7502 Tu, 12:15-12:30 (P20)

Toward a structural model of the urinary bladder wall

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In addition to functional deficiencies (1), bladder pathologies involve changes in tissue morphology (2) and mechanical properties (3), suggesting a strong relation between the three. A structural constitutive model of the urinary bladder wall is needed to clarify this relation. For this, the multiaxial mechanical data of the tissue and quantitative morphology of intact bladder wall are needed. In addition to the mechanical properties of rat bladder wall tissue in the inactive state, in which muscle function is abolished, mechanical properties of the tissue in the passive (i.e. with muscle tone) and the active state are determined, using biaxial testing in Krebs solution. The smooth muscle orientation was determined and structural data of the ECM is acquired using SALS. It was found that the urinary bladder exhibits significant anisotropy (being stiffer in the longitudinal direction than in the circumferential direction), in both the inactive and the passive state. The passive stress–strain behavior is found to be strain-rate insensitive and differs from the inactive behavior. Electrical stimulation resulted in active contraction of the bladder tissue, with different levels of stress in the circumferential and longitudinal directions. The collagen orientation is found to be along the longitudinal axis, which is the same preferred orientation of the smooth muscle cells. This is the first time that the actual multiaxial passive behavior of the urinary bladder wall is shown. Now all the necessary data is obtained to develop a structural constitutive wall of the intact urinary bladder, i.e. the multiaxial mechanical behavior of the passive and active state and the quantitative morphology of the smooth muscle cells and the ECM, a structural model can be derived.

20.4. Soft Tissues

5326 Tu, 14:00-14:15 (P23)

Growing shells

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Soft shell-like structures are ubiquitous in living organisms, ranging from organelles and cell membranes to lymph and blood vessels, the alimentary canal and respiratory ducts, the urinary tract, and the uterus. The mechanical response of all of these structures – a key feature of their physiological and pathological functioning – is subtle and elusive. Another critical issue is their ability to grow and remodel, in a way which is both biochemically controlled and strongly coupled with the prevailing mechanical conditions. While the characterization of the mechanical response of soft tissue is progressing at a reasonably fast pace nowadays, we find that growth mechanics is definitely the weakest link in the modelling chain. Our study focusses precisely on the two-way coupling between growth and stress, which we model within the theoretical framework set forth in [1,2]. In this dynamical theory, bulk growth is governed by a novel balance law (the balance of remodelling couples). We develop and implement a layered shell theory, in order to eschew unduly restrictive hypotheses on growth distribution across the thickness. As a first application, we consider toy problems inspired by the evolution of saccular aneurisms [3] and by the enlargement of the uterus during pregnancy [4].

References

[1] A. DiCarlo, S. Quiligotti. Growth and balance. Mechanics Research Communications 2002; 29: 449–456. A

[2] DiCarlo. Surface and bulk growth unified. In: Mechanics of Material Forces (P. Steinmann and G.A. Maugin, eds.). 2005; Springer, New York, pp. 53–64. Also available at http://www.ima.umn.edu/preprints/may2005/2045.pdf.

[3] J.D. Humphrey. Cardiovascular Solid Mechanics: Cells, Tissues, and Organs. 2001; Springer, New York.

[4] S. Socrate, A.P. Paskaleva, K.M. Myers, M. House. Connection between uterine contractions and cervical dilation: a biomechanical theory of cervical deformation. Oral presentation at 1st International Conference on Mechanics of Biomaterials & Tissues, Waikoloa, HI, December 11–15, 2005.

4194 Tu, 14:15-14:30 (P23)

Bio acoustical and bio mechanical methods for mechanical study of soft tissues

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In order to perform comparative multi-scale analyses of soft tissues, three experiments have been developed: (a) high frequency (600 MHz) imaging and phase acquisition for longitudinal velocity measurement; (b) low frequency echography (from 5 to 50 MHz) with two coupling fluids (H_2O and D_2O) for ultrasonic velocity and thickness measurements; and (c) ultrasonic indentation with specific longitudinal sensor for both velocity and Young modulus evaluation in one measurement. These different approaches will be presented first, validated by test on various materials.

Then these methods will be comparatively applied on normal and dystrophic muscles. We used mdx mice diaphragm that better reproduces the lost of muscle membrane integrity found in muscles from Duchenne muscular dystrophy patients (DMD).

First results on diaphragm from mdx mice show that the ultrasonic velocity is not very sensitive to pathology. With few meters variation per second between mdx and control diaphragms, the recorded data cannot constitute a reliable result. Then, the ultrasonic indentation was used. In specific experimental condition, some force–displacement curves were obtained and then analysed using finite elements calculations [1,2]. First evaluations of Young modulus are performed and demonstrate, when compared to ultrasonic velocity measurements, that the micro indentation provides better correlation with the muscle dystrophic phenotype.

References

[1] P.L. Larsson, S. Carlsson. On microindentation of viscoelastic polymers. Polymer Testing 1998; 17: 49–75.

[2] Y. Zheng, A.F.T. Mak, B. Lue. Objective assessment of limb tissue elasticity: development of a manual indentation procedure. Journal of Rehabilitation Research and Development 1999; 36(2).

5020 Tu, 14:30-14:45 (P23)

Biomechanical remodeling of obstructed guinea pig jejunum with reference to the zero-stress state

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Small intestinal obstruction is a frequently encountered clinical problem. To understand the mechanisms behind obstruction, data are needed on the relation between the morphometric and biomechanical remodeling of the intestinal wall during chronic obstruction. We aimed to determine the effect of partial obstruction on biomechanical and morphometric properties of the guinea pig small intestine. Male guinea pigs weighing about 600 grams were used in this study. Partial obstruction and sham operation were created surgically in four groups living for two days, four days, one week and two weeks. Six guinea pigs were included in each group. Another ten guinea pigs were used as normal control. Segment of 7 cm proximally to obstruction site was harvested. Two rings from each side of the segment were cut to obtain no-load state and zero-stress state. The remaining segment was put into an organ bath for biomechanical distension test in vitro. The proximal end was connected to a syringe pump for applying pressure up to 10 cm H_2O. The distal end was ligated to manipulator for applying different longitudinal stretch ratios. The outer diameter change during the inflation was monitored by microscope with CCD camera. Compared with sham operation and normal groups, the lumen area, circumferences, wall thickness and area were increased in the segments at the obstruction group in time-dependent manner. The opening angle and absolute value of residual strain decreased ($p<0.01$) while the wall stiffness in circumferential direction significantly increased after two weeks obstruction ($P<0.01$). Furthermore, the circumferential wall stiffness increased with the longitudinal stretch ratio of the segments in all groups. However, the morphometric and biomechnaical data did not differ between the sham and normal groups ($P>0.05$). Partial obstruction remodeled the morphological and biomechanical properties of small intestine proximally to the obstruction site.

4822 Tu, 14:45-15:00 (P23)

Multicompartment poroelastic model of perfused soft tissue: Pressure rise prediction during deformation impacts

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The study is devoted to mathematical modelling of localized pressure increase induced by deformation during impacts. The macroscopic model reflects the hierarchical structure of pores treated in terms of multiple compartments separated by permeable interfaces. It is suggested how the effective coefficients of the macro-model can be identified with support of the homogenization-based upscaling of a specific tissue microstructure. As an advantage, this approach allows to find relationship between different effective coefficients and geometrical features. Vice versa, having computed the macroscopic figures (pressure distribution in different compartments of the pore hierarchy) the local stress at the microscale can be identified. Such multiscale approach should assist in modelling and understanding the damage mechanisms in fluid saturated porous tissues (myocardium, kidneys). The model is implemented in a FEM code, numerical examples are presented, e.g. pressure response and stress distribution in microstructure to a step change in macroscopic deformation. (This work is supported by project MSM 4977751303.)