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Basic Properties of Ring-Type Ultrasonic Probe for Biopsy
穿刺用リング型超音波プローブの基礎特性

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1. Introduction

Ultrasonography is widely used for imaging internal body structure or a fetus and is also used in biopsy procedures. The ultrasonic probes usually used in biopsies are either the convex type of probe or the endoscopic ultrasound-guided fine-needle aspiration (EUS-FNA) probe. The convex type is large because it is manipulated in contact with the surface of the body, whereas the EUS-FNA probe is small enough to be manipulated in an endoscope. In abdominal surgery and laparoscopic surgery one needs an ultrasonic probe that is small and can control the position of the puncture needle precisely. In this study, we fabricated a small ring-type ultrasonic probe with a through hole and investigated its basic operation in biopsies while observing the positions of the puncture needle and the lesion in the front of the probe.

2. Experiments using ring-type probe

2.1 Measurement principle

A structure of ring-type ultrasonic probe with a through hole is shown in Fig. 1. The positions of the front object and the puncture needle were determined at the same time by using a pulse-echo technique and a diffraction at needle tip, respectively [1].

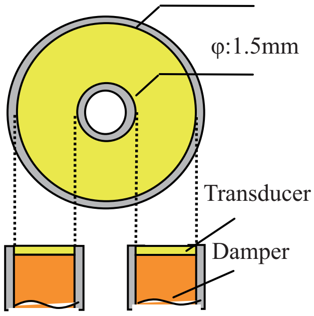

Fig.1 Structure of ring-type ultrasonic probe.

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The ability of the diffraction technique to determine the position of the puncture needle was evaluated experimentally as follows. The intensity of the signal from the inserted puncture needle was measured when covers with various aperture angles were attached to the front of the ultrasonic probe as shown Fig. 2 in order to partially muffle the ultrasonic wave. The relation between the aperture angle θ and the intensity of the signal received from a puncture needle 9 mm away from the probe is shown in Fig. 3.

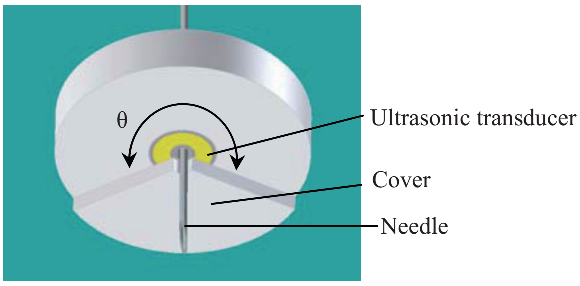

Fig.2 Cover on ring-type probe.

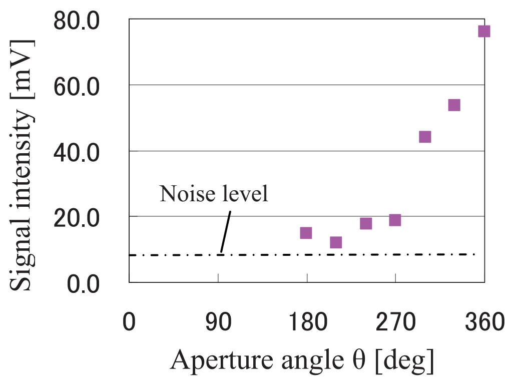

Fig.3 Signal intensity vs. aperture angle θ.

When θ was less than 180° the intensity of the received signal was at or below the noise level, and when θ was 180° or more the intensity of the received signal increased with θ. The results of this experiment confirmed that the wave diffracted from the puncture needle was received at the opposite side against the transmit side of the transducer. This diffraction is used in the Time-of-Flight-Diffraction (TOFD) technique to detect flaws in steel stock or pipes.

2.2 Medical application

The puncture needle was inserted through the ultrasonic probe that was set on a part of the resected stomach wall with a space in water. A paper towel was placed under the stomach wall so that the stomach wall would not float on the water. The signals labeled ①, ②, ③, and ④ in Fig. 4 respectively correspond to the wave reflected from the water-stomach border, the diffracted wave from the puncture needle in the stomach, the wave reflected from the paper towel, and the wave reflected from the bottom of the case. The signal ② was confirmed to be the diffracted wave from the puncture needle because its position shifted as the puncture needle was inserted. The results of this experiment confirmed that the pulse-echo technique can determine the position of the stomach in the front of the probe and that the diffraction technique can determine the position of the puncture needle.

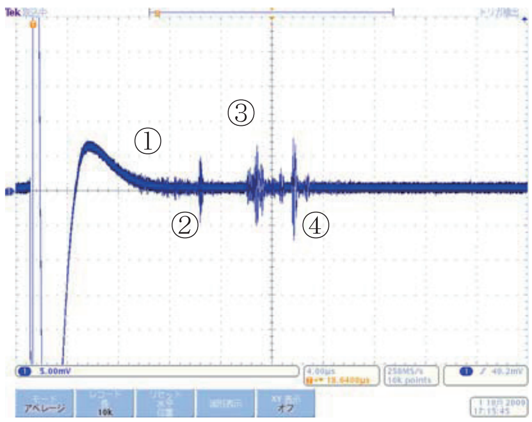

Fig.4 Signals from needle and stomach wall

3. Structure of ring-array-type ultrasonic transducer and results of a preliminary experiment in simulated tissue

To perform biopsies while observing the position of the lesion and the position of the puncture needle, we made an ultrasonic probe consisting of a ring-array-type transducer surrounded by 12 fan-type transducers (Fig. 5). The lesion is imaged by the 12-transducer array, and the puncture needle is imaged by the ring-type probe at the center. The probe was worked by the modified PAL3 pulsar-receiver (Krautkramer Japan, Ltd.). A lesion in normal tissue was modeled by putting 5 mm thick silicone rubber on a layer of agar 1.4 mm thick. When a puncture needle was inserted into the agar the waves reflected from the puncture needle and the border between the agar and the silicone rubber were evident in the B-mode image (Fig. 6).

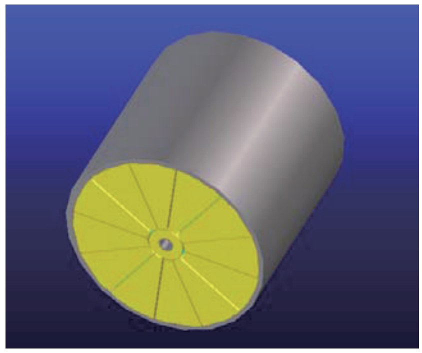

Fig.5 Ring-array-type ultrasonic probe.

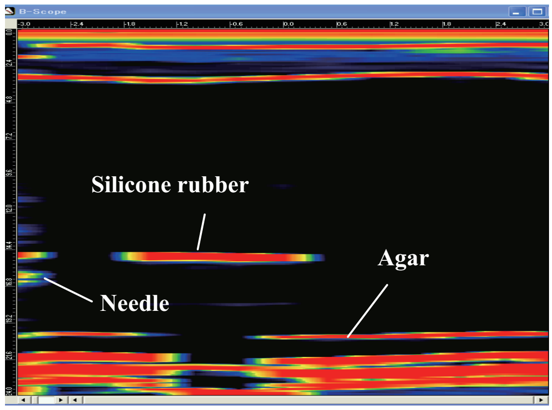

Fig.6 B-mode image of needle and silicone rubber in agar.

4. Conclusion

When a ring-type ultrasonic probe is used during a biopsy the position of the lesion can be determined by using the pulse-echo technique and the position of the puncture needle can be determined by using the diffraction technique. Experimental results obtained using a 13-element ultrasonic probe confirmed that the lesion and puncture needle could be seen at the same time in the B-mode image.

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References

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