In vivo ultrasound scatterer size imaging on liver tumors with a clinical scanner

Wu Liu

Benign liver tumors are common and usually symptom free. The most common type is cavernous hemangioma, which occurs in about 5% of the population. The vast majority of these tumors are small, asymptomatic, and do not require treatment. However, with increasing frequency they are being detected as incidental findings in CT, MRI, and abdominal ultrasound studies, requiring further diagnosis. Their differentiation from malignant liver tumors is difficult without biopsy, so noninvasive differentiation is highly desired.

The specific aim of this thesis is to differentiate between hemangiomas and malignant liver tumors using ultrasound parametric imaging based on scatterer size. Histological specimens show that hemangiomas exhibit significantly larger internal inhomogeneities, likely the sources of acoustic scattering, than malignant tumors. To investigate whether scatterer size imaging can provide this differentiation, simulations, *in vitro* measurements, and *in vivo* studies were conducted.

Scatterer size imaging is done by measuring absolute backscatter coefficients of samples and performing a modified least squares fit between the measured values and scatterer size-dependent theoretical backscatter coefficients. Algorithms for performing this task were developed and factors that contribute to accurate and precise scatterer size images were investigated, as were limitations of currently used clinical scanners when forming parametric images. Performance tests of different spectral estimation methods were done, showing that the Welch method yields the best results when attempting to keep the computational load low. Averaging 7-12 independent samples with 9-15 wavelength axial windows (4-7 pulse lengths) optimized tradeoffs between spatial resolution and signal-to-noise ratio (SNR). Angular and elevational compounding were also used to improve the SNR. Theoretical derivations showed that spectral compounding often performs better than parameter compounding, and this was verified experimentally. Experiments on spectral and scatterer size estimation correlation were performed to determine the best compounding strategy.

Clinically, hemanigomas generally had larger effective scatterer sizes than surrounding normal liver, whereas a malignant tumor had smaller relative scatterer sizes. Combining B-mode features, such as halo, with scatterer size estimates may be helpful to confirm a benign or malignant classification.

Scatterer size imaging using a capacitive microfabricated ultrasonic transducer (CMUT) is also introduced.