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Experimental Study of Small Calculus Detection for Medical Acoustic Imaging Using Correlation between Echo Signals

医用超音波イメージングのためのエコー信号間の相関を用いた小結石検出の実験検討

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1. Introduction

The detection of calculi is important for a distinction between malignant masses and benign ones, and therefore the improvement of acoustic imaging in small calculus detection is strongly desired to serve an effective and convenient clinical imaging tool without ionizing radiation[1, 2].

We have reported a novel method to detect small calculi utilizing cross-correlation between RF signals behind the range of a measurement point, and confirmed the effectiveness of the method in a simulation study [3, 4]. In this paper, we investigate the calculus detection method experimentally.

2. Cross-correlation of RF signals behind a measurement point

The proposed calculus detection method employs the cross-correlation of acoustic RF signals behind a measurement point. When a calculus exists in an acoustic beam, the waveform of a transmit wave changes severely. Therefore the echo waveform of a scan line with a calculus is quite different from that without a calculus, where the echoes return from a range behind the calculus. **Figure 1** shows the schema of this process. We can presume the existence of a calculus from a dip in the cross-correlation. In this study we employed a modified Wiener filter to suppress the influence of noise on the cross-correlation coefficients calculated by the proposed method. The cross-correlation value behind a measurement point with the modified Wiener filter is expressed as follows,

$$r(x+\frac{\Delta X}{2},z)=\frac{\left|\sum_{z'=z_1}^{z_2} g(x,z')g(x+\Delta X,z'+L\Delta Z)^*\right|+N}{\sqrt{\sum_{z'=z_1}^{z_2}\left|g(x,z')\right|^2\sum_{z'=z_1}^{z_2}\left|g(x+\Delta X,z'+L\Delta Z)\right|^2}+N}$$

where x and z are the lateral and vertical components of a measurement point on a B-mode image, $g(x,z)$ is the acoustic RF signal at $P(x,z)$, $g(x,z)^*$ is the conjugate of $g(x,z)$, ΔX is the interval of scan lines, ΔZ is the range interval, Z_1 and Z_2 are the minimum and maximum of the z coordinates of a correlation window behind the measurement point $P(x,z)$, N is a constant to raise a cross-correlation coefficient to 1 when the echo intensity cut out by a correlation window is low, and L is equal to l when the correlation coefficient behind a measurement point, $G(x, z, l)$, is maximum.

$$G(x,z,l)=\frac{\left|\sum_{z'=z_1}^{z_2} g(x,z')g(x+\Delta X,z'+l\Delta Z)^*\right|}{\sqrt{\sum_{z'=z_1}^{z_2}\left|g(x,z')\right|^2\sum_{z'=z_1}^{z_2}\left|g(x+\Delta X,z'+l\Delta Z)\right|^2}}$$

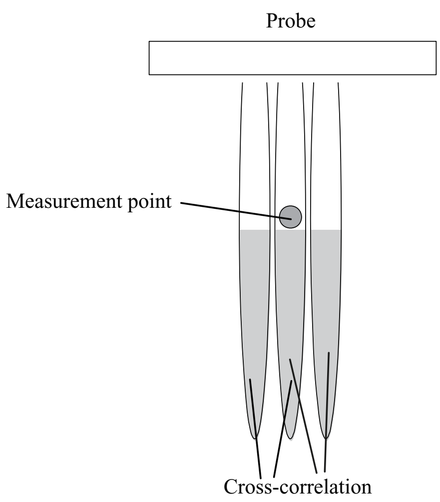

Fig. 1 Cross-correlation between RF signals of adjacent scan lines for calculi detection.

3. Calculus phantom

When a specular echo returns just behind a

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calculus, the calculus is hardly detected in a B-mode image. To evaluate the effect of the proposed calculus detection method in the severe condition, we prepared a calculus phantom employing three different copper wires 0.2, 0.29 and 0.40 mm in diameter, as shown in **Fig. 2**. The wires are embedded in a 4 % agar gel block for a 2 cm depth, and the wire interval is 1 cm. A polyethylene sheet 0.1mm thick is put close behind the wire. Agar gel contained 0.5 % spherical polymer particles 7 μm in diameter (Tech Polymer; Sekisui Plastics Co., LTD.). We utilized RF signals of a medical acoustic imager (EUB-8500; Hitachi Co., LTD.), where the center frequency of a transmit pulse is 7.5 MHz. We set the correlation window as 8.3mm behind a measurement point.

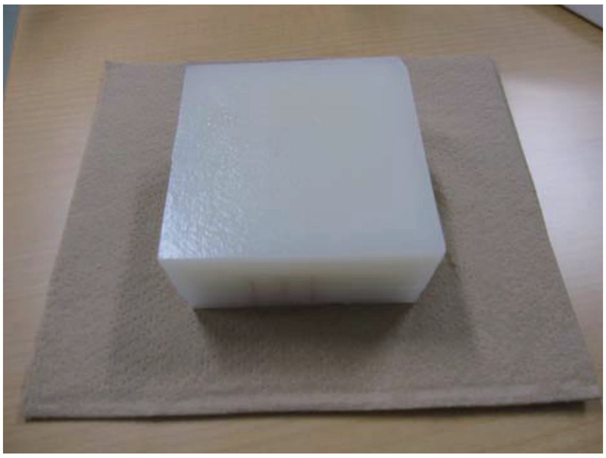

Fig. 2 Calculus phantom used in this study. Three wire targets are embedded in an agar gel.

4. Result

Figure 3 is a B-mode image of the calculus phantom, showing that specular echoes return from a polyethylene sheet behind wire targets. **Figure 4** is the cross-correlation coefficient profile calculated from the RF data of the B-mode image. In the profile two clear dips exist at the points of the center and right copper wires. By contrast, the left copper wire brings an obscure dip. The dips extended along the range direction to the length of correlation window. This result indicates that the proposed calculus detection method has an ability to detect small calculi sensitively.

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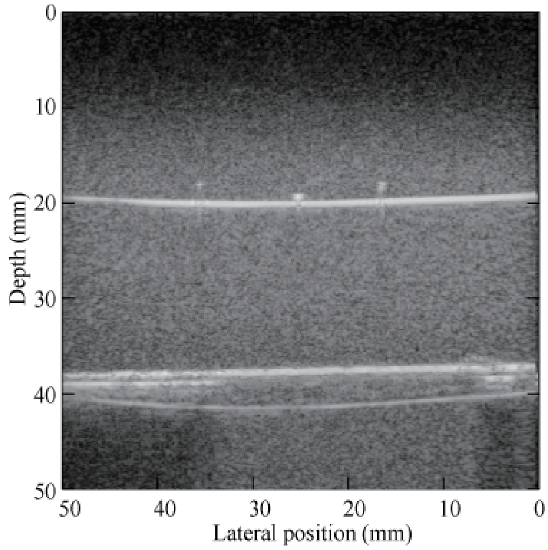

Fig. 3 B-mode image of the calculus phantom.

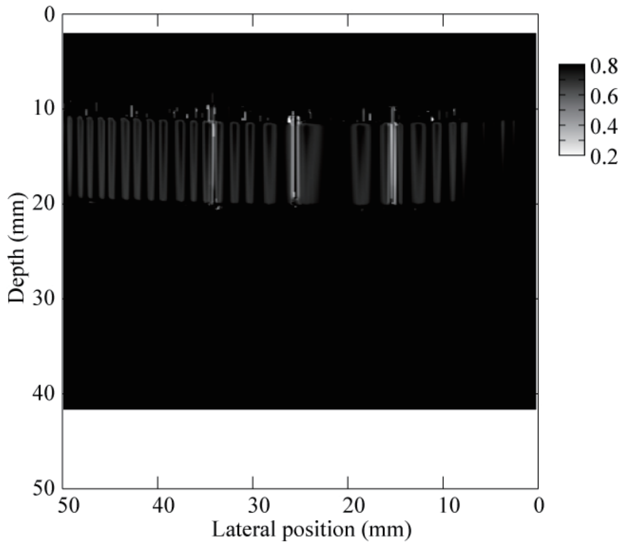

Fig. 4 Cross-correlation profile of a section of an agar gel block with three wire targets. The diameters of wires are 0.2, 0.29 and 0.4 mm in left to right order.

References

1. H. Özdemir, M.K. Demir, O. Temizöz, H. Genchellac, and E. Unlu, J. Clin. Ultrasound., **36** (2008) 16.
2. K.A.B. Fowler, J.A. Locken, J.A., J.H. Duchesne and M.R. Williamson, Radiology, **222** (2002) 109.
3. H. Taki, T. Matsuda and T. Sato, Proc. USE2008.
4. H. Taki, T. Matsuda and T. Sato,Proc. ASJ 2009 spring meeting.