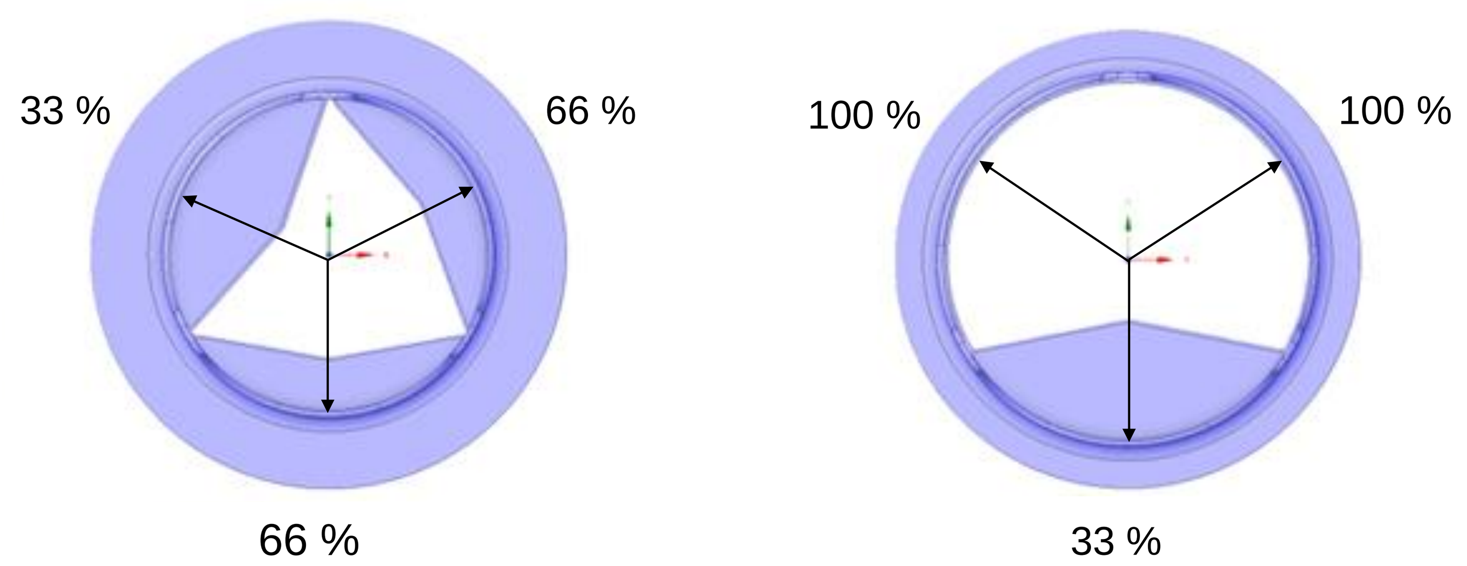

Fig. 2: Valve leaflet opening with the respective percentage of the leaflet opening. The left valve shows Case 1, and the right valve shows Case 2.

RESULTS

The results show that the 23mm valve, has the highest values of wall shear stress area and shear stress area in Case 1 which represents a more critical scenario with higher overall values. However, in Case 2 peak wall shear stress area is detected in the 27 mm valve and peak shear stress in the 25 mm valve.

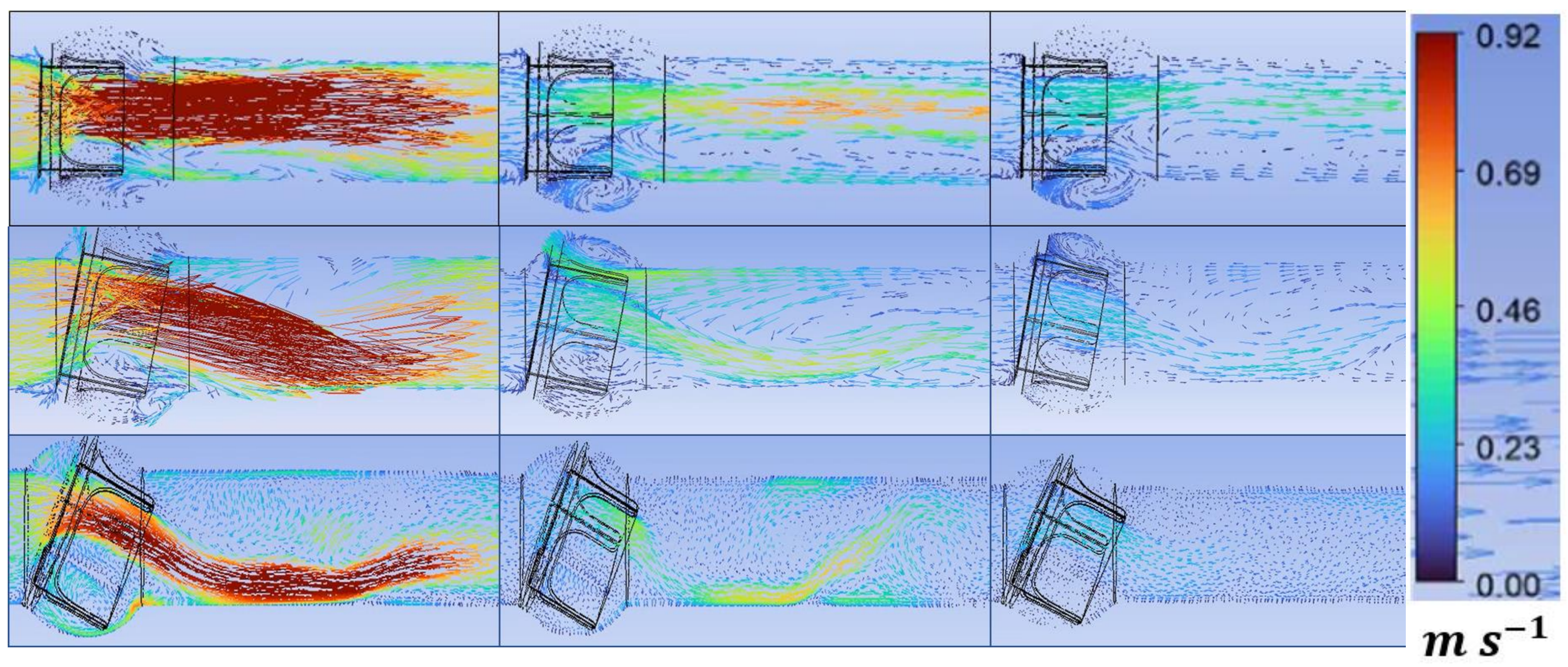

Fig. 3: Visualization of the velocity field in Case 1. The top row shows the 23 mm valve, the middle row the 25 mm valve, and the bottom row the 27 mm valve. The flow direction is from left to right

The visualization shows that a larger valve size with a slightly tilted valve has lower peak shear stress, but also creates localized high stress regions. In figure 3 and 4 the flow visualization is displayed and shows higher velocities in Case 1. The highest total turbulent kinetic energy values in both cases are found in the 27 mm valve.

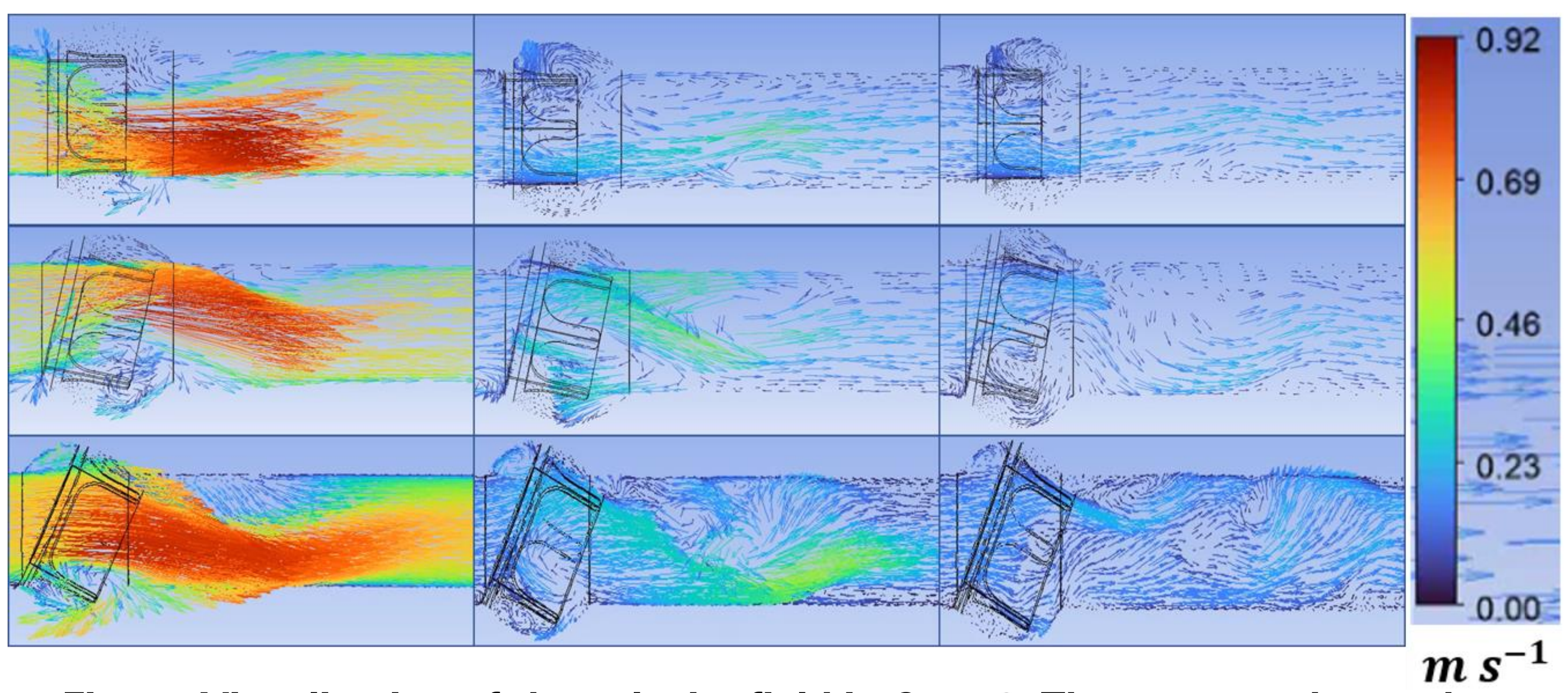

Fig. 4: Visualization of the velocity field in Case 2. The top row shows the 23 mm valve, the middle row the 25 mm valve, and the bottom row the 27 mm valve. The flow direction is from left to right

DISCUSSION

The results suggest using an intermediate or larger valve, such as the 25 mm or 27 mm configuration with a tilt, is preferable for improving flow conditions, reducing damaging shear stress and minimizing the risk of thrombosis. However, a tilted valve leads to a broadly distributed shear stress and WSS within the heart valve, as well as higher TKE values, which can result in energy loss and can lead to damage of the aortic wall.

COOPERATION PARTNER

Logo

References:

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