Minimally Invasive Bioprosthetic Aortic Valve Implantation Under Real Time MRI Guidance - Engineering Challenges

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Heart disease is the leading cause of death in the modern world, aortic stenosis and aortic regurgitation being the most common types of aortic valvular disease in the aging population. Traditionally, aortic valve replacement procedures required a sternotomy and use of cardiopulmonary bypass (CPB). Currently, for patients with high-surgical risk a less invasive alternative to open heart surgery is Transapical or Transcatheter Aortic Valve Replacement (TAVR). The bioprosthetic valves, affixed into a balloon-expandable or self-expanding stents, are delivered via catheters using transarterial or transapical approaches and are implanted within diseased aortic valves. These minimally invasive approaches reduce trauma and speed recovery for the patient. However, minimally invasive surgical procedures are more technically demanding and constrained than traditional open heart surgery. Restricted vision and complexity of instrument manipulation are the limitations to the full implementation of minimally invasive approaches. Typically, the imaging employed for percutaneous valve placement is X-ray fluoroscopy with adjuvant echocardiography, which provides real-time 2D visualization with little soft tissue contrast. Magnetic Resonance Imaging (MRI) provides high resolution images of cardiovascular anatomy without contrast use or radiation. Real-time MRI (rtMRI) allows physicians to monitor the progress of the procedure and also provides the ability to immediately assess the results, such as ventricular and valvular function, and myocardial perfusion. However, the MRI environment has special requirements for the safety and compatibility of the aortic prostheses and their corresponding delivery devices. Our team has investigated the use of real time rtMRI to provide precise anatomic detail and visual feedback to implant a bioprosthetic aortic valve through a transapical approach in a beating heart of an animal model, both with manual and robotic approach. Some of the most important technical challenges of this minimally invasive procedure under rtMRI guidance are presented.