Mini-Symposia Title:

Quantitative Ultrasound and Shear Wave Elastography for Diagnosis, Intervention, and Therapeutics

Mini-Symposia Organizer Name & Affiliation:

Laura Brattain, Techincal Staff, Human Health and Performance Systems Group, MIT Lincoln Laboratory, Lexington, MA USA

Mini-Symposia Speaker Name & Affiliation 1:

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Mini-Symposia Speaker Name & Affiliation 2:

Anthony E. Samir, Chief of Abdominal Imaging and Director of Center for Ultrasound Research and Translation, Massachusetts

Mini-Symposia Speaker Name & Affiliation 3:

Mark Palmeri, Associate Professor of the Practice in the Department of Biomedical Engineering, Duke University, Durham, NC USA

Mini-Symposia Speaker Name & Affiliation 4:

Viksit Kumar, Instructor in Radiology. Institution. Massachusetts General Hospital, Boston, MA USA

S Mini-Symposia Speaker Name & Affiliation 5:

Kai Thomenius, Research Scientist, MIT, Boston, MA USA

Mini-Symposia Speaker Name & Affiliation 6:

Theme:

- ○ 01. Biomedical Signal Processing
- ● 02. Biomedical Imaging and Image Processing
- ○ 03. Micro/ Nano-bioengineering; Cellular/ Tissue Engineering &
- ○ 04. Computational Systems & Synthetic Biology; Multiscale modeling
- ○ 05. Cardiovascular and Respiratory Systems Engineering
- ○ 06. Neural and Rehabilitation Engineering
- ○ 07. Biomedical Sensors and Wearable Systems
- ○ 08. Biorobotics and Biomechanics
- ○ 09. Therapeutic & Diagnostic Systems and Technologies
- ○ 10. Biomedical & Health Informatics
- ○ 11. Biomedical Engineering Education and Society
- ○ 12. Translational Engineering for Healthcare Innovation and Commercialization

Mini-Symposia Synopsis— Max 2000 Characters

Ultrasound (US) measures tissue acoustic impedance while shear wave elastography (SWE) assesses tissue stiffness, a biomechanical property. SWE can be overlaid on top of an US image, thus can be used in conjunction of US. In comparison to other leading medical imaging modalities such as x-ray, CT, and MR, US and SWE are portable, non-ionizing, and can provide real-time feedback and diagnosis. US is used at all levels of care, from point of injury, field clinics, to large hospitals. US is widely used for diagnosis, intervention, and therapeutic.

SWE is an emerging imaging modality and has shown promise in a number of diagnostic applications, such as musculoskeletal condition, liver fibrosis, breast tumor, and thyroid nodules.

Despite the advantages, US and SWE are highly operator dependent and suffer from high variability in data acquisition and interpretation. Both limitations greatly hinder the efficacy of US and SWE.

Quantitative ultrasound and SWE (QUS/ SWE), achieved by applying advanced imaging processing, including machine learning, can help address the challenges and improve the utility of US and SWE.

In this mini symposium, we will discuss recent advances in QUS/ SWE, and how they have been used in diagnosis, intervention, and therapeutics. This mini symposium of multidisciplinary group of

AI-Enabled Semi-Automated Vascular Access

Laura Brattain, Ph. D., MIT Lincoln Laboratory, Lexington, MA USA

***Abstract*— We present an AI-guided semi-automated vascular access system that aims to improve the accuracy and speed of medics in the field.**

I. Introduction

Although medics are trained for vascular access, it is still a time-consuming procedure for no experts. In addition, vascular access for trauma patients who suffer from non-compressible hemorrhage scenarios can be further complicated by a collapsed vein due to severe hemorrhage and hemorrhagic shock. Here we present a semi-automated vascular cannulation assistance technology suitable for field-forward use by a wide variety of personnel. Our initial focus is on femoral access, which offers low anatomic variation, large vessel size, and existing femoral vascular access cannulas.

II. Methods

Our technology combines handheld diagnostic ultrasound imaging, advanced image processing techniques, and a customized venous cannulation set to (1) automatically identify the femoral vein and artery, (2) define an optimal trajectory for femoral vascular cannulation, (3) assist the user in placing the femoral vascular cannula along that optimal trajectory, and (4) confirm correct vascular placement through imaging and conventional venous blood "flash-back."

Our initial work prototypes the machine learning-based femoral vessel detection using US cine clips of 5 human cases and 2 porcine cases, collected with a Terason tablet (Terason, Burlington, MA). Data comprise ~3500 images of the femoral vein and artery and are augmented to yield 20,000 of additional training samples. Study was approved by the IRB and IACUC from Massachusetts General Hospital. All human data are de-identified. 5-fold cross validation was used to train a You only look once (YOLO) real-time object detection deep learning neural network.

III. Results

Initial results on combine vessel detection and separate-vessel detection are shown in Fig. 1 and Fig. 2. Our preliminary results on femoral vessel detection achieves high accuracy (AUC: Artery and Vein 0.97/Artery 0.99/Vein 0.9377). The detection rate for vein is slightly lower because there is a higher degree of variability in the appearance of veins across the cases. The inference algorithm has been integrated to the Terason tablet machine and perform detect at ~ 5 frames per second without GPU.

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IV. Discussion & Conclusion

A system for guiding a medic to femoral vascular access is being developed. Such AI-enabled assistive device can be used to improve the accuracy, speed, and non-expert use of vascular access.

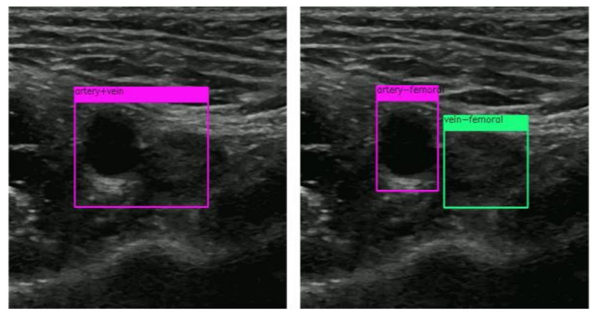

Fig. 1 Example femoral artery and vein detection results. (Left) Combined vessel detection. (Right) Separate-Vessel detection.

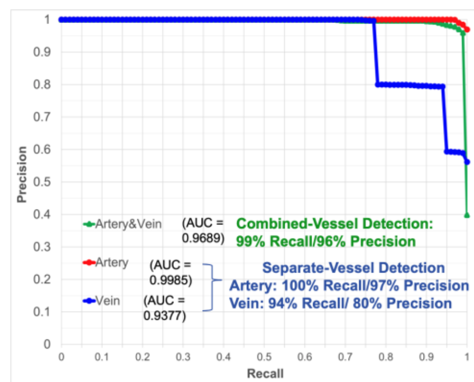

Fig. 2 Precision recall curve for femoral vessel detection

Acknowledgment

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References

[1] Brattain, L, Telfer, B, Dhyani, M, Grajo, J, Samir, AE (2018), Machine Learning for Medical US, *Abdom Radiol* https://doi.org/10.1007/s00261-018-1517-0.

No-human-in-the-loop Healthcare with AI: Risk, Rewards, and Regulations

Anthony E. Samir, M.D., MPH, Massachusetts General Hospital, Boston, MA USA

Abstract— **Recent improvements in hardware and algorithms have resulted in human-level machine performance at tasks requiring perception and control of complex systems. AI-enabled image processing tools have resulted in numerous FDA-approved assistive technologies for use by Radiologists and other physicians. However, despite extensive media attention, robust private sector investment, and great interest in the physician community, the adoption of these tools remains modest, with those presently clinical deployed primarily as adjuncts to conventional clinical care. This talk will initially focus on clinical, cultural, and regulatory barriers to the widespread adoption of AI in healthcare and present a framework for engineers to consider when endeavoring to develop AI-enabled healthcare technologies. These ideas will then be extended to the concept of no-human-in-loop automated healthcare. Automated healthcare delivery through AI-guided interventional procedures will be discussed, clinical situations where such technologies may be accepted will be described, and the different and evolving regulatory frameworks that will govern these technologies will be discussed.**

Application of Deep Learning to Ultrasound Image Processing Chain

Viksit Kumar, Ph. D., Massachusetts General Hospital, Boston, MA USA

***Abstract*- Despite the advances made in ultrasound imaging technology it still suffers from various artifacts due to the limitations of both the transducer and the patient physiology. Deep learning provides a powerful tool to create better images with limited resources. The abstract discusses the applications of deep learning at various stages of ultrasound image processing. The attendees will learn about the ultrasound image processing chain, artifacts, and challenges faced in ultrasound imaging and how deep learning can act as a tool to solve various ultrasound image reconstruction problems.**

Constructive Shear Wave Interference (CSI) Imaging to Quantify Skin Sclerosis

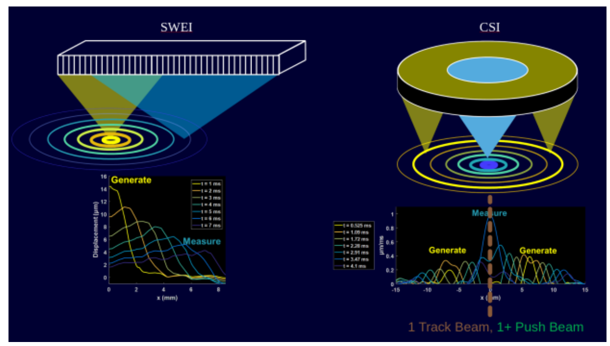
Mark Palmeri, M.D., Ph. D., Biomedical Engineering,
Duke University

Graft-Versus-Host-Disease (GVHD) and morphea are two sclerotic skin diseases that result in skin lesions with higher stiffness, where stiffness correlates with disease progression and severity. Current clinical protocols to score the severity of the skin sclerosis are notoriously subjective and variable, motivating the need for a more robust, quantitative measurement tool to stage disease progression.

Acoustic Radiation Force Impulse (ARFI) and Shear Wave Elasticity Imaging (SWEI) have been studied to quantify skin stiffness and have shown success in differentiated healthy from diseased skin across many anatomic locations [1]. Unlike other relatively large organs that have been clinically studied for ARFI/SWEI stiffness characterization (e.g., liver), skin presents some unique challenges to characterizing shear elasticity. The fibrosis associated sclerotic skin can generate very high elastic moduli, resulting in shear wave speeds that can exceed 5-6 m/s. These relatively stiff tissues limit acoustic radiation force-induced displacements to be single microns and create temporal sampling challenges in tracking the propagating shear waves given limitations in tracking beam pulse repetition frequencies.

We have developed a novel approach to measuring shear elasticity in the skin to help overcome these challenges. While traditional SWEI methods utilize a single acoustic radiation force excitation and track the resultant shear wave at a series of spatially-offset positions, Constructive Shear Wave Interference (CSI) imaging generates acoustic radiation force in a ring, and the resultant shear waves propagate towards the center of that ring, where they constructively interfere (see figure). Using the known radius of the excitation ring, the shear wave speed can be estimated by the arrival time of the shear wave front at the center of the ring, where the displacement amplitude is greatly increased through the constructive interference process, and the arrival time of shear wave is delayed enough to adequately temporally sample.

The feasibility of the CSI technology has been demonstrated *in silico*, and a custom acoustic radiation force excitation ring transducer has been developed with a center tracking piston to validate the CSI technology in tissue-mimicking phantoms of layered media. A clinical study in patients with chronic GVHD is being conducted to demonstrate the clinical utility of this technology and compare it to traditional SWEI methods.



[1] https://doi.org/10.1016/j.ultrasmedbio.2015.06.007

Quantitative Ultrasound and the Liver

Kai Thomenius, Research Scientist, MIT

Diffuse diseases of the liver ranging from steatosis to fibrosis have received an increased amount of attention from researchers working of various aspects of quantitative ultrasound (QUS). These methods range from the application of envelope statistics on B-mode images to estimation of longitudinal speed of sound in the liver for the assessment of steatosis or to spectrum analysis of the RF data for the measurement of attenuation and the backscatter coefficient. This group of methods are distinct from the use of elastography for shear wave speed estimation. This talk will review the QUS methods and look at the possibility of their application to novel liver application such as transplant liver quality assessment.