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A Study on Estimation of Reflector Angle to Assist Epidural Anesthesia by Ultrasound

超音波による硬膜外麻酔補助を目指した反射体の角度推定に関する検討

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1. Introduction

In epidural anesthesia, it is difficult to identify the puncture position for the needle, especially in the thoracic spine, because of the complex bone surface structure and the very narrow gap. Although the ultrasound image is used to assist in locating the puncture points, it is not clear. Thus, clearer ultrasound imaging of the bone surface is required. Our previous study proposed the depiction method using different acoustic properties between soft tissues and bone[1)]. As a result, the depiction of bone was successfully enhanced, however, the depiction of muscle tissues still remained. In the present study, we investigated a method to estimate the slope of a reflecting object based on the measured scattering and reflection characteristics to distinguish depictions of bones from muscle tissues.

2. Method

Figure 1 shows the flow to estimate the slope of a target object at a position P(x, z). We take advantage of the difference in the scattering and reflection properties and the inclination dependence of the reflection properties. First, the amplitude on the ideal delay line is extracted from the measured data at each element of the ultrasonic probe before applying the delay-and-sum processing, and the amplitude characteristics $R(\theta; \mathrm{P}(x, z))$ are obtained (①). The angle of the target object is estimated by comparing the obtained characteristic with the scattering and reflection characteristics, $R_{\mathrm{S}}(\theta; z)$ and $R_{\mathrm{R}}(\theta; z, \varphi)$, which were obtained in the water-tank experiments in advance (②). The normalized cross-correlation functions are used for the comparison. When the correlation with the scattering characteristic $R_{\mathrm{S}}(\theta; z)$ is the largest, it is concluded that a scatterer exists at point $\mathrm{P}(x, z)$. When the correlation with the reflection characteristics at $\varphi = \varphi_{\max}$ $R_{\mathrm{R}}(\theta; z, \varphi_{\max})$ is the largest, it is concluded that a reflector with slope $\varphi_{\max}$ exists at $\mathrm{P}(x, z)$. The estimated results are superimposed on each

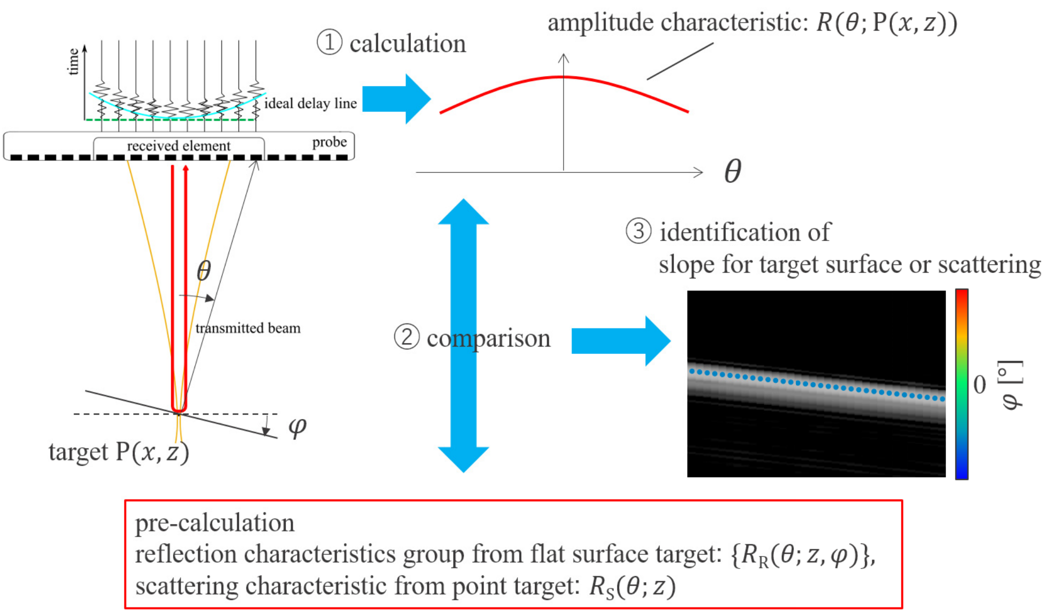

Fig. 1. Flow of estimating the slope of a target object.

point P(x, z) in the B-mode image (③).

3. Experiments in a water tank

Figure 2 shows the schematic view of the water-tank experimental system. The angular characteristics of scattering or reflection were measured. The scattering characteristics were measured for a tungsten wire put up along the y-axis direction. The reflective properties were measured by tilting the acrylic block at every 1° from 0° to -15° to the probe surface. The inclination of the reflector concerning the surface of the probe was defined as φ and the prospective angle from the irradiated point by the transmitted beam on the target surface to each receive element of the probe was defined as θ. The depth of the surface of the target object and the focus of the transmitted ultrasound was set at 30 mm. Focused waves were transmitted with 96 elements. The ultrasound diagnosis apparatus was Prosound α10 (Hitachi Aloka), with a sampling frequency of 40 MHz. A linear array probe with a center frequency of 7.5 MHz, a spacing of 0.2 mm between elements, and a total of 181 elements was used.

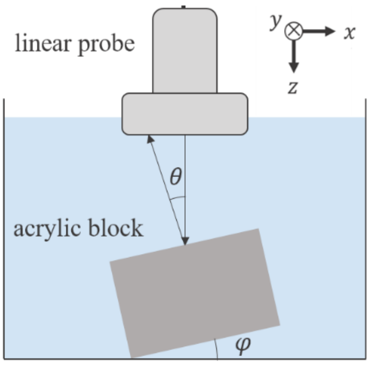

Fig. 2. Illustration of the experimental system.

4. Result and Discussion

Figure 3 shows the results of the scattering and reflection characteristics. The scattering and reflection characteristics are shown with red and blue lines, respectively. The slope of the acrylic block is indicated as the color change from black to blue in the figure. As shown in Fig. 3, the reflection characteristics have a large θ dependence, but the scattering characteristics have a small θ dependence. The reflection characteristics shifted in the θ-axis direction with the change in φ with the relationship of $\theta = 2\varphi$. These features of the angular characteristics of reflection and scattering are used to estimate the slope of an object.

Figure 4 shows the estimated results for an acrylic block surface with $\varphi = -5°$. Figure 4(a) shows a B-mode image of the measured acrylic block, and Fig. 4(b) shows the estimated slope of the acrylic block superimposed on the B-mode image. From the measured B-mode image, the tilt angle of the acrylic block was estimated to be -5.3°. In the present study, the slope was estimated only on the surface of the acrylic block, where the reflected waves could be acquired. The estimated results were roughly -4 ° to -6°. Therefore, we succeeded to quantitatively estimate the reflector angle.

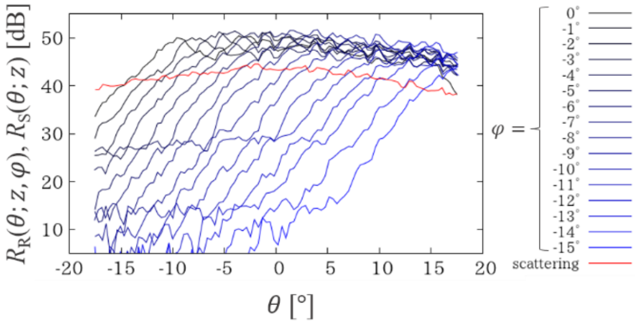

Fig. 3. Reflection and scattering characteristics acquired from a reflector and a scatterer.

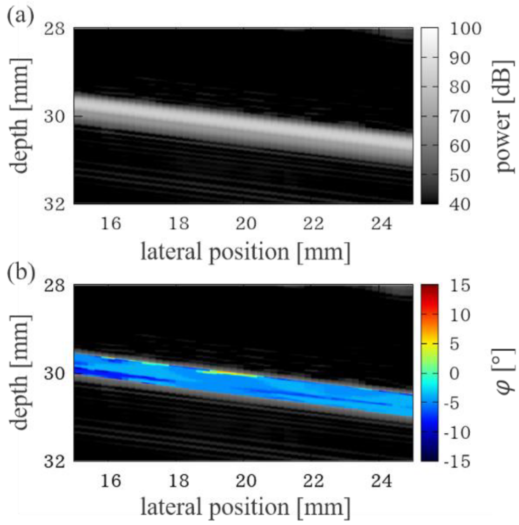

Fig. 4. Results for the acrylic block ($\varphi = -5°$).
(a) B-mode image,
(b) Estimated angles of the object.

5. Conclusion

In the present paper, we discussed the estimation method of the tilt angle of the target object to assist epidural anesthesia by ultrasound. In the basic experiments, the angle of the reflector was estimated almost correctly. The present results would allow us to separate the depiction of muscle tissue and bone. In the future, we apply the proposed method to *in vivo* experiments.

References

1) T. Yokoyama, S. Mori, M. Arakawa, E. Onishi, M. Yamauchi, and H. Kanai: J. Med Ultrasonics, **42** (2019) pp. 3-11.

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