SUPPLEMENT

Supplementary Material 1

The Theoretical Background of QUS Technique

Tissue Attenuation Imaging (TAI)

Tissue attenuation imaging (TAI) is based on the ultrasound attenuation properties of different frequency components in the tissue. As the attenuation of the higher frequency component is greater than that of the lower frequency component, the power spectrum of radiofrequency signals demonstrates a downward shift of the center frequency according to depth. Assuming a Gaussian-shaped transmit pulse with invariant variance along with the depth, the relationship between the center frequency shift and attenuation coefficient (AC) is given as follows [1,2]: AC (dB/cm/MHz) = $[-8.686/(4\sigma^2)] \times [df_c(z)/dz]$, where z is the depth of the region of interest from the transducer, σ^2 is the variance of the transmit pulse, and fc(z) is the center frequency of the power spectrum at depth z. To create a TAI-map consisting of the local center frequency, the sliding window (3 mm x 1 scan line) technique is applied through the entire radiofrequency signal data with a shift of the one-pixel step, and the local center frequency is assigned to a new pixel located at the center of the window each time.

Tissue Scatter-Distribution Imaging (TSI)

Tissue scatter-distribution imaging (TSI) is a pixel-by-pixel map based on the shape parameter of the Nakagami distribution, and it reflects the arrangements and concentration of the scatterers [3,4]. The Nakagami parameter can be calculated as follows: "Nakagami parameter = $([E(R^2)]^2)/(E[R^4] - [E(R^2)]^2)$," where R and E (·) represent the backscattered-signal envelope and the expected value, respectively. The distribution of the backscattered-signal envelope changed from the pre- to the post-Rayleigh, and the pre-Rayleigh distribution indicated that there are a few scatterers randomly distributed in the tissue. In contrast, the post-Rayleigh distribution indicates that there are periodic scatterers of local high-concentration scatterer aggregation. The Nakagami parameter varied from 0 to larger than 1, as the backscattered-signal envelope changed from the pre-Rayleigh to the post-Rayleigh distribution. Scatter-distribution coefficient at TSI was defined as "Nakagami parameter x 100". To create a TSI map consisting of local Nakagami parameters, the square sliding window (3 x 3 mm^2) technique was applied through the entire envelope image with the shift of a one-pixel step, which assigns a local Nakagami parameter for a new pixel located at the center of the window.