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Ex-Vivo Tumor Characterization using the Multimodal ARFI Imaging System

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1. Introduction

We built a multimodal acoustic radiation force impulse (ARFI) imaging system based on high frequency ultrasound biomicroscopic (UBM) and reflectance multi-spectral imaging system for ex-vivo tumor characterization.

Mechanical property of an organ is one of key indicators for determination of the disease status. In particular, it has been shown that tumor regions exhibited stiffer than normal regions. Therefore, many biological tools capable of measuring the mechanical properties of biological samples have been so far developed. However, a biophysical tool with high resolution is still needed to be developed in a non-contact manner. In addition, in the early stage tumor such as gastric and colorectal cancer is not seen with the naked eye using white light source. Therefore, we utilized the multi-spectral imaging system for determination the doubt region of tumor before quantify the stiffness of the tumor by ARFI imaging system.

Thus, we here demonstrate a multimodal ARFI imaging system based on UBM system and multi-spectral imaging system, which is capable of measuring elasticity of a tissue.

2. Materials and methods

2.1 Construction of tissue-mimicking phantoms with different elasticity

In order to evaluate the performance of developed ARFI imaging system, tissue-mimicking phantoms were made with agar-powder at different young's modulus respectively as described previous report. The agar powder was hydrated with deionized water and n-propanol which can allow to maintain the acoustic speed at about 1540m/s, and did the degassing operation to the mixture in a vacuum oven. And then, a graphite powder particle size of between 10 and 30 um is mixed to the mixture for echogenic enhancement. The mixture was stirred for obtaining homogeneous gelation and cooled down to 20°C for cross-linking in an ice bath for 1 minutes.

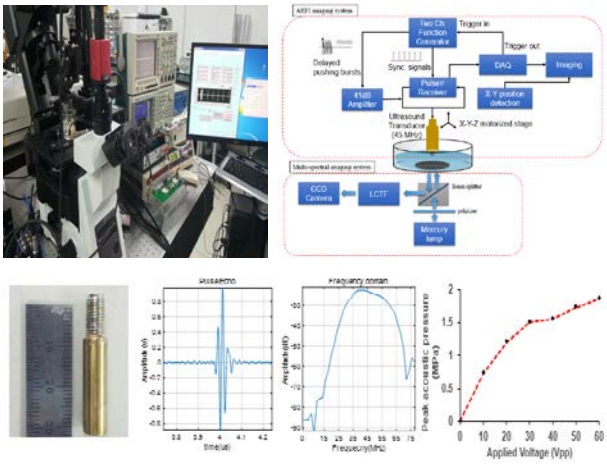

Fig. 1 photographic image, schematics of the multimodal ARFI imaging system and a characterization of a 45 MHz ultrasound transducer.

2.2 Imaging sequence and system configuration

The ARFI imaging system is consisted with a 45MHz transducer yielding better resolution by sacrificing depth of penetration, x-, y- motorized stages for making the 2-dimensional elastography. In addition, a broad band customized power amplifier, high speed digitizer and pulser/receiver configured the system for generation of ARFI, obtaining the raw signal from target and tracking the target displacement. The multi-spectral imaging system utilized the liquid crystal tunable bandpass filters (Thorlabs, Kurios, USA), polarizer in front of mercury lamp, beam splitter and high sensitive CCD camera.

They are attached to an inverted microscope (Olympus IX71, USA) for combining the ARFI imaging system with the multi-spectral imaging system. We, firstly, evaluate the performance of the developed ARFI imaging system using a tissue-mimicking phantoms with different mechanical properties. A tracking beam is generated to the target for measuring a reference location of a target. And then, the delayed sinusoidal bursts are generated to the membrane of a target for pushing the target. Finally, we can estimate the displacement by tracking the location after push the target using ARFI application. After the described previous sequence, the transducer starts to laterally scan a target about 5 mm for generating a 2-dimensional elastography.

Figure 1 illustrate the block diagram, photographic image of the multimodal ARFI imaging system and a characterization of a 45 MHz ultrasound transducer. The developed the system is operated sequentially as shown this figure 1. Firstly, operator should image the target a doubt region of tissue using the multi-spectral imaging system. And then, we can quantify the stiffness of a target regions by ARFI imaging system.

2.3 Data analysis

The acquired the RF data are up-sampled to 2 GHz by cubic splines interpolation method in order to preserve the original data points. And normalized cross-correlation calculation between the reference and track RF signals was then performed to obtain the maximum displacement. A coefficient threshold of 0.8 was set to avoid the inaccurate estimation of displacement after ARFI.

3. Results and Conclusion

We built a multimodal ARFI imaging capable of mapping the elasticities of biological tissues. The system allowed us to discriminate mechanical properties of agar phantoms at a specific regions by imaging sequentially. Also, by using it, elasticity of target due to ARFI application could be tracked precisely and the mechanical properties of colorectal tumors and normal tissues could further quantified. Thus, these results demonstrated that the multimodal ARFI imaging system have the potential to measure the elasticity of biological samples at an accurate regions of tumor in a non-contact manner, thus may become a very useful biophysical tool for various medical and biological applications.

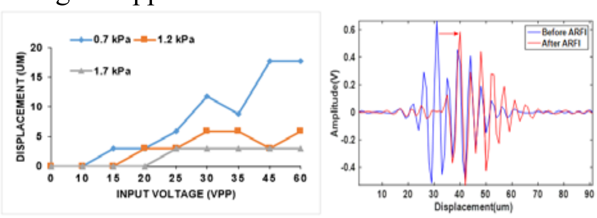

Fig 2. Displacements of a tissue-mimicking phantoms at different young's modulus after ARFI

4. References

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