2P5-7

Experimental Study on Reflection and Scattering Characteristics from Bone and Muscle Tissue for Ultrasonic Visualization of Thoracic Surface

超音波による胸椎表面描出のための
骨・筋組織からの反射・散乱特性に関する実験的検討

Tomohiro Yokoyama[1‡], Shohei Mori[2], Mototaka Arakawa[1,2], Eiko Onishi[3], Masanori Yamauchi[3], and Hiroshi Kanai[2,1] ([1]Grad. School Biomed. Eng., Tohoku Univ.; [2] Grad. School Eng., Tohoku Univ.; [3] Dept. of Anesthesiology Tohoku Univ. School of Med.)

横山　智大 [1†], 荒川　元孝 [2], 森　翔平 [2], 大西　詠子 [3], 山内　正憲 [3], 金井　浩 [1,2]
([1] 東北大院　医工, [2] 東北大院　工, [3] 東北大医　麻酔科)

1. Introduction

Epidural anesthesia is local anesthesia puncturing a needle from the spinal gap into the epidural space. Medical ultrasound is used to specify the puncture position, especially in the thoracic spine having narrow gap. However it is difficult to detect the gap from the ordinary B-mode image. In the previous study[1)], we proposed a method of depicting the thoracic spine by the envelope method considering specular reflection of ultrasound at the thoracic spine. However, there is still a problem that fascia existing in the shallower region than thoracic spine is also depicted. In the present study, we investigated the reflected signals from thoracic spine and fascia to distinguish them focusing on the reflection and scattering characteristics of the ultrasound.

2. Method

In the present study, we analyzed the signal measured by each receive element before delay and sum processing, and examined the difference of the characteristics between the scattering in muscle and reflection in bone. We used an ultrasound diagnosis appratus (ProSound α-10, Aloka) and a linear array probe which has the element pitch of 0.2 mm. We set the number of transmit beams, transmit frequency, sampling frequency and focal distance as 181, 10 MHz, 40 MHz and 30 mm, respectively.

3. Experiment and Result

3.1 Pantom experiment

At first, we examined the reflected waves from a plastic plate showing similar reflection characteristics to bone.

Figure 1 shows the received signals obtained from a plastic plate. The black lines show the delay time distributions assuming the scattered waves from a point scatterer. Received signals were obtained at depth of 31.5 mm and 32.5 mm. They

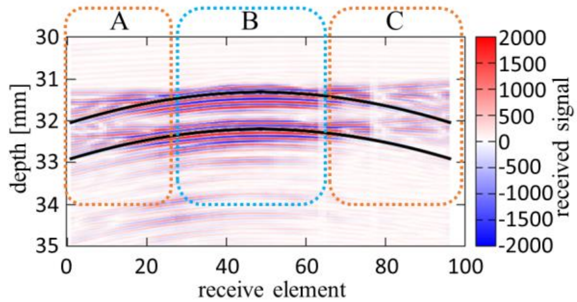

Fig. 1. Received signals from plastic plate.

corresponded to the reflected waves from front and back surfaces of the plastic plate with a thickness of 1 mm. Around the center receive elements (region B), received signals were detected along parabolic delay-time distribution (black line). On the other hand, in the outer regions of their receive elements (regions A and C), the received signals were also detected in shallower positions than the black line. To transmit a focused wave having the maximum intensity at the focal point, ultrasound was transmitted from each element in order from both edges to center. Therefore, when the target object was parallel to the probe, the transmitted wave from the element at the edge was reached to the edge element earlier than that transmitted from the center element. As a result, reflected waves from the edges of the object were earlier than the parabolic delay-time distribution. Thus, it is expected that dispersive parabolic delay-time distribution is observed in the received waves reflected from a planar object like bone.

3.2 Biceps brachii muscle experiment

The muscle structure around the thoracic spine is complicated. So, we examined the characteristics of received waves at the biceps brachii muscle which has simple structure in advance. The measurement surface was set parallel to the muscle fibers.

Figure 2(a) shows the B-mode image of the

t.yokoyama@ecei.tohoku.ac.jp

biceps brachii muscle and Fig. 2(b) shows the received signals for a transmission beam from the center. In the B-mode image, plural linear structures with high reflection intensity were observed in the depth range from 15 mm to 30 mm (blue frame in Fig. 2(a)) and it is considered that they are perimysium. In the received waves from the perimysium, they coincided with the parabolic delay-time distribution. Although the fascia also has a planar structure, dispersion of the received waves from the parabolic delay-time distribution was not observed, because the ultrasound was scattered at each point in the fascia and the phases were not in phase other than the focal point.

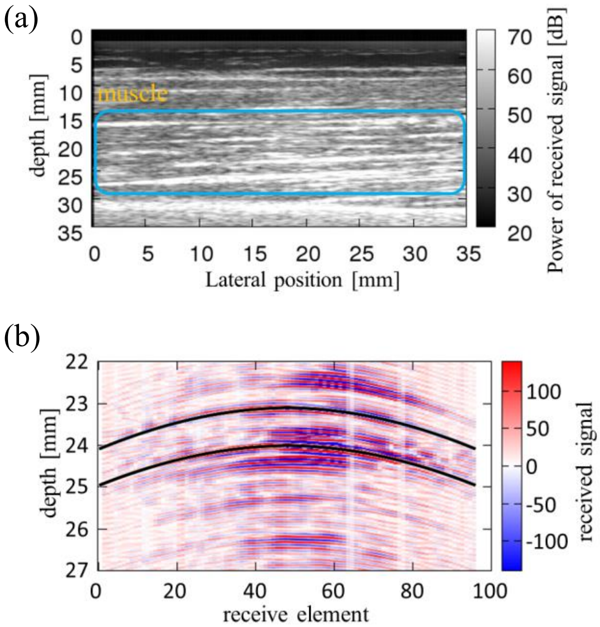

Fig. 2. Received signals from biceps brachii muscle. (a) B-mode image. (b) Received element data at the center transmission beam.

3.3 Thoracic spine experiment

Finally, we examined received waves on the thoracic spine and the muscle tissues existing shallower than it.

Figure 3 shows the received waves from a thoracic spine and muscle tissues. In the muscle tissues (Fig. 3(b)), multiple parabolic delay-time distributions were observed as well as those for the biceps brachii muscle in Fig 2. Therefore, the received signals exhibited scattering characteristics from the muscle tissues. The number of parabolas is less than that in the biceps brachii muscle. On the other hand, in the bone, received signals within the dotted frame in Fig. 3(c) dispersed to a shallower position than the parabolic delay-time distribution. The result was similar to that for the plastic plate. The variation of the delay-time distribution was observed only on the left-side element because the thoracic spine was inclined to the probe surface.

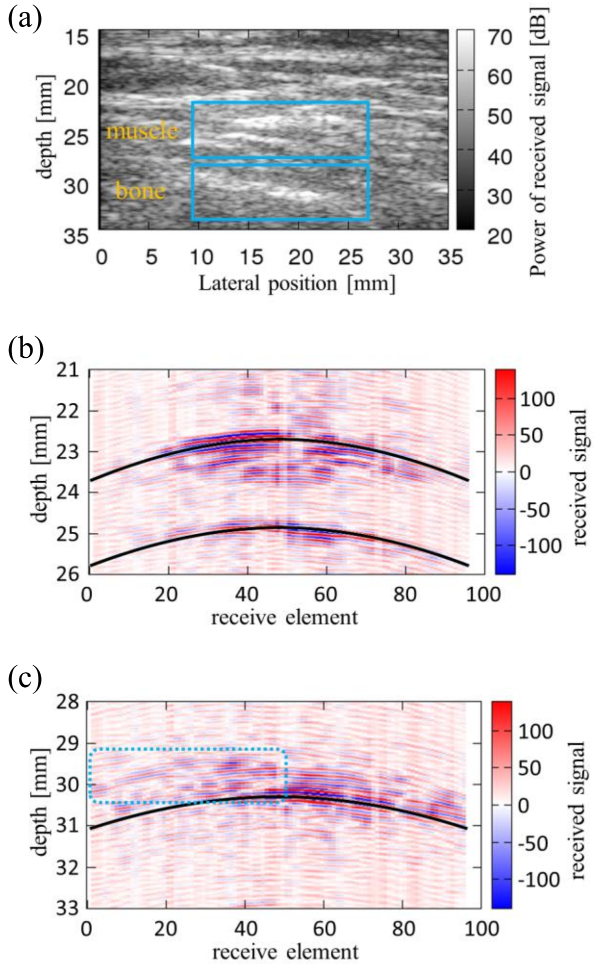

Fig. 3. Received signals from muscle and thoracic spine. (a) B-mode image. (b) Received element data of muscle and (c) Received element data of thoracic spine at the center transmission beam.

4. Conclusion

In the present study, reflection and scattering characteristics of ultrasound from bone and muscle tissues were investigated. The received waves obtained from the muscle tissues had similar propagation delay-time distributions from the point scatterer. On the other hand, the received waves from bone showed a tendency that delay times of received waves dispersed to the shallow position unlike point scattering. This is due to the specular reflection of ultrasound at the bone surface. Thoracic spine and muscle tissue could be distinguished by using the difference between the characteristics of scattering and specular reflection.

References

1. K. Takahashi, H. Taki, E. Onishi, M. Yamauchi and H. Kanai: Jpn. J. Appl. Phys. **56** (2017) 07JF01.