Original Article

Characterization of limb lymphedema using the statistical analysis of ultrasound backscattering

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Background: Lymphedema is a disease in which tissue swelling is caused by interstitial fluid retention in subcutaneous tissue. It is caused by a compromised lymphatic system. Lymphoscintigraphy is the current and primary modality used to assess lymphatic system dysfunction. Ultrasound elastography is a complementary tool used for evaluating the tissue stiffness of the lymphedematous limb. Tissue stiffness implies the existence of changes in tissue microstructures. However, ultrasound features related to tissue microstructures are neglected in clinical assessments of lymphedematous limbs. In this study, we aimed to evaluate the lymphedematous diagnostic values of ultrasound Nakagami and entropy imaging, which are, respectively, model- and nonmodel-based backscattered statistical analysis methods for scatterer characterization.

Methods: A total of 60 patients were recruited, and lymphoscintigraphy was used to score the patient's clinical severity of each of their limb lymphedema (0: normal; 1: partial lymphatic obstruction; and 2: total lymphatic obstruction). We performed ultrasound examinations to acquire ultrasound backscattered signals for B-mode, Nakagami, and entropy imaging. The envelope amplitude, Nakagami, and entropy values, as a function of the patients' lymphatic obstruction grades, were expressed in terms of their median and interquartile range (IQR). The values were then used in both an independent *t* test and a receiver operating characteristic (ROC) curve analysis.

Results: For each increase in a patient's score from 0 to 2, the envelope amplitude values were 405.44 (IQR: 238.72–488.17), 411.52 (IQR: 298.53–644.25), and 476.37 (IQR: 348.86–648.16), respectively. The Nakagami parameters were 0.16 (IQR: 0.14–0.22), 0.26 (IQR: 0.23–0.34), and 0.24 (IQR: 0.16–0.36), respectively, and the entropy values were 4.55 (IQR: 4.41–4.66), 4.86 (IQR: 4.78–4.99), and 4.87 (IQR: 4.81–4.97), respectively. The P values between the normal control and lymphedema groups obtained from B-mode and Nakagami analysis were larger than 0.05; whereas that of entropy imaging was smaller than 0.05. The areas under the ROC curve for B-mode, Nakagami, and entropy imaging were 0.64 (sensitivity: 70%; specificity: 47.5%), 0.75 (sensitivity: 70%; specificity: 75%), and 0.94 (sensitivity: 95%; specificity: 87.5%), respectively.

Conclusions: The current findings demonstrated the diagnostic values of ultrasound Nakagami and entropy imaging techniques. In particular, the use of non-model-based entropy imaging enables for improved performance when characterizing limb lymphedema.