Development of a Surgical Assistance System for Guiding Transcatheter Aortic Valve Implantation

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Abstract

Development of image-guided interventional systems is growing up rapidly in the recent years. These new systems become an essential part of the modern minimally invasive surgical procedures, especially for the cardiac surgery. Transcatheter aortic valve implantation (TAVI) is a recently developed surgical technique to treat severe aortic valve stenosis in elderly and high-risk patients. The placement of stented aortic valve prosthesis is crucial and typically performed under live 2D fluoroscopy guidance. To assist the placement of the prosthesis during the surgical procedure, a new fluoroscopy-based TAVI assistance system has been developed. The developed assistance system integrates a 3D geometrical aortic mesh model and anatomical valve landmarks with live 2D fluoroscopic images. The 3D aortic mesh model and landmarks are reconstructed from interventional angiographic and fluoroscopic C-arm CT system, and a target area of valve implantation is automatically estimated using these aortic mesh models. Based on template-based tracking approach, the overlay of visualized 3D aortic mesh model, landmarks and target area of implantation onto fluoroscopic images is updated by approximating the aortic root motion from a pigtail catheter motion without contrast agent. A rigid intensity-based registration method is also used to track continuously the aortic root motion in the presence of contrast agent. Moreover, the aortic valve prosthesis is tracked in fluoroscopic images to guide the surgeon to perform the appropriate placement of prosthesis into the estimated target area of implantation. An interactive graphical user interface for the surgeon is developed to initialize the system algorithms, control the visualization view of the guidance results, and correct manually overlay errors if needed.

Retrospective experiments were carried out on several patient datasets from the clinical routine of the TAVI in a hybrid operating room. The maximum displacement errors were small for both the dynamic overlay of aortic mesh models and tracking the prosthesis, and within the clinically accepted ranges. High success rates of the developed assistance system were obtained for all tested patient datasets.

The results show that the developed surgical assistance system provides a helpful tool for the surgeon by automatically defining the desired placement position of the prosthesis during the surgical procedure of the TAVI.