Oral Presentation
Track 16: Reproductive Biomechanics
16.6. Penile Mechanics and Hemodynamics

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State of knowledge in structural mechanics of penile erection, and some areas of ignorance

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Penile rigidity is determined by geometrical properties, intracavernosal pressure (ICP), tissue mechanical properties and interactions between these factors. Here we review the points of strength and of weakness in the state of knowledge regarding each factor.
Geometrical properties: Ultrasound is now in routine clinical use for evaluating the anatomy of the flaccid and erect penis, and can demonstrate expandability of corpora during erection, their level of symmetry, and the thickness and integrity of the tunica albuginea. MRI was also utilized in basic research and clinical studies of erection, and is able to visualize finer details such as lesions and tears in the tunica and corpora. Both ultrasound and MRI allow for subject-specific structural modeling of the penis, and are particularly suitable for producing three-dimensional finite element (FE) models.
Intracavernosal pressure: ICP was measured in normals and erectile dysfunction patients by inserting a catheter instrumented with a pressure transducer to the corpus cavernosum. In animal models (mostly mice, rats and rabbits), the dependence of ICP on dose and frequency of administration of vasodilators had been characterized. ICP changes were reported to occur with age, diseases (diabetes and Peyronie's), and radiation therapy of prostate cancer. It is also known that ICP relates to the buckling force resistance of the penis. From a biomechanical standpoint, experimental data on ICP and its time course of build-up during erection, as well as data on influence of age, disease, and pharmaceutical drugs are essential for setting boundary conditions in FE models.
Tissue mechanical properties: This factor is by far less studied than those discussed previously. The organized structure of collagen in the tunica - the most important load-bearing structure - suggests that it is a highly anisotropic material. The large tissue deformations which occur in the penis during erection also require a constitutive law suitable for large deformation analysis. Since the rigidity phase of erection lasts several minutes, during which soft penile tissues may undergo viscoelastic creep, it is also necessary to characterize the long-term creep modulus of the tunica. Similar experimental data and constitutive modeling are required for the corpus cavernosal tissue.