Validation of a Computational Model for Predicting Left Ventricular Flow after Transcatheter Mitral Valve Replacement

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Introduction: Mitral valve regurgitation affects over 4 million people in the United States, with current surgical treatment options being unavailable to approximately 49% of patients due to high surgical risk. For these patients, transcatheter mitral valve replacement (TMVR) is an emerging technique which aims to replace the mitral valve through a minimally invasive, catheter-based approach on a beating heart. The early experience with TMVR has shown promise; however, obstruction of the left ventricular (LV) outflow tract (LVOT) is a potentially lethal complication which may occur. Computational flow modeling has been proposed as a method to predict the occurrence of LVOT obstruction in these patients, however limited clinical validation data exist to date. The current study explores a potential computational model for predicting TMVR-related LVOT obstruction, and reports on the validation to clinical echocardiography-derived hemodynamic metrics recorded following device implantation.

Materials and Methods: A contrast-enhanced, ECG-gated computed tomography (CT) dataset was acquired post-device implantation from a patient who underwent TMVR. The LV blood volume geometry and implanted transcatheter heart valve were segmented and reconstructed in 3D, with advanced visualization facilitated by the EchoPixel True 3D platform. Computer aided design manipulations were used to prepare the model for input into a computational fluid dynamics (CFD) software (ANSYS Fluent). CFD modeling using a large eddy simulation was performed with an inlet at the LV apex and an outlet at the aortic valve. The boundary conditions were derived from clinical measurements. Trans-esophageal echocardiography (TEE) was acquired post-device implantation and the Doppler velocity across the LVOT was used to validate the simulated LVOT velocity from the computational model.

Results and Discussion: The simulated velocity across the LVOT was 1.098 m/sec, compared with a measured LVOT velocity of 1.128 m/sec based on TEE post-device implantation (Figure 1). These velocity values were within a 2.7% difference, indicating that our computational simulation approach accurately predicted LV flow and the potential for LVOT obstruction after TMVR. In this patient, the LVOT velocity was not clinically significant.

Translational Impact: Accurate computational modeling for predicting left ventricular flow after TMVR is feasible. Our validation study confirms that CFD modeling of the left ventricle can generate hemodynamic values which are in good agreement with those measured by echocardiography. Additional larger cohort studies are needed to better understand the accuracy of these simulations across different patients and implantation scenarios.

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