

Title

Macroscale backscattering analysis for characterization of skin lymphedema considering microscale acoustic and histopathological properties

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Background, Motivation and Objective

Skin lymphedema (LE) with middle severity has tissue properties such as inflammation, fibrosis, and edema. It is assumed that quantitative ultrasound (QUS) parameters have different features related to different backscattering properties between negative and positive LE skin. We aimed to clarify the correlation among QUS parameters, microscopic acoustic properties, and histopathological features to understand the effect of the differences in microscale collagen and elastin fibers for those in the macroscopic backscattering properties.

Statement of Contribution/Methods

Measurement objects were 10 ex vivo human skin samples diagnosed as negative ($n = 5$) and positive ($n = 5$) LE. Three-dimensions radio-frequency (RF) data were collected using the laboratory-made scanner with 15 MHz single element transducer. The backscatter coefficient (BSC) and envelope statistical analyses were applied to estimate integrated BSC (IBS) and scatterer homogeneity parameter of Homodyned-K distribution ($HK - 1/\alpha$) as QUS parameters. Additionally, the cross-sectional samples were observed using the scanning acoustic microscopy system with 80 MHz single element transducer to analyze the acoustic impedance. The number densities of collagen and elastin were computed in the local regions of digital histopathological images with Elastica van Gieson stain.

Results/Discussion

Correlation diagrams between QUS parameters, mean and standard deviation (SD) of the acoustic impedance, and histopathological features are shown in Fig. 1. The medians of QUS parameters show that the positive LE group had lower IBS, $HK - 1/\alpha$, and mean of acoustic impedance than the negative LE group; the difference between their groups is statistically significant ($p < 0.05$). For all patients in negative and positive LE, IBS is positively correlated to the mean of the acoustic impedance ($r = 0.70$, $p < 0.05$) and $HK - 1/\alpha$ is positively correlated to the mean ($r = 0.75$, $p < 0.05$) and SD ($r = 0.73$, $p < 0.05$) of the acoustic impedance. In contrast, there is poor association between QUS parameters and histopathological features. The differences on average and variation of the acoustic impedance are considered to give different backscattering properties more advantage over those of collagen and elastin number densities of skin LE.

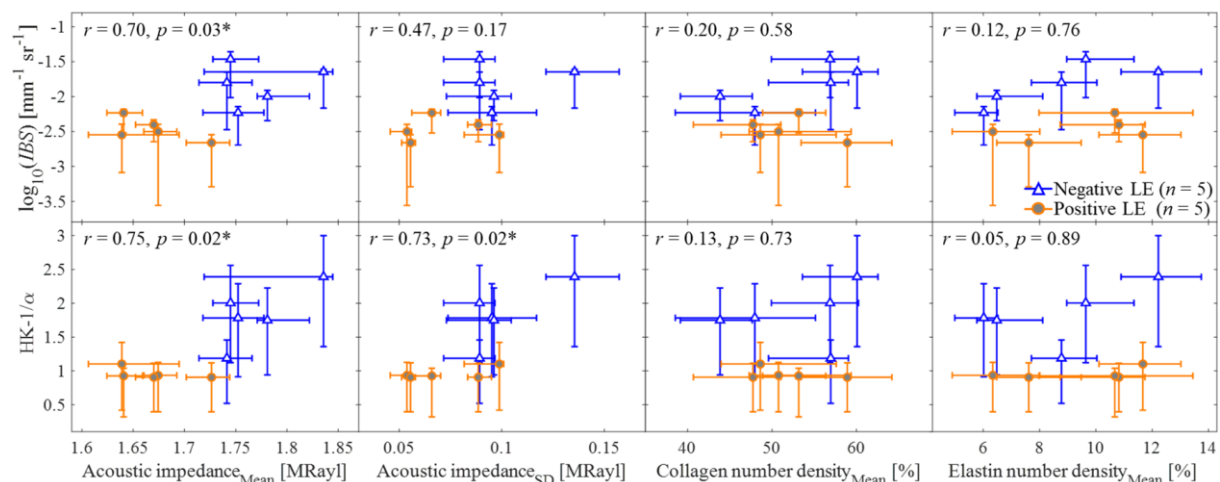


Fig. 1. Correlation among QUS parameters, acoustic impedance, and histopathological features for negative and positive LE dermis. Each marker and error bar corresponds to the median and 25–75 percentiles of each patient data. The Spearman rank correlation coefficient and its p -value were calculated from the medians of all patients for both negative and positive LE ($n = 10$).