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The Biomechanics of Erections: Modeling the Penis as a One-Comparment Pressurized Vessel vs. Modeling it as a Two-Compartments Pressurized Vessel

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Previous biomechanical models of the penis that have attempted to simulate penile erections have either been limited to two-dimensional geometry, simplified three-dimensional geometry or made inaccurate assumptions altogether. Most models designed the shaft of the penis as a one-compartment pressurized vessel fixed at one end, when in reality it is a two-compartments pressurized vessel, in which the compartments diverge as they enter the body and are fixed at two separate points. This study began by designing simplified two-dimensional and three-dimensional models of the erect penis using Finite Element Analysis (FEA) methods with varying anatomical considerations for analyzing structural stresses, axial buckling and lateral deformation. The study then validated the results by building physical models replicating the computer models. Finally a more complex and anatomically accurate model of the penis was designed and analyzed. There was a significant difference in the peak von-Mises stress distribution between the one-compartment pressurized vessel and the more anatomically correct two-compartments pressurized vessel. Furthermore, the two-compartments diverging pressurized vessel was found to have more structural integrity when subject to external lateral forces than the one-compartment pressurized vessel. This study suggests that Mother Nature has favored an anatomy of two corporal cavernosal bodies separated by a perforated septum as opposed to one corporal body, due to better structural integrity of the tunica albuginea when subject to external forces.

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Design of a Catheter-Based Device for Performing Percutaneous Chordal-Cutting Procedures

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In this paper we detail the rapid design, fabrication and testing of a percutaneous catheterbased device that is envisioned to enable externally controlled manipulation and cutting of specific chordae tendinae within the heart. The importance of this work is that it (a) provides a means that surgeons may use to alleviate problems associated with some forms of mitral valve regurgitation and (b) demonstrates how a deterministic design process may be used to drive design innovation in medical devices while lowering development cost/time/resources. In the United States alone, approximately 500,000 people develop ischemic or functional MR per year. A chordal cutting procedure and device could allow many patients, who would otherwise be unable to survive open-heart surgery, to undergo a potentially life-saving operation at reduced risk. The design process has enabled us to generate a solution to this problem in a relatively short time. A deterministic design process was used to generate several design concepts and then evaluate and compare each concept based on a set of functional requirements. A final concept to be alpha prototyped was then chosen, optimized, and fabricated. The design process made it possible to make rapid progress during the project and to achieve a device design that worked the first time. This approach is important to medical device design as it reduces engineering effort, cost, and the amount of time spent in iterative design cycles. An overview of the design process will be presented and discussed within the context of a specific case study–the rapid design/fabrication of a chordal cutting device. Experimental results will be used to assess: (i) The performance of the catheter in maneuvering into the heart and grasping various structures. (ii) The effectiveness of the catheter's RF ablation tip at cutting chordae inside of a heart. In the first experiment, the catheter was guided to the basal chordae under direct visualization, which showed that the catheter is capable of successfully grasping a chord. During the second experiment, ultrasound was shown to be a viable method of visualizing the catheter within the heart. During this experiment, once contact between the chord and RF ablator tip was confirmed, the chord was successfully ablated. We will also discuss experiments that are currently underway to visualize the catheter utilizing a Trans-Esophageal Echo probe, as well as imaging the mitral valve from the apex of the heart with a laparoscope so that video of the basal chord being grasped and cut can be acquired on a heart whose anatomical structures are intact. A brief synopsis will then be given of how the design process has been used in research and educational collaborations between MIT and local hospitals.