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Patient-Specific 3D Modeling and Printing of Valvular and Thoracic Aortic Pathologies: A Feasibility Study

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Introduction: Congenital and acquired valvular heart diseases, as well as thoracic aortic aneurysms, remain a significant cause of morbidity and mortality worldwide. Personalized three-dimensional (3D) modeling and printing of cardiac valves and thoracic aortic structures have emerged as promising tools to support surgical planning, patient-specific interventions, and education. However, the generation of accurate 3D reconstructions requires robust segmentation workflows that integrate multimodal imaging data.

Methods: We are developing a novel workflow for segmentation and 3D reconstruction of cardiac valves and thoracic aortic disease using computed tomography (CT) and echocardiography datasets. The methodology involves preprocessing of DICOM images, applying semi-automated segmentation algorithms, and performing multimodal image registration. Segmented structures are rendered into high-fidelity 3D models and optimized for additive manufacturing. Physical replicas are then printed from and anonymized patient dataset, enabling surgeons to rehearse and refine procedural techniques.

Preliminary Results: The proposed workflow successfully integrates CT and echocardiographic images, enabling precise delineation of valve structures, thoracic aorta, and surrounding anatomy. The segmentation accuracy supports the generation of high-fidelity 3D renderings that preserve geometric integrity. Printed valve and aortic prototypes demonstrate anatomical consistency with original imaging, with acceptable reproducibility across cases. This approach reduced the need for manual post-processing and provided rapid turnaround from imaging to physical model.

Next Steps: This study demonstrates the feasibility of a multimodal segmentation workflow for 3D rendering and printing of cardiac valves and models of thoracic aortic disease. The integration of CT and echocardiography improves anatomical accuracy compared to single-modality approaches, while facilitating the creation of patient-specific physical models. These findings support future applications of 3D printing in preoperative planning, surgical simulation, and personalized cardiovascular interventions. Therefore, what follows is the validation of this workflow in larger datasets and its translation into clinical practice for both valvular and thoracic aortic pathologies.