Aortic tissue-stent mechanical interaction in transcatheter aortic valve replacement
Joseph Mummert, Eric Sirois and Wei Sun
Tissue Mechanics Lab, Biomedical Engineering, University of Connecticut, Storrs, CT 06269

Statement of Purpose: Since the first procedure in 2002 [1], there has been an explosive growth in transcatheter aortic valve replacement (TAVR). By the end of 2011, about 50,000 TAVRs have been performed worldwide. Short- and medium-term outcomes after TAVR are encouraging with significant reduction in rates of death. However, adverse events associated with TAVR have been detected, including stroke, myocardial infarction, peripheral embolism, injury to the aorta, perivalvular leak, and access site injury [2, 3]. Furthermore, long-term durability and safety of these valves are largely unknown and need to be evaluated and studied carefully [4-6]. Successful deployment and function in TAVR is heavily reliant on the tissue-stent interaction. For instance, excessive radial force of the stent may cause aortic injury, while insufficient force may lead to paravalvular leakage and device migration. Therefore, a better understanding of the aortic tissue-TAV interaction is critical to TAVR success.

Methods: In this study, braided Nitinol stents were developed and tested to determine stent crimped diameter vs. stent radial force using a stent crimp experiment. We quantified important tissue-stent contact variables of self-expanding transcatheter aortic valve (TAV) stents when deployed into ovine and porcine aortic roots, such as the stent radial expansion force, stent pullout force, the annulus deformation response and the coefficient of friction on the tissue-stent contact interface. Furthermore, we conducted material and structural tests of tissues in the annulus region using uniaxial tensile and ring tests to quantify regional tissue properties. By doing so, we aimed to link the strength of tissues in the annulus region to the radial force of the stent to predict TAVI-induced tissue tearing.

Results: The results indicated that when crimped at body temperature from 26 mm to 19, 21 and 23 mm stent radial forces were approximately 30-40% higher than those crimped at room temperature. Coefficients of friction leveled to approximately 0.10 ± 0.01 as stent wire diameter increased and annulus size decreased from 23 to 19 mm. Regardless of aortic annulus size and species tested, it appeared that a minimum of about 2.5 mm in annular dilatation, caused by about 60N of radial force from stent expansion, was needed to anchor the stent.

Conclusion: This study helps to address important issues in the TAVR debate relating to device/aortic wall interactions; such data may facilitate TAV device design improvements to avoid aortic tissue rupture.

Acknowledgement: NIH HL108239, HL104080, and NSF GRFP pre-doctoral fellowship

References: