Sample entropy as an information theoretical approach for ultrasound parametric imaging and tissue characterization

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Background, Motivation and Objective

The ultrasound backscattered signals depend on the properties of the scatterers in the tissue. Several statistical distributions have been applied previously to imaging the backscattered statistics for characterizing tissues. Compared with the distribution parameters, the use of information Shannon entropy does not require the backscattered data to follow a specific distribution, providing a more flexible solution to visualize the statistical properties of ultrasound echoes. However, an accurate estimation of the Shannon entropy relies on enough data length and reliable reconstruction of the probability density function. In this study, we proposed the sample entropy for ultrasound parametric imaging and tissue characterization without needing reconstructing the probability density function and too much signal samples.

Statement of Contribution/Methods

An algorithmic scheme of ultrasound parametric imaging using the sample entropy was designed. Phantom experiments were performed to confirm the optimal dimension and tolerance parameters used for estimating the sample entropy as a function of the number densities of scatterers. To validate clinical usefulness, a total of 204 patients with hepatic steatosis underwent ultrasound examinations using a scanner equipped with a 3 MHz transducer to acquire the image raw backscattered data for sample entropy imaging, which was further compared with the histological findings and conventional Shannon approach. The diagnostic performance was evaluated by the area under the receiver operating characteristic curve (AUROC).

Results/Discussion

The results obtained from the phantoms showed that the sample entropy is able to detect variations in the number density of scatterers when the dimension and the tolerance parameters were set 4 and 0.1, respectively. Using the above algorithmic settings, the performance of ultrasound sample entropy imaging in diagnosing hepatic steatosis (AUROC: 0.82) was superior to that of conventional Shannon entropy approach (AUROC: 0.78). This study is the first to reveal the usefulness of the sample entropy in imaging the statistical properties of backscattered data, affording a new insight into ultrasound parametric imaging based on information theory for tissue characterization.

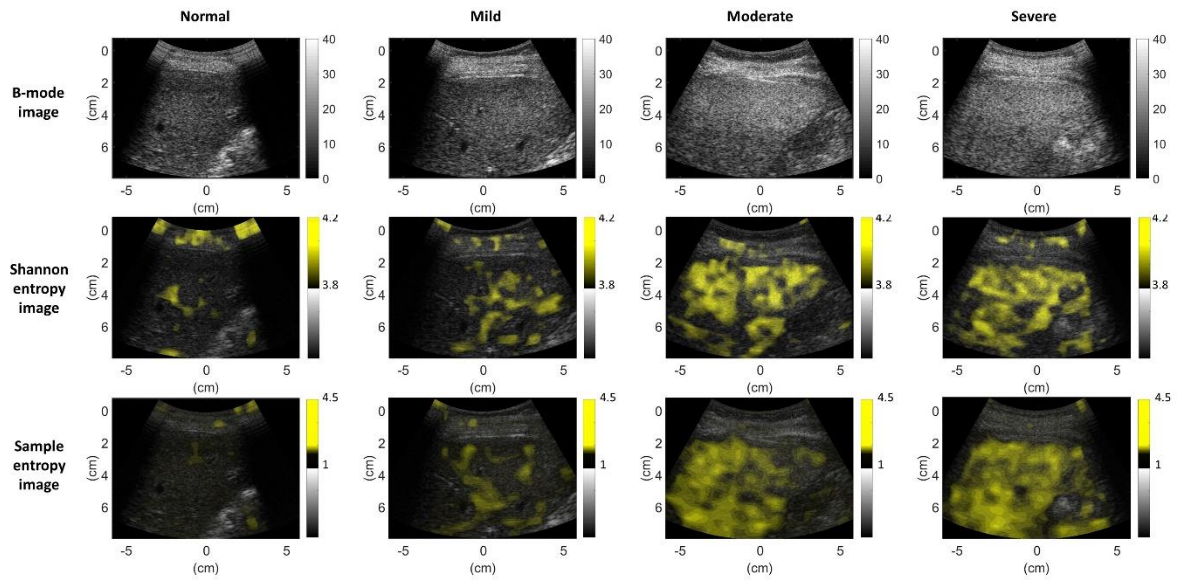

Figure 1. Ultrasound B-mode, Shannon entropy, and sample entropy images of different stages of hepatic steatosis. With increasing the severity of hepatic steatosis, the entropy values increase to represent a more significant signal uncertainty of ultrasound backscattering. Compared with the Shannon entropy, the sample entropy improved the diagnostic performance of parametric imaging in the assessment of hepatic steatosis.