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Comprehensive scattering characteristics analysis of rat livers with high-frequency annular array

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Background, Motivation and Objective

In previous phantom experiments, we demonstrated that a high-frequency ultrasound (HFU, >20 MHz) annular-array probe permitted an extended depth of field (DOF) relative to a single-element transducer for quantitative ultrasound (QUS) analysis. Here, we extend the work by applying the QUS methods, envelope statistics and backscatter coefficient (BSC) analysis, to ex vivo rat liver tissue.

Statement of Contribution/Methods

A 20-MHz annular-array transducer with 5 elements (total aperture: 10 mm, geometric focus: 31 mm) was used to acquire raw RF data from freshly excised, control and fatty model rat livers. The rat livers were placed in a water bath for the scanning. A stack of scan planes spaced at 30-µm between planes was obtained for each transmit-to-receive pair. The RF data were then synthetically focused (SF) in post-processing and then QUS methods were applied. For the envelope statistics, we estimated the shape parameters with the Nakagami distribution. For the BSC analysis, we estimated the scatterer diameter (ESD) using a reference phantom method. The analyses were performed on the interior of each liver. A 3D ROI was defined as a region 3x the -6-dB lateral resolution and 8x the wavelength of the center frequency (540 µm by 600 µm). The results for each liver were compared to the fixed-focus (FF) case with no SF.

Results/Discussion

Figure 1 shows the result of the envelope statistics and the BSC analysis in the control model rat livers. In the parametric images of Nakagami µ [Fig. 1(b)], the small structures such as the blood vessels of the whole liver area in SF case are shown with a low value of µ around 0.5 (yellow). However, in the case of FF, the Nakagami µ contrast in the range of 0.5 and 0.8 was low in the deep part of the liver, known as common liver parenchyma (orange). Similarly, in BSC analysis [Fig. 1(c)], the SF evaluation accuracy in the deep part of the liver was consistent with the shallow part, whereas the accuracy was poor in the deeper part of the liver for the FF case (15.4% improved). Therefore, it was confirmed SF annular array maintained the accuracy to estimate QUS parameters outside of the geometric focal zone when compared with the FF case. HFU annular arrays enable stable QUS estimates over a wide depth range ex vivo.

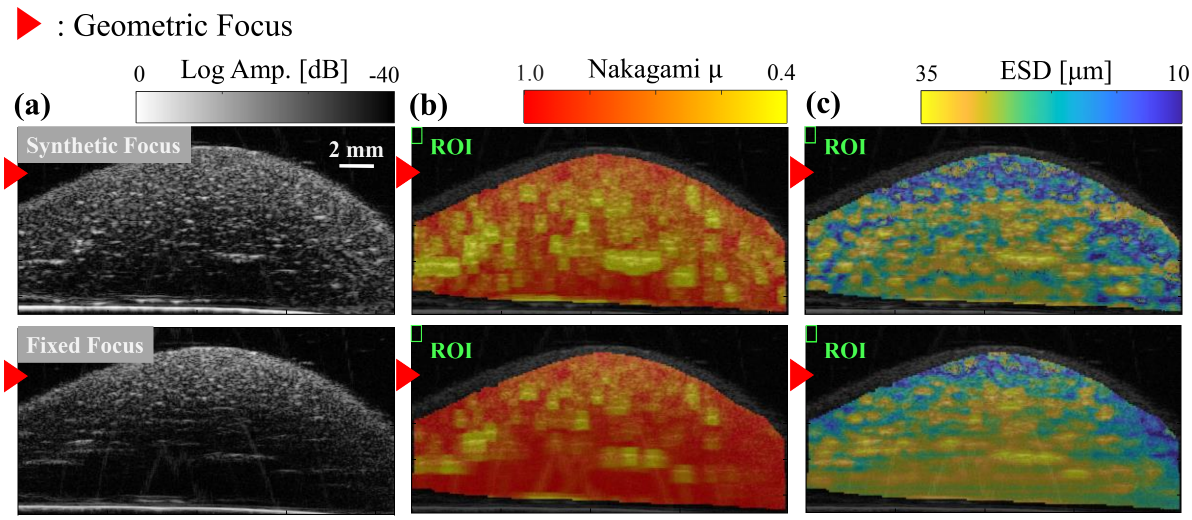

Figure 1: Images of the B-mode images (a), the QUS parameters (µ and estimated scatterer diameter) overlaid on B-mode [(b), (c)].