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Ultrasound Imaging by Replacing Conventional Ultrasound Jelly with Double-Network Gel for High Image Quality and Low Operator Dependency

ダブルネットワークゲルを用いる高画質･低術者依存性ゼリーレス超音波撮像

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1. Introduction

Among medical imaging modalies, such as X ray CT or MRI, ultrasound has very unique advantages in portability, real-timeness, and non-invasiveness over other modalites. Regarding the portability of ultrasound-imaging systems, imaging can be done by having a small probing device (probe) come into contact with the surface of a region of interest (ROI) coupled with soft meterialas called ultrasound jelly.

We propose replacing ultrasound jelly (viscotic material) with elastic gels. The assumed advantages of using elastic gels are as follows:

1) High image-quality due to improved coupling
2) Operator-independent images due to operator-independent fixed coupling regions and contacting probes.
3) Examinee comfort since there is no need of using sticky (visous) materials on bodies after imaging.

To confirm such advantages, a coupling gel needs to posses enough mechanical strength and acoustic transparency. We found that a double-network (DN) (hydro) gel fulfils this requiremnt.

DN gel has high mechanical strengh due to the interacting of two different gel networks prepared at the same site in sequence [1]. In this study, we used polyacrylamide (PAA) gel and alginate gel to prepare DN gel.

2. Methods

2.1 Gel Preparation.

DN Gel was prepared in accordance with previous studies [1]. PAA gel was first formed in a vessel with a radical reaction, and Alginate gel was formed with ion binding in the same mold. The concentration of PAA and Alginate gels is typically 6 and 0.5%, respectively.

2.2 DN-Gel-Property Measurements.

The mechanical properties (maximum deformation ratio (MDR) and Young's modulus) of the DN gel were measured with a force gauze (ZTA-5N Imada) attached to a stage (MZ2-500N) using samples of the gel of 6×1.5×1 cm. We used MDR as a measure of deformability.

2.3 Ultrasound Imaging with DN Gel

Imaging was carried out with a scanner ARIETTA 850 (Hitachi) equipped with a convex probe (C35) or a linear probe (L64). Imaging targets were abdominal and fetus phantoms (Kyoto Kagaku).

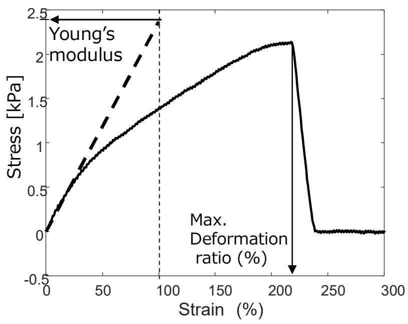

Fig. 1 Typical Stress-Strain Curve of DN Gel

	Water	PAA gel	DN gel	Silicone rubber
MDR (%)	-	35 ±10	210 ±15	> 300
Young's modulus(kPa)	-	2.2 ±0.3	2.4 ±0.6	3.5
Attenuation (dB/MHz)	<0.05	<0.05	<0.05	0.48
Speed of sound (m/s)	1540	1545 ±3	1547 ±3	1025

Fig. 2 Mechanical and Acoustic Properties of Materials

3. Results and Discussion

Figure 1 shows a typical stress-strain curve of the prepared gels along with Young's modulus and MDR. MDR was 221% and Young's modulus was 2.4 kPa.

Figure 2 shows the mechanical and acoustic properties of PAA gel and DN gel (combination of PAA and Alginate). Measured data of water and silicone rubber are also shown for comparison. The

PAA gel posses very similar acoustic properties to water but is not deformable. In contrast, silicone rubber has the opposite properties; acoustic properties are not similar to those of water but it is very deformable. DN gel, unlike the other materials, has similar acoustic properties as water and is about 7 times more deformable than PAA gel. From these results, DN gel was found to be suitable as a coupling medium for ultrasound imaging.

We then conducted experiments to confirm the usefulness of DN gel as a coupling medium for ultrasound imaging with phantoms mimicking organs inside the body.

Figure 3 shows images of a phantom mimicking a human fetus in a pregnant body. Figure 3(a) is the image taken with the conventional ultrasound jelly and Fig. 3(b) is that with DN gel. Figure 3(a), shows the chest of the fetus. On the right side of the image, there is a non-displayed area because the probe we used was canvex and the surface of pregnant abdomen was also convex. Using all the probe elements is very difficult. Figure 3(b) shows the head and chest of the fetus. Due to the deformability of DN gel, all probe elements can be used, and there is no need for additional jelly or liquid.

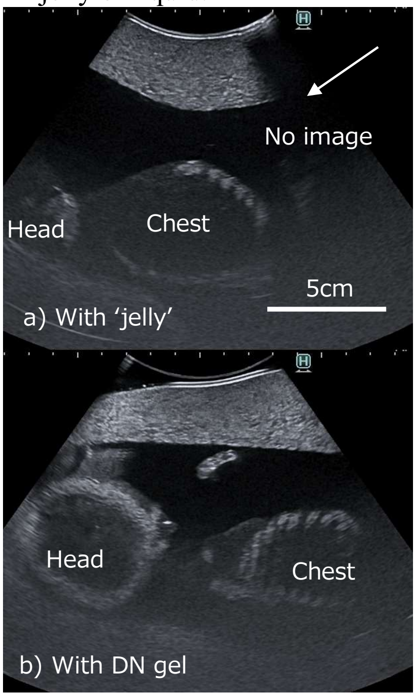

Fig. 3 Ultrasound Image of human fetus phantom a) with conventional ultrasound jelly and b) DN gel

Figure 4 shows images of a phantom mimicking abdominal organs. Figure 4(a) is an image with the conventional ultrasound jelly and Fig. 4(b) is that with DN gel. The imaged site is the liver near the ribcage. In Fig. 4(a), the image quality is very poor because the surface of the ROI is very rough. The main reason of the poor image quality is assumed to be that only a part of each element of the probe came into contact with the surface of the ROI. The DN-gel image has high image quality. Images such as that in Fig. 4(b) are possible with the conventional ultrasound jelly by adjusting the amount of jelly used or probe positioning, but such adjustment requires an experienced operator or extra time. Note that the image in Fig. 4(b) was taken by just placing the probe onto the DN gel without additional adjusting.

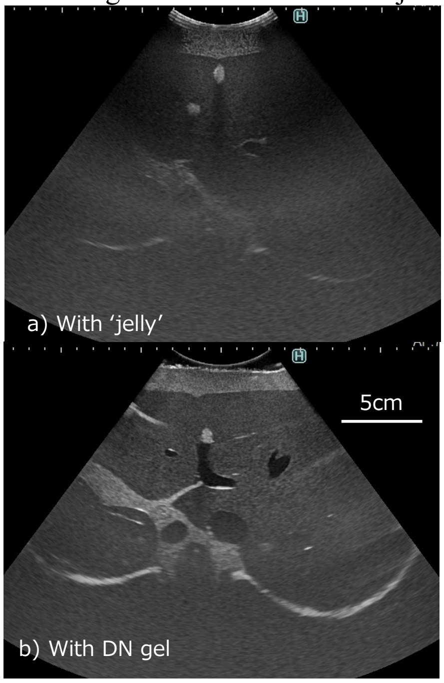

Fig. 4 Ultrasound Image of liver phantom with a) conventional ultrasound jelly and b) DN gel

4. Conclusions

We established a preparation method of highly deformable and acoustically transparent DN gel.

The effect of DN gel as a superior substitute to ultrasound jelly was confirmed.

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Acknowledgments

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References

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