Editorial Comment

Are All Valves for All Aortas?

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Transcatheter aortic valve implantation (TAVI) is associated with a complex interaction between the device and the aortic root anatomy at several levels, including the upper left ventricular outflow tract and aortic annulus, the sinuses of Valsalva and valve leaflets, and the sinotubular junction and ascending aorta.[1] Because of the complex aortic root anatomy, advanced imaging is increasingly used, not only for accurate preoperative planning, but also for the design and further development of TAVI systems.

Preoperative planning is crucial for a successful outcome, with the most important decisions for the interventional cardiologist being: 1) the selection of the proper implant type and size, based on patient-specific anatomic characteristics; and 2) device suitability. Concerning the aortic root characteristics, device selection depends not only on the anatomy of the native valve, but also on the angulation of the aortic annulus plane, the distance of the coronary ostia from the annulus, and the leaflet length. Since the first-in-man TAVI performed in 2002, technology has evolved and various new TAVI devices, so-called "second-generation devices", are now CE marked; all reportedly have excellent flow characteristics, but each has specific features and aortic anatomical requirements (Table 1).[2-3] The specific characteristics of each valve (e.g. balloon- or self-expandable) and the landing zone (supra-annular, annular or sub-annular) may have a different impact on the structural and functional properties of the device in each patient.

Besides the variation in the anatomical features, a quantitative understanding of the biomechanical and rheological changes involved in TAVI seems to be critical for the success of the procedure.[4] Incurring changes in haemodynamics after TAVI may potentially accelerate leaflet degeneration, reduce prosthetic stability, or cause haemostatic abnormalities.[5] However, the determination of the appropriate interaction forces between the device and the native tissue is a challenging task. A limited number of studies have used computational approaches to analyse the TAVI procedure, investigating distorted leaflet geometries, valve positioning, migration forces, and the biomechanical interaction of the valve stent with the aortic root.[6-10]

In this issue of the HJC, Kopanidis et al describe a computational model they used to investigate variations in aortic flow patterns induced by the deployment of two different valve designs.[11] Although the aortic model was derived from computed tomography coronary angiography images that were free of pathologies, this study demonstrates that the virtual implantation of bioprosthetic aortic valves and the prediction of post-implantation aortic flow patterns by computer modelling is feasible. Such models, by simulating delivery, deployment and valve deformation, can theoretically be applied in preoperative planning with a view to assessing the structural, functional and rheological outcomes of implantation for the selection of the most appropriate valve system.

The future challenge for TAVI devices is to ensure levels of safety and efficacy that may justify an extension of this procedure to patients at intermediate and low risk for surgery. By individualising the technical aspects of the TAVI procedure to each patient, the risk of stroke, vascular injury, paravalvular regurgitation and pacemaker implantation will eventually decrease. The ideal aortic valve prosthesis for each patient should be durable, aim at optimising radial forces to provide a better seal in large anatomies and extensive calcification, and have optimal haemodynamic performance.

Computer modelling of devices intended for implantation in the aortic root may allow analysis of their structure and the interaction between different devices and the aortic anatomy. As imaging methods and computational tools continue to evolve, these techniques may provide critical input for valve system design, testing, and clinical guidance. Since the current technology provides multiple valve systems, the selection of the appropriate valve should be customised. The contribution of such computational models needs to be further clarified, adding important information to the clinical judgement of the operators.

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Table 1. Design and characteristics of second generation TAVI devices.

Valve type	Medtronic Evolut R	Medtronic Engager	Edwards Sapien 3	Edwards Centera	Boston Lci Lotus	Direct Flow Medical	St Jude Portico	Symetis ACURATE	JenaValve
Design	Self-expandable	Self-expandable	Balloon-expandable	Self-expandable	Mechanically-expanded	Inflatable balloon ring	Self-expandable	Self-expandable	Self-expandable
Leaflets	Porcine pericardium	Bovine pericardium	Bovine pericardium	Bovine pericardium	Bovine pericardium	Bovine pericardium	Bovine pericardium	Porcine pericardium	Porcine aortic root
Frame	Nitinol	Nitinol	Cobalt-chromium stent	Nitinol	Nitinol	Polyester	Nitinol	Nitinol	Nitinol
Size (mm)	23, 26, 29, 32	23, 26	23, 26, 29	20, 23, 26, 29	23, 25, 27	23, 25, 27, 29	23, 25	23, 25, 27	23, 25, 27
Annulus (mm)	18-30	21-26.7	18-28	18-27	19-27	19-29	18-25	21-27	21-27
Rapid Pacing	No	Yes	Yes	Yes	No	No	No	Yes	No
Repositionable	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Retrievable	Yes	No	No	Yes	Yes	Yes	No	No	No
Address vascular complications	Yes	-	Yes	Yes	-	-	-	-	-
Address paravalvular leak	Yes	-	-	Yes	-	-	-	Yes	Yes
Address conduction disturbances	Yes	-	-	Yes	-	-	-	Yes	Yes