Single-Transducer Elasticity Measurements Using Reflected Shear Waves

Shang-Chin Yang[1], Pei-Yu Chao[1], Pai-Chi Li[1,2], [1]Graduate Institute of BEBI, National Taiwan University, Taipei, Taiwan, [2]Electrical Engineering, National Taiwan University, Taipei, Taiwan

Background, Motivation and Objective

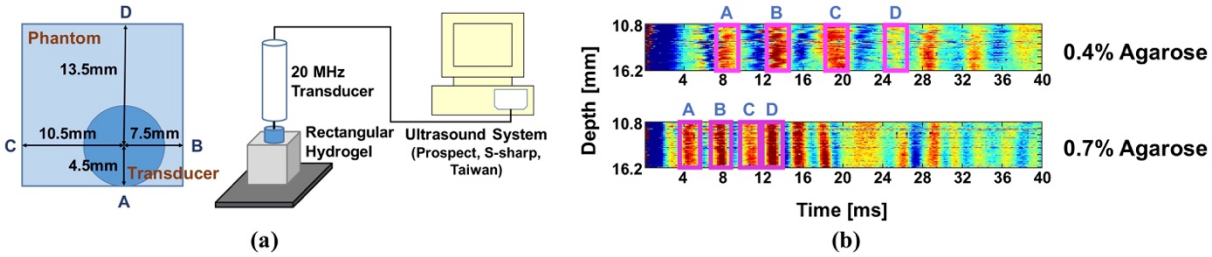
The stiffness of the extracellular matrix (ECM) has been found to regulate specific cellular functions such as proliferation and migration. Recent studies of the mechanical interactions between cells and their microenvironment have widely employed 3D cell culture systems. These systems formed from matrix hydrogels or composite materials tend to have micrometer-to-millimeter-scale dimensions. In addition, mechanical interactions between cells and ECM is a dynamic process. Therefore, there is a need for developing a system that can provide elasticity measurements on the millimeter-scale sample with < 1 second temporal resolution. Here we report a shear wave (SW) imaging system comprising only a single-element focused ultrasound transducer that serves as both push and imaging transducer. The location of the transducer relative to the boundaries of an 18 mm × 18 mm × 10 mm (L×W×H) rectangular sample was fixed. We hypothesize that the arrival times of the reflected SW from four side boundaries can be used to estimate the average SW speed of the sample.

Statement of Contribution/Methods

Acoustic radiation force is induced by the focused ultrasound transducer (20 MHz, F-number = 2.5), and thereafter, the same transducer is switched to the detection mode. The one-way distance between the center of the transducer to the four boundaries of the rectangular sample, as shown in Fig.(a) is 4.5 mm, 7.5 mm, 10.5 mm, and 13.5 mm, respectively. The averaged SW speed of the sample can be thus calculated by dividing the two-way propagation distance d_i by the arrival time of the respective reflected SW t_i, $\text{SW Speed} = \frac{\sum_{i=1}^{4} d_i/t_i}{4}$.

Results/Discussion

Fig.(a) shows the imaging system setup and the position of the transducer relative to the four boundaries of the sample. The reflected SW arrival-time plots from two homogeneous phantoms (0.4% and 0.7% agarose) are shown in Fig.(b), and the average shear wave speeds estimated for each phantom are 1.10 m/s and 2.83 m/s, and the standard deviation of the shear wave speeds measured from four boundaries are 0.006 m/s and 0.080 m/s, respectively. Feasibility of the single transducer setup for elasticity measurements of 3D cell culture systems is demonstrated. Investigation of other types of hydrogel will be presented in the full report.



(a) Schematic of the imaging system and (b) reflected SW arrival-time plots for 0.4% and 0.7% agarose samples.