Quantitative ultrasound fat detection using a weight filter and a double Nakagami distribution model

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Background, Motivation, and Objective

We have proposed the double Nakagami probability density function (DN-PDF) model as a quantitative ultrasound (QUS) method for fatty-liver diseases. The DN-PDF results permitted more accurate detection of a moderate fatty liver than the single Nakagami PDF model. However, the estimated fit parameters were less robust when the number density of lipid droplets in the liver were smaller than the luminal structure. In this study, we propose the use of a weight filter to suppress overestimation in healthy livers, thereby increasing detection accuracy.

Methods

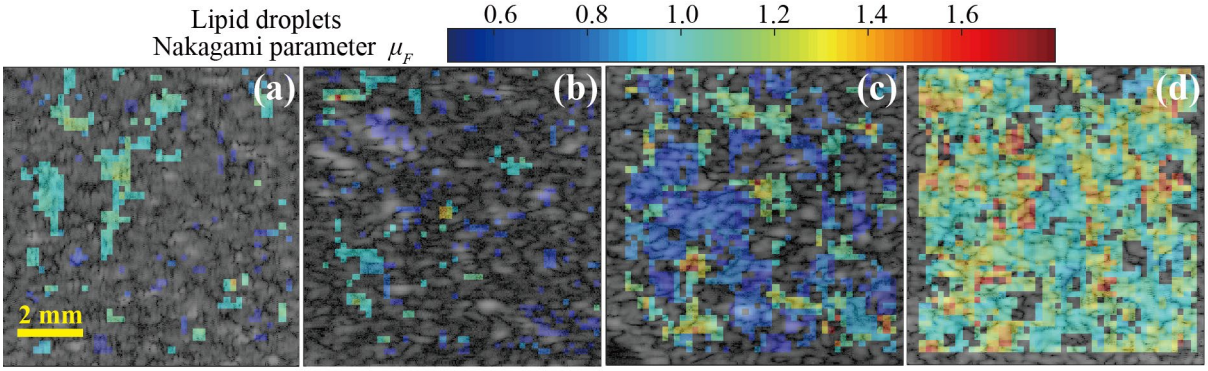
The DN-PDF model assumes that the fatty liver is composed of lipid droplets and healthy liver tissues. The echo data sets were experimentally acquired from excised healthy (0 % of hepatocytes contain lipid droplets), moderately fatty (10 to 20 %), and very fatty (~70 %) rat livers using a 15-MHz single-element transducer. The relationship between the lipid droplet number density and the three parameters of DN-PDF was examined using healthy liver datasets. The weight coefficients for regions having lipid droplets were determined using the control dataset. Especially, the proposed weight filter has a stronger effect in cases where discrimination between lipid droplets and healthy liver tissues is difficult.

Results/Discussion

Figure 1 displays weighted Nakagami parameter images. The uncolored area is estimated to have the characteristic of healthy liver tissues. Comparing each steatosis stage images (i.e. Fig.1 (a) - (d)) shows that the colored area increases with steatosis progression. Nevertheless, a difference exists in the colored area of Fig.1 (b) and (c), despite the fact that both are moderately fatty livers images. This is because the difference in the number density of lipid droplets was directly reflected in the analysis results.

In addition, comparing Fig.1 (c) and (d), both results colored almost all region because of lipid droplets were distributing in the whole liver. The Nakagami parameter of lipid droplets was significantly high in a very fatty liver. This indicates that the number density of lipid droplets is larger in liver shown in Fig.1 (d) than that shown in Fig.1 (c).

In conclusion, the weight filter suppressed overestimation of healthy liver tissues, and allowed quantitatively evaluating the amount of lipid droplets with high sensitivity from an early stage of fatty liver.



Healthy liver	***Moderately fatty liver***	***Moderately fatty liver***	***Very fatty liver***
Steatosis ratio: 0 %	Steatosis ratio: 10 %	Steatosis ratio: 20 %	Steatosis ratio: 70 %
Colored area : 14.2 %	Colored area : 14.4 %	Colored area : 47.6 %	Colored area : 84.2 %

Figure 1 Weighted Nakagami parameter image. (Steatosis ratio was evaluated by a pathologist)