1Pb5-7

Examination of Stability of Backscattering Coefficient Evaluation Under Clinically Applied Transmission/Reception Conditions

臨床応用される送受信条件下における後方散乱係数評価の安定性の検討

Takuma Oguri[1, 2†], Masaaki Omura[3, 4], Wakana Saito[1], Kenji Yoshida[4], and Tadashi Yamaguchi[4] ([1]Grad. School Sci. and Eng., Chiba Univ.; [2]Ultrasound General Imaging, GE Healthcare; [3]Fac. Eng., Toyama Univ.; [4]CFME, Chiba Univ.)

大栗　拓真 [1, 2†], 大村　眞朗 [3, 4], 西東　若菜 [1], 吉田　憲司 [4], 山口　匡 [4] ([1] 千葉大院・融合理工, [2]GE ヘルスケア・ジャパン　超音波製品開発部, [3] 富山大・工, [4] 千葉大・CFME)

1. Introduction

Several *in vivo* experiments to evaluate various tissues, e.g. fatty liver and breast tumor, by evaluating backscattering coefficient (BSC) with conventional linear phased array transducers and ultrasound scanners have been reported [1], [2]. However, the effect of the difference of transmission (Tx)/reception (Rx) conditions for BSC evaluation hasn't been investigated enoughly.

The aim of this study is to confirm the stability of BSC evaluation under clinically applied Tx/Rx conditions. In this report, BSC has been evaluated on two kinds of uniform phantoms, which the diameter and concentration of composed scatterers are different, by conventional low and high frequency phased linear array tranceducers and ultrasound scanner with different Tx/Rx conditions. Evaluated BSC on different Tx/Rx conditions were compared to confirm the stability of BSC evaluation.

2. Materials and Method

2.1 Tissue-Mimicking Phantoms

Two kinds of homogenous phantoms (Target No. 1 and No. 2) which have different scatterer diameters (SD) and concentrations (SC) were created. Each phantom contained spherical scatterers with 20 µm or 30 µm (MX-2000 and MX-3000, Soken, Aichi, Japan) at the concentration of 0.5 wt% or 5.0 wt%. The solution was mainly composed of 2.0 wt% agar (A1296, Sigma-Aldrich, MO, USA) and degassed purified water. A reference phantom was also created with 10 µm spherical scatterers (MX-1000, Soken, Aichi, Japan) at the concentration of 0.5 wt%. The speed of sound (SoS) and AC of each phantom were evaluated with 5.0 MHz single-element transducer (Table I). Theoretical BSC value of each phantom was calculated by Faran model [3].

2.2 Data Acquisition

RF signals for each phantom were acquired by low and high frequency phased linear array transducers with different Tx conditions. A clinical ultrasound scanner LOGIQ S8 (GE Healthcare, Tokyo, Japan) was employed to data acquisition with phased linear array transducers 9L-D and ML6-15-D (GE Healthcare, Tokyo, Japan). The properties of each transducer were shown in Table II. To demonstrate different Tx conditions, different number of Tx elements of 5, 40, 81 and 192 elements with fixed Tx focus depth at 2 cm (Tx condition No. 1) and different Tx focus depth of 1, 2, 4 and 8 cm with fixed 81 Tx elements (Tx condition No. 2) were employed. The PSF in lateral direction at 2 cm depth on Tx condition No. 1 and No. 2 are shown in Figs. 1(a) and 1(b), respectively. The number of Rx elements, Tx waveform and sampling frequency were 192 elements, rectangular 1.5 waves with center frequency of each transducer and 50 MHz, respectively. All phantoms were set in the degassed water at 23 °C during data acquisition.

Table I Properties of phantom

Phantom	SD [µm]	SC [%]	SoS [m/s]	AC [dB/cm/MHz]
Reference	10	0.5	1488	0.12
Target No. 1	20	0.5	1488	0.10
Target No. 2	30	5.0	1511	0.67

2.3 Backscattering Coefficient Evaluation

The reference phantom method [4], using a homogenous phantom which AC and BSC are known, was employed to evaluate BSC with compensating the characteristics of Tx/Rx conditions. BSC was evaluated as

$$BSC(f) = \log_{10}\left\{\frac{S(f,d)}{S_{ref}(f,d)}\right\} + A(f,d) + BSC_{ref}(f)$$

where $S(f)$ and $S_{ref}(f)$ are measured power spectrum of echo signal from a target and the reference phantom at the frequency f, and d is the depth of region of interest (ROI), $A(f, d)$ is attenuation compensation function for a target and the reference phantom [5].

Five times of the PSF in lateral and axial direction at 2 cm depth of each Tx/Rx condition were

Table II Properties of phased linear array transducer

Transducer	Bandwidth (-12 dB) [MHz]	Number of elements	PSF in elevation at 2 cm [mm]
9L-D (1 D)	6.5±2.5	192	4.6
ML6-15-D (1.5 D)	10.0±3.0	336×3 rows	2.3

used for the sizes of ROI in each direction. ROI was scanned in lateral direction with overlapping a half of PSF in lateral direction at 2 cm depth. The BSC was evaluated in -12 dB bandwidth in each ROI position, and mean value in each frequency was calculated. Root mean square error (RMSE) between evaluated and theoretical BSC values was calculated by

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\{BSC(f_i) - BSC_{theoretical}(f_i)\}^2}$$

3. Results

Figure 2(a) and 2(b) show RMSE on Tx condition No.1 and No.2, respectively. On Tx condition No.1, RMSE decreased as the number of Tx elements increased and PSF in lateral direction decreased on all transducers and phantoms. On Tx conditions No. 2, RMSE with Tx focus 2 cm was smaller than other Tx focus conditions as observed in PSF in lateral direction on all transducers and phantoms. The relationship between RMSE and PSF, scatterer diameter and concentration was also observed, since the tendency was observed more significant on ML6-15-D and Target No. 2 than other conditions. Except for RMSE on Tx condition No. 2 with ML6-15-D and Target No. 2, RMSE on ML6-15-D was smaller than 9L-D due to the difference in PSF in elevation direction and the error in attenuation compensation.

4. Conclusion

The dependency on PSF in lateral direction was observed in BSC evaluation by the reference phantom method. The accuracy of BSC evaluation increased when PSF in lateral direction was small. The stability of BSC evaluation was related with not only PSF in lateral direction but also the properties of phantom, i.e. scatterer diameter and concentration.

Reference

1. S. C. Lin et al.: Clin. Gastroenterol. Hepatol. 13 (2015)
2. L. Sannachi et al.: Medical Image Analysis, 20 (2015)
3. M. F. Insana et al.: J. Acoust. Soc. Am. 87 (1990)
4. L. X. Yao et al.: Ultrasonic Imaging 12 (1990)
5. M. L. Oelze et al.: J. Acoust. Soc. Am. 111 (2002)

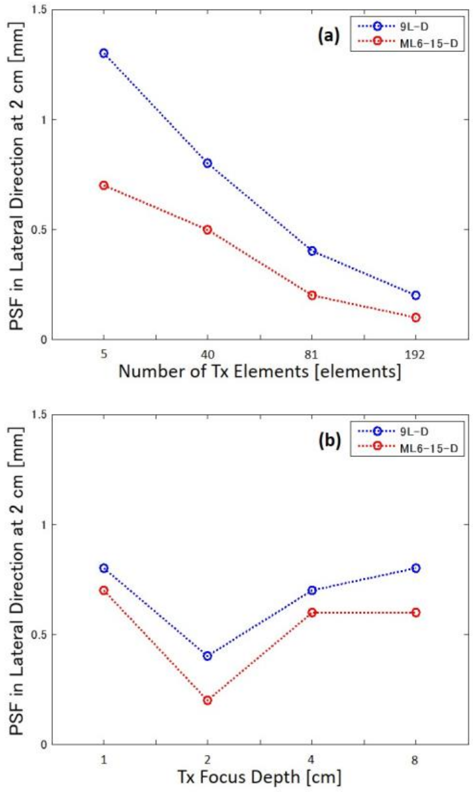

Fig. 1 PSF in lateral direction. (a) is Tx condition No. 1, (b) is Tx condition No. 2.

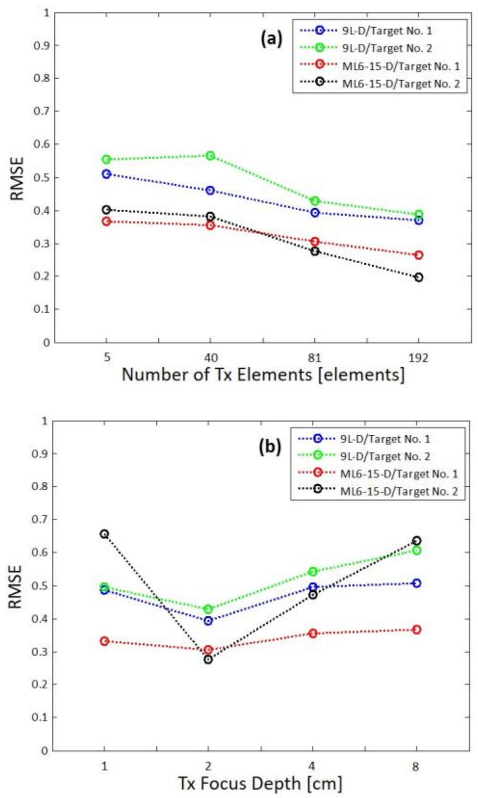

Fig. 2 RMSE at 2 cm depth. (a) is Tx condition No. 1, (b) is Tx condition No. 2.