Dynamic Testing Characterizes Frequency Dependence of Liver Tissue

The Challenge:

Correlate Elastic Contrast from Imaging to Actual Liver Tissue Mechanical Properties

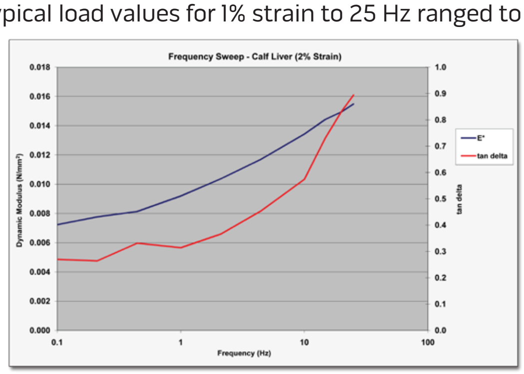
Background

Sonoelastography imaging is being investigated as a method of imaging the creation of thermal lesions induced by high intensity focused ultrasound (HIFU) or radio frequency (RF) ablation. When experimenting with liver tissue, higher frequency vibration (above 300 Hz) did not enhance the contrast of RF ablation lesions. It was hypothesized that viscoelastic effects were the cause of this phenomenon. Since tumor detectability in sonoelastography depends on the elastic contrast between lesion and healthy tissue, it is necessary to determine the frequency response to predict the contrast. Cyclic testing of normal and ablated tissue was investigated as a means of determining the frequency dependence of liver.

Meeting the Challenge

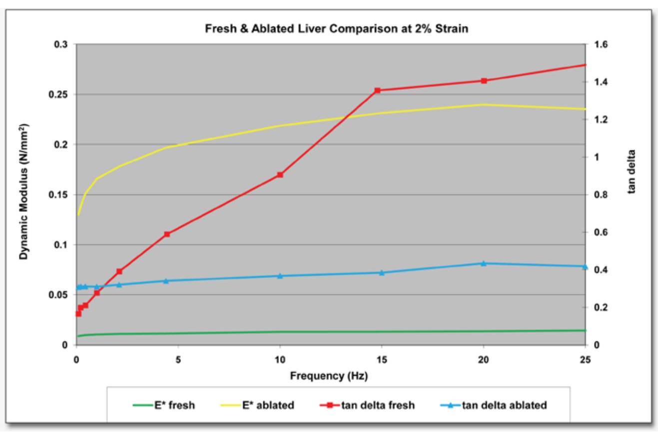
Researchers at the University of Rochester (NY) utilized an ElectroForce® 3200 test instrument to perform uniaxial, unconfined cyclic compression testing. The test system is rated for cyclic testing up to 200 Hz and is ideal for low load testing of soft tissue for determining its viscoelastic properties.

Samples of normal (n=2) and ablated (n=2) bovine liver were tested. All four samples were tested in the range of 0.1 to 25 Hz. The sample geometry was 15 mm x 15 mm x 20 mm high for the normal sample while the ablated bovine liver was cylindrical (15 mm x 20 mm tall). The Bose® DMA software adjusts for various shape factors. Testing also included strain ranges of 1, 2, 5 and 8% strains and frequency sweeps to 200 Hz. Typical load values for 1% strain to 25 Hz ranged to 0.2 N.



Typical modulus vs. frequency curve for 2% strain

The magnitude of the complex Young's modulus was found to fit the Kelvin-Voigt fractional derivative model. This model gives the complex Young's modulus as $E(w) = E_o + h(jw)^a$, where E_o is the Young's modulus at zero frequency, h is the dashpot parameter and a is the fractional exponent. Experimental data was fit to the model to extract the parameters. The two normal tissue samples, from different cow livers, measured E_o = 0.6 kPa, h = 6.35 kPa sec^a, a = 0.17 (1) and E_o = 0.6 kPa, h = 8.5 kPa sec^a, a = 0.09 (2) respectively. Two thermally ablated tissue samples from the same calf liver, measured E_o = 130 kPa, h = 55.5 kPa sec^a, a = 0.29 (3) and E_o = 95 kPa, h = 30.5 kPa sec^a, a = 0.29 (4) respectively.



Dynamic modulus of normal vs. ablated liver

These results show that liver has a frequency-dependent Young's modulus. Future work will involve testing normal and ablated tissue from the same animal so that the lesion elastic contrast can be measured as a function of frequency. This would help determine optimal frequencies for sonoelastography imaging of thermal lesions.

The ElectroForce 3200 instrument is rated for cyclic testing up to 200 Hz. During the testing of sample 1, resonance was observed at 150 Hz. Initially it was believed that this was a resonance in the test system; however, preliminary calculations suggest that the sample itself is resonating. Correct selection of sample size should allow testing in the range of frequencies normally used for sonoelastography.

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