Opportunity 2024021

TAVR-AID: A Digital Twin for Personalised Aortic Valve Replacement Therapy

TAVR-AID, is a novel digital twin simulation pipeline that starts with imaging (CT, ultrasound) and produces an accurate mechanistic simulation of blood flow in the patient's aorta. This simulated blood flow is used as part of an AI predictive clinical decision support system to assist with valve selection, positioning, orientation and outcome prediction for Transcatheter Aortic Valve Replacement (TAVR).

Background

Aortic stenosis is a condition characterised by the restriction or narrowing of the aortic valve, leading to valve dysfunction and restricting blood flow from the left ventricle into the aorta and the rest of the body. This results in increased cardiac workload leading to symptoms such as chest pain, fainting, shortness of breath and heart failure if left untreated. Transcatheter Aortic Valve Replacement (TAVR) is a minimally invasive procedure involving the placement of a new prosthetic valve into the heart via a catheter. This new valve is deployed to replace the existing aortic valve, where it expands and takes over the function of the diseased valve, thereby restoring normal blood flow into the aorta.

The Problem

The location and orientation of the implanted valve directly influence hemodynamics by affecting the flow dynamics and pressure gradients across the valve, thereby determining the efficiency of blood ejection from the heart. Flow dynamics and resulting vortices can impact aortic wall shear stress, potentially affecting the structural integrity and durability of the implanted valve over time. When planning the TAVR procedure, the patient's heart care team faces the challenge of considering multiple factors including valve selection, positioning based on the aortic root geometry, and orientation to optimise hemodynamics and ensure long-term valve durability.

Invention: Benefits & Application

TAVR-AID is a digital twin pipeline that provides mechanistic simulation of a patient's blood flow coupled with predictive capabilities of artificial intelligence. TAVR-AID is designed as a pre-interventional decision-support tool, helping the heart care team responsible for the TAVR procedure anticipate and mitigate potential complications, optimise valve selection and placement, and tailor the TAVR procedure to the unique needs of each patient, thereby enhancing patient care.

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The digital twin provides patient specific simulation, though the use of aortic CT scan to provide a structural view of the patient's 3D aortic anatomy and pre-interventional echocardiography to assess the hemodynamic severity of the aortic stenosis and cardiac hemodynamics. AI is used to perform segmentation of CT images and to prepare a 3D mesh suitable for computational fluid dynamics. Based on the flow patterns, patient information contained in the electronic healthcare record, and measurements from the CT and echo images, an AI model makes recommendations for the intervention, including which valve to use, the valves size, its positioning (height and orientation), and risk of complication such as stroke, paravalvular leak or device failure (Figure 1). TAVR-AID can provide clinical decision support to the multi-disciplinary heart team in planning the intervention to optimise the valve's operation and longevity once implanted. The tool is not designed to replace human decision making, rather it is intended to assist human planning to produce a better outcome than if the digital twin had not been used.

The development of TAVR-AID was spearheaded by a uniquely interdisciplinary team that combines the expertise of cardiologists, interventional surgeons, engineers, research nurses, computer scientists, and a patient. This diverse group brings a powerful blend of clinical insight and advanced technological skills, ensuring that the models are not only sophisticated and state-of-the-art but also grounded in practical, real-world clinical requirements.

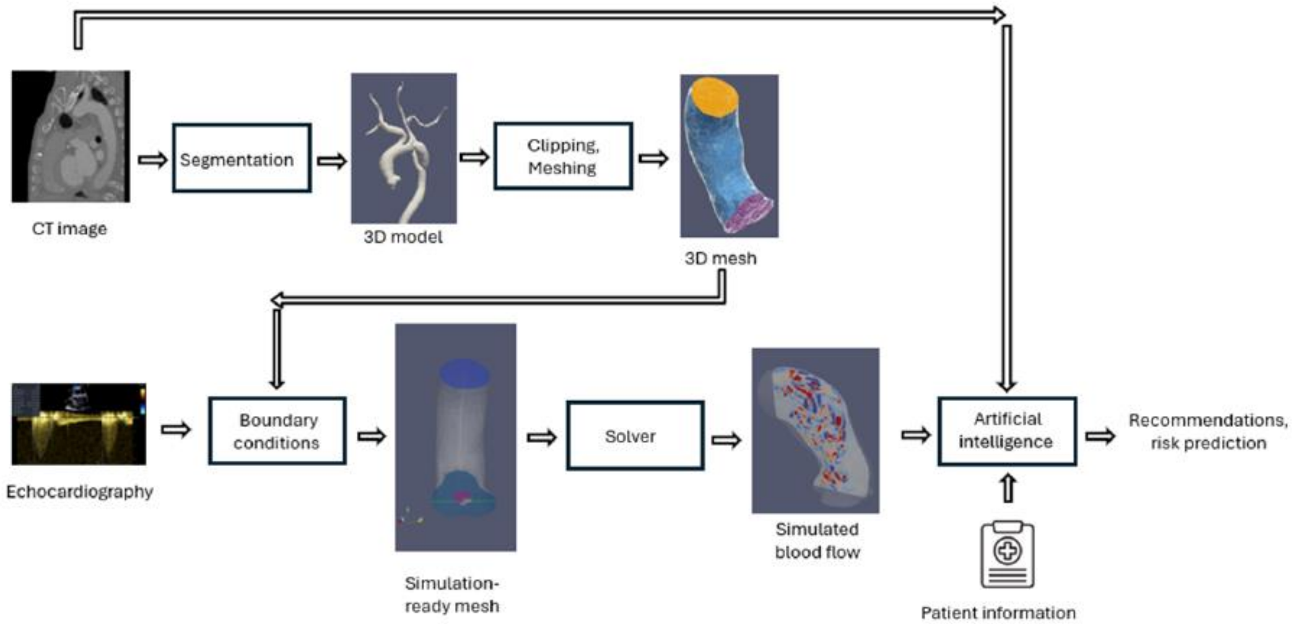

Figure 1: The TAVR-AID pipeline: The patient's aortic root geometry is segmented automatically from a CT image, then clipped and meshed appropriately for flow simulation according to patient anatomy, requirements of the solver used, and outputs of interest. Boundary surfaces are extracted, and conditions specified from patient's flow measurements. Blood flow through the patient's aorta is simulated and the outputs used to develop and train machine learning algorithms to predict likely outcomes of TAVR.

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Patent

A provisional patent application has been filed.

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