Computational and Experimental Characterisation of Bioprosthetic Heart Valve Positioning to Enhance Long Term Performance

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Abstract

Transcatheter Aortic Heart Valve Implantation (TAVI) is a minimally invasive alternative to surgical heart valves. The first CE certification was awarded FDA approval for clinical trials in 2011. Therefore the long term performance of implanted TAV's is still unknown. The most recent TAV valve designs (Boston Scientific Lotus Valve, Transcatheter Technologies Trinity Valve) allow for precise positioning without the need for revision surgery if the valve is primarily placed incorrectly. However it remains that the optimal positioning of TAV's has not been established and requires investigation. The objective of this research is to develop computational models to predict the role of positioning on the mechanical performance of TAV's.

1. Introduction.

Aortic Stenosis (AS) is an age related degenerative disease of the aortic valve that causes progressive narrowing of the valve and aortic regurgitation. The current gold standard of treatment involves open heart surgery to replace the stenotic valve. However approximately 30% of the patients are refused this highly invasive surgery because of the high preoperative mortality risk. Transcatheter Aortic Valve Implantation (TAVI) is a minimally invasive alternative to open heart surgery. TAV's consist of animal derived tissue leaflets, which are mounted onto an expandable metallic frame and are delivered to the site of the native stenotic valve via a catheter through a transfemoral or transapical approach. However, incorrect positioning of the heart valve can cause adverse effects as the extension of the heart valve into the left ventricle can lead to mitral insufficiency, arrhythmias or aortic injury [1]. Precise placement of TAV's might overcome the need for revision surgery and enhance the long term mechanical performance. The objective of this research is to develop computational models to predict the role of positioning on the mechanical performance of TAV's.

2. Methods.

A finite element model was created to investigate the stresses experienced by a TAV and the aortic tissue when the TAV was placed in three different positions; on the aortic annulus, 5mm above the annulus and 5mm below the annulus. The model was created in ABAQUS to include the expansion of the TAV to be positioned precisely on the aortic annulus, marginally above the annulus and marginally below the annulus. A small section of the aortic root was modelled. The aortic tissue was modelled as linear elastic for the purpose of this model with the aim of increasing the complexity of the model in further studies. The Young's modulus used was 983kPa as this was found to be the mean value for men between the ages of 60-64 years old and a Poisson's ratio of 0.17 [2,3]. Non-displacement boundary conditions were applied a few millimetres antegrade and retrograde of the aortic annulus in the x, y and z directions.

3. Results

The results showed the maximum Von Mises stresses predicted for all three deployment positions are well below the rupture stress of the aortic tissue (1.75MPa [4]). The highest stresses in both the aortic tissue and the stent were observed when the stent was deployed centrally, at the aortic annulus. Interestingly, the lowest stresses in both the aortic tissue and the stent were found when the stent was deployed at the 5mm sub annular position.

4. Discussion and Conclusion:

These results indicate the TAV stent may be less anchored in the sub annular position and could be more likely to undergo embolization, as has been shown with migration into the left ventricle in subannular positioned prosthesis in vivo [5].

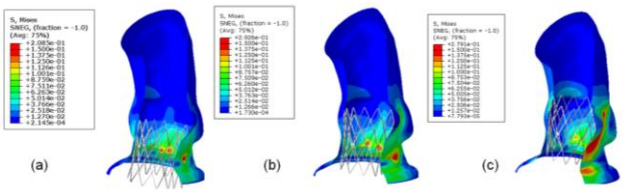

Figure 5. Contour plots of Von Mises stresses (MPa) in stent deployed (a) sub –annular (b)on the aortic annulus and (c) supra-annular

4. References

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