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A configurable module-based ultrasound imaging system: all-in-one ultrasound, photoacoustics, and elasticity imaging

Heechul Yoon[1], Yiying I. Zhu[1], Donald VanderLaan[1], Vadakkancheril S. Jisha[1], Andrei Karpiouk[1], Stanislav Emelianov[1,2]

[1]*School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA, United States,* [2]*Wallace H. Coulter Department of Biomedical Engineering, Georgia Institute of Technology and Emory University School of Medicine, Atlanta, GA, United States*

Background, Motivation, and Objective

The sensitivity and specificity of widely used clinical ultrasound (US) imaging systems are relatively low compared to other imaging modalities. To address this limitation, shear wave elasticity imaging (SWEI) and spectroscopic photoacoustic (sPA) imaging were developed to provide additional diagnostic information based on mechanical or optical contrast. Furthermore, contrast agents such as optically triggered/responsive nanoagents have been developed for molecular and cellular imaging. This study introduces a configurable system combining these synergetic imaging technologies to further enhance ultrasound-based diagnosis of cancer and other diseases based on simultaneous anatomical, functional, and molecular imaging of tissue.

Statement of Contribution/Methods

Based on a programmable US system (Vantage 256) and a tunable pulsed laser (Phocus Mobile), we developed a configurable imaging system capable of supporting unconstrained allocation of imaging modules that allows users to create customizable imaging sequences (**Fig. 1a**). As an example, an imaging sequence acquiring pre-laser US images, three sPA images each followed by post-laser ultrafast US images, and two shear-wave velocity (SWV) images was implemented (**Fig. 1b**). This sequence was used to image a tissue mimicking gel phantom with a stiff gel inclusion containing perfluorohexane nanodroplets (PFHnDs) loaded with a squaraine dye (650 nm peak absorption).

Results/Discussion

The inclusion was barely visible in the pre-laser US image. In response to pulsed laser irradiation, PFHnDs vaporized and generated contrast in PA images. The PA signals were largest at 700 nm and decreased as wavelength increased. The vaporized PFHnDs temporarily persisted as gas bubbles, providing contrast in US images. As expected, the differential US (ΔUS) signals from PFHnDs were strongest immediately after the 700 nm laser pulse, and then decreased in subsequent US frames as the PFHnDs recondensed. Finally, two SWV maps successfully identified the inclusion based on quantitative stiffness assessment. This study introduces a module-based, configurable ultrasound-laser imaging system that demonstrates simultaneous support of ultrafast US, sPA, and SWEI with imaging contrast mechanisms related to acoustic, optical, and mechanical properties of tissue for comprehensive diagnosis.