Imaging of nonlinear tissue response using pressure dependent nonlinearity index

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Background, Motivation and Objective

In the range of acoustic pressures used in ultrasound imaging, the waves propagating in tissue are distorted due to the nonlinear properties of the tissue. The adipose tissue exhibits up to two times greater nonlinear behavior than other tissue, so estimating tissue nonlinear properties can potentially aid diagnosis of hepatic steatosis.

In general, the acoustic nonlinearity of media is addressed by using the B/A parameter measured in transmission mode and requiring wide band reception systems. We aimed at estimation of tissue nonlinear properties in echo mode, basing only on the fundamental frequency of the signal (without using harmonics) which allows for better adjustment of the transmit frequency to the probe band.

Statement of Contribution/Methods

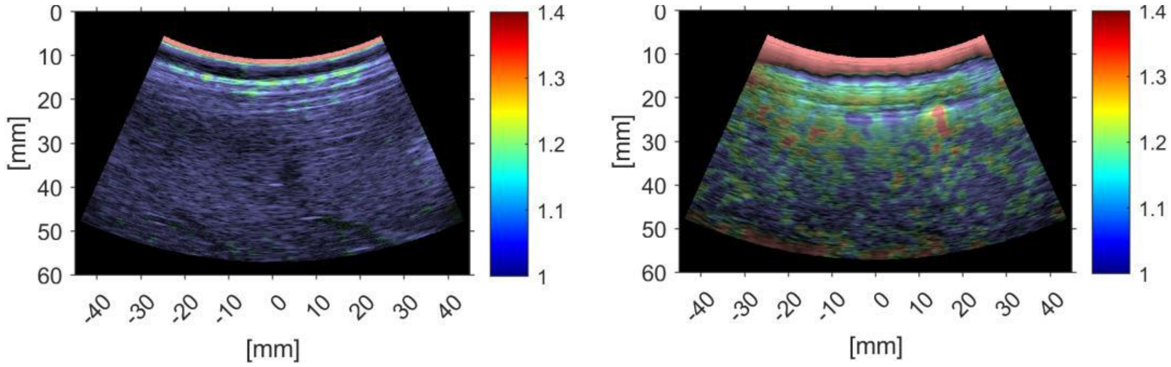
We propose a new simple approach for estimating the non-linear properties of tissue. The proposed method involves acquiring two ultrasound images using scanning beams with significantly different acoustic pressures and recording the echoes only in the fundamental frequency band. The image acquired for lower pressure is then amplified to correct for the pressure difference between the beams. In the last step the non-linearity index (NLI) is estimated as a ratio of local amplitudes of the amplified low-pressure image (ALPI) to the high-pressure image (HPI).

For a linear medium (B/A=0) the two images should be identical (excluding noise), and the NLI is close to 1. In the case of nonlinear media (B/A≠0) some energy of the wave is transferred from the pulse fundamental frequency to higher harmonics, which affects mainly the HPI. With the harmonics being filtered out from the signal, the HPI amplitude becomes lower than ALPI amplitude. As a result, the NLI becomes higher than 1 and increases with nonlinearity coefficient of the imaged tissue.

As an initial validation of the presented approach we performed the NLI imaging of healthy and fatty livers of the authors of this article using us4R-lite (us4us Ltd.) and SonixTouch (Ultrasonix) systems.

Results/Discussion

Preliminary studies on the livers of the authors of the article showed that for "healthy" livers the NLI was below 1.1 (image: left), while in one of the authors with previously diagnosed steatosis at the level of interscore1 and score 2 the NLI locally exceeded 1.3 (image: right). The results confirm the potential usability of the proposed non-linearity index in the diagnosis of hepatic steatosis.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