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COMPUTATIONAL TOOLS FOR THE INVESTIGATION OF BIOMECHANICS OF THE LOWER URINARY TRACT

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Aims

Lower Urinary Tract (LUT) dysfunction describes symptoms related to problems of the lower urinary tract, with consequent incontinence. Artificial Urinary Sphincters (AUS) are adopted to obtain continence conditions via urethral occlusion by applying pressure load defined on the basis of an empirical approach [1]. Computational Solid Mechanic (CSM) analyses are developed to evaluate the interaction between the cuff itself and the urethral duct, with reference to the lumen occlusion process for maintaining urinary continence. Furthermore, the methods of Fluid Structure Interaction (FSI) analyses allow contemplating the coupling of such fluid dynamics and solid mechanics problems.

Materials and methods

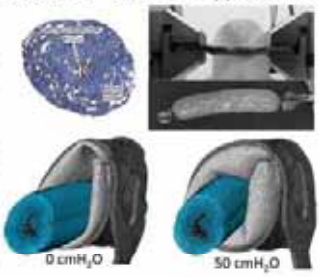
CSM investigation

urethra biomechanics

- tensile tests on urethral tissues along longitudinal and circumferential directions
- inflation tests on tubular segments of the urethral duct [2]
- finite element model developed from histological images
- mechanical behavior of tissues described by a hyperelastic formulation [3-4]

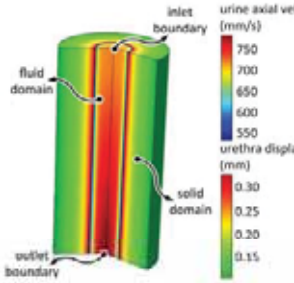
AUS cuff mechanics

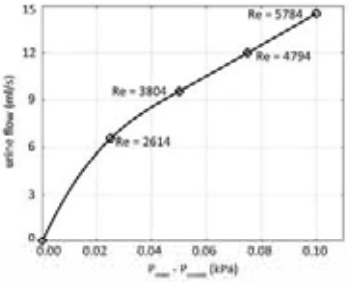
- tensile and inflation tests and physicochemical analysis [5]
- finite element model developed by Computed Tomography (CT) scanning
- urethra is investigated when 50 cmH_2O cuff pressure is applied, according to clinical practice



FSI investigation

- coupled investigation of solid mechanics (urethral wall domain) and fluid dynamics (urine domain) problems
- FSI simulation of micturition along a segment from bulbar urethra (superposition of displacement and velocity fields over solid and fluid domains)
- relationship between urine flow and local pressure gradient

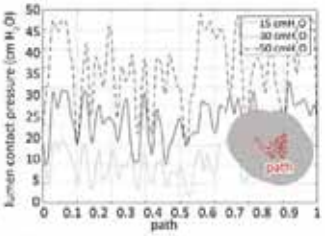


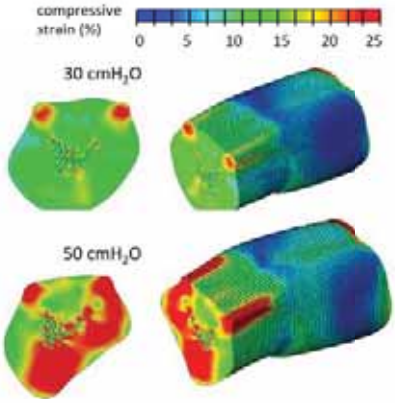


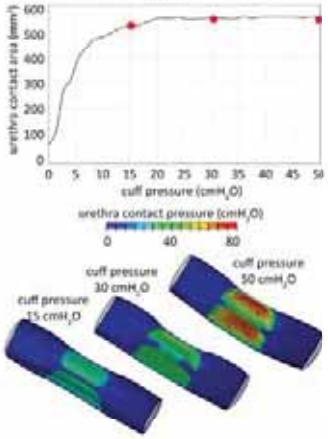
Results

CSM results

- contact pressure on the lumen path at different level of internal AUS pressure is analyzed
- contact area during inflation step are reported in relation with internal pressure of AUS
- high stress and strain regions are identified

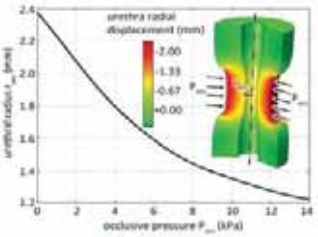


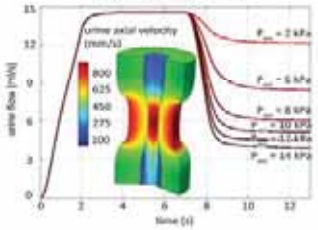


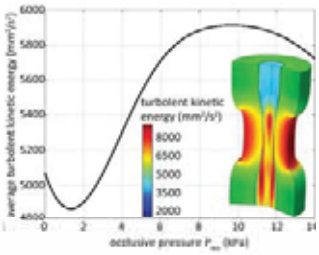


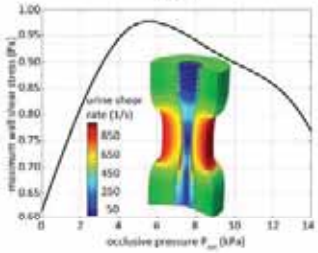
FSI results

- relationship between lumen radius and occlusive pressure during micturition for a 0,1 kPa gradient pressure condition
- evaluation of relationships between local pressure gradient, occlusive pressure and urine flow
- investigation about the influence of (residual) occlusive actions on urine turbulence and wall stresses:
  - development of inflammatory and remodeling phenomena









Discussion and conclusion

Several complications, as tissue atrophy and erosion, are observed after medium-long term implantation. This aspect stresses the relevance of an accurate knowledge of the cuff material and structural characteristics, while duct properties represent a variable datum in dependence on age of the subject and of potential pathologies that must be take into account for the identification of AUS cuff internal pressure. The most reliable investigation should account for a full FSI analysis including both urethra and AUS device. The action entails really complex model formulation and is under development at the CMBM.

References

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