S31: Cardiovascular Biomechanics from Cells to Organs

S31-1 Biorheology of bile

Minh NGUYEN NGOC[a], Hiromichi OBARA[a], Kenji SHIMOKASA[b], Junfang ZHU[c]

[a]*Mechanical Engineering Department, Tokyo Metropolitan University, Japan*
[b]*Faculty of Industrial Technology, National University Corporation of Tsukuba University of Technology, Japan*
[c]*National Institute of Advanced Industrial Science and Technology, Japan*

Bile is an important secretion from a liver for our life and one of the most important rheological characteristics is extensional rheology. Due to the extensional viscosity of bile is much greater than shear viscosity. Bile flow in biliary is also influenced by extensional viscosity. In this study, a shear thinning capillary device was used to measure the stretching properties of bile. The liquid bridge was set up between upper and lower endplates. The endplates with diameter D_0=1mm initially separated by h_0= 0.5mm (aspect ratio=0.5) were used for the measurements of the filament. In the experiment, the top plate moves up rapidly to a set distance h_{max} = 4mm. The mid-point diameter of a liquid bridge was recorded by laser micrometer (Keyence corp.) and plotted against time. The zero point of the time (t_0= 0 s) measurement was defined as the timing of the end of the moving process of the plate. The filament self-thinning dynamics were captured by a high-resolution digital video using a high-speed camera. The results showed the stretching phenomenon of bile. Additionally, the shear viscosity of bile was examined by a rheometer (HAAKE RS600, Thermo Fisher Scientific, USA). All samples showed the shear thinning behavior. At the low shear rate, the viscosity of bile behaved as a non-Newtonian fluid and the viscosity of bile behaved as a low constant value at the high shear rate.

S31-2 Electrical impedance spectroscopic technique for cancerous cell sensing by considering the extracellular fluid around cells

Daisuke Kawashima[a], Songshi Li[a], Michiko Sugawara[a], Hiromichi Obara[b], Masahiro Takei[a]

[a]*Chiba University, Japan*
[b] *Tokyo Metropolitan University, Japan*

This study proposes a novel method of cancer cell detection by using microchannel with multi-layer electrodes based on electrical impedance spectroscopy (EIS) technique. This cancer cell detection method is based on the ion production of biological cells through their ion channel. By using EIS the ion production rate can be measured from the impedance change in extracellular fluid. We apply the ion production rate to the detection of cancer cell because the ion channel can be different in between normal cells and cancer cells and it causes the different ion production rate. In the experiment, we measure the electrical impedance spectroscopy in order to estimate the ion production rate in microchannel which has five sensing section with 16 layer electrodes in each section in the case that different kinds of cells are flowed into the channel. The results show the difference of ion flux among the different kinds of cells.

S31-3 Matrix metalloprotease production of vascular endothelial cells under extremely high wall shear stress condition

Naoya Sakamoto[a], Yuki Oyama[a], Yuta Horie[a], Masanori Nakamura[b], Naoyuki Kimura [c]

[a]*Tokyo Metropolitan University, Japan*
[b]Nagoya Institute of Technology
[c] Jichi Medical University Saitama Medical Center

Dilatation, dissection, and rupture of the ascending aorta are frequently associated with bicuspid aortic valves. It has been reported that the aortic wall is exposed to eccentric flow jets due to the abnormal valve anatomy and wall shear stress more than 10 Pa exerts on endothelial cells lining the lumen of the wall, whereas physiological shear stress in arteries on average is 2 Pa. Hence, such extremely high wall shear stress may induce imbalance between proteases and their inhibitors through changes in matrix metalloprotease (MMP) expression, leading to the aneurysm formation. However, the detailed mechanism is still unknown. In this study, we evaluated the effect of extremely high wall shear stress on the expression of MMP-2/-9, known to degrade elastic fibers and associate with the early stage of the aneurysm formation. Bovine aortic endothelial cells were exposed to fluid shear stress up to 40 Pa for 24 h using a parallel-plate flow chamber. After the flow-exposure experiment, endothelial cells were cultured with serum-free medium for 8 h, and MMP-2/-9 activities of the conditioned medium were then detected by gelatin zymography. After being exposed to shear stress of up to 40 Pa, cells aligned to the direction of wall shear stress and maintained an intact monolayer. The level of the MMP-2 activity showed a tendency to decrease according to the increase in shear stress. The MMP-9 activity was also lower at 10 Pa compared to the static, and we could not detect the MMP-9 activity at 20 and 40 Pa conditions. To reveal the effect of high shear stress conditions on the aneurysm formation, we will further investigate the regulators for MMPs activities such as their inhibitors and nitric oxide, and the roles of smooth muscle cells in tunica media.

S31-4 Observation of microscopic elastic structure in arterial tissue by use of a scanning haptic microscope (SHM)

Takeshi Moriwaki[a], Sadao Omata[b], Yasuhide Nakayama[c]

[a]*Hirosaki University, Japan*
[b]*CYBERDYNE, INC., Japan*
[c]*National Cerebral and Cardiovascular Center Research Institute, Japan*

We developed a scanning haptic microscope (SHM) for precise observation of the distribution of the elastic modulus over slice sample of biological tissues. We have mainly measured vascular tissues, and have revealed variations of the microscopic elastic structure along the entire length and strain condition. In this study, to evaluate mechanical compatibility and regeneration degree, autologous collagen vascular graft called Biotube was measured by SHM.

The SHM measurements were performed on circumferential slice samples of the canine carotid artery and biotubes before and after implantation. Embedded and implantation period of biotubes were 2 weeks and 3 months, respectively. After the SHM measurements, the slice samples ware stained with elastic-van Gieson stain for elastin or Masson's trichrome stain for collagen.

In the SHM measurement of the carotid artery, hard / soft laminated structure corresponding to elastin and collagen layer was observed. SHM image of Biotube before implantation had relatively soft elastic structure, its main component was collagen fibrils. After 3months implantation, the main component of biotube remained as collagen fibril, although invasion of elastin fibers was observed near the luminal surface of biotube. In the SHM measurement, however, the biotube after implantation had hard / soft laminated structure, and its average elastic modulus was almost the same as that of the carotid artery. It is thought that collagen fibrils in Biotube reorganized by cyclic mechanical load due to heart beat after implantation and its elastic structure also changed.

SHM can be expected to be useful for evaluating compatibility and regeneration degree of implantation tissues by measured the differences from native tissues and the changes after implantation.

S31-5 Ultrafast imaging of cell elasticity with optical microelastography

Guy Cloutier[a] , Grasland-Mongrain[a], Ali Zorgani[b,] Shoma Nakagawa[a], Simon Bernard[a], Lia Gomes Paim[a], Greg FitzHarris[a], Stefan Catheline[b]

[a]*University of Montreal Hospital Research Center, Canada*
[b]*INSERM, France*

Elasticity is a fundamental cellular property that is related to the anatomy, functionality and pathological state of cells and tissues. However, current techniques based on cell deformation, atomic force microscopy or Brillouin scattering are rather slow and do not always accurately represent cell elasticity. Here, we have developed an alternative technique by applying shear wave elastography to the micrometer scale. Elastic waves were mechanically induced in live mammalian oocytes using a vibrating micropipette. These audible frequency waves were observed optically at 205,000 frames per second and tracked with an optical flow algorithm. Whole cell elasticity was then mapped using an elastography method inspired by the seismology field. Using this approach, we showed that the elasticity of mouse oocyte is decreased when the oocyte cytoskeleton is disrupted with cytochalasin B. The technique is fast (less than 1 ms for data acquisition), precise (spatial resolution of a few micrometers), able to map internal cell structures, robust, and thus represents a tractable novel option for interrogating biomechanical properties of diverse cell types. This new technique is opening the possibility of studying dynamic cellular processes and elucidating new mechanocellular properties.
We call this technique “cell quake elastography.