2E2-1

Proceedings of Symposium on Ultrasonic Electronics, Vol. 37 (2016)
16-18 November, 2016

Accuracy Improvement of Multimodal Measurement of Speed of Sound Based on Image Processing
画像処理によるマルチモーダル音速測定の精度改善

Naotaka Nitta[1†], Akio Kaya[1], Masaki Misawa[1], Koji Hyodo[1], and Tomokazu Numano[2] ([1]AIST; [2]Tokyo Metropolitan Univ.)
新田尚隆[1†]，賀谷彰夫[1]，三澤雅樹[1]，兵藤行志[1]，沼野智一[2] ([1]産総研, [2]首都大学東京)

1. Introduction

Since speed of sound (SOS) reflects tissue characteristics and is expected as an evaluation index of elasticity and water content, noninvasive measurement of SOS is eagerly anticipated. However, it is difficult to measure the SOS by using ultrasound device alone, because the ultrasound device measures the time of flight (TOF) as it is well known. Therefore, we have presented noninvasive measurement method of SOS using ultrasound (US) and magnetic resonance (MR) images. This method determines the longitudinal SOS based on the thickness measurement using the MR image and the TOF measurement using the US image, as follows.

$$C_{vivo} = 1530 \times \text{MR-thickness} / \text{US-thickness} \quad (1)$$

The accuracy of SOS measurement is affected by the accuracy of image registration and the accuracy of thickness measurements in the MR and US images. This study addresses the accuracy improvement in the latter thickness measurement, and presents a image processing-based method for improving the accuracy of thickness measurement. The method was investigated by using in vivo data obtained from the tissue-engineered cartilage implanted in the back of rat.

2. Materials and Methods

All animal procedures were approved by the Animal Care and Use Committee of our institution. 12- and 18-week-old male F344/NJcl-rnu/rnu rats were used. In the back of rat, the different type of tissue-engineered cartilage (#1 to 5, n = 6 for each type) was subcutaneously implanted. Under anesthesia, MR and US images including same cross-sections were acquired separately, by using a 2.0-T Biospec 20/30 System with a B-GA20 Gradient System (Bruker, Karlsruhe, Germany) and an ultrasound diagnosis device (Hitachi, EUB-8500, Japan) with a center frequency of 13 MHz, as shown in **Fig. 1**.

n.nitta@aist.go.jp

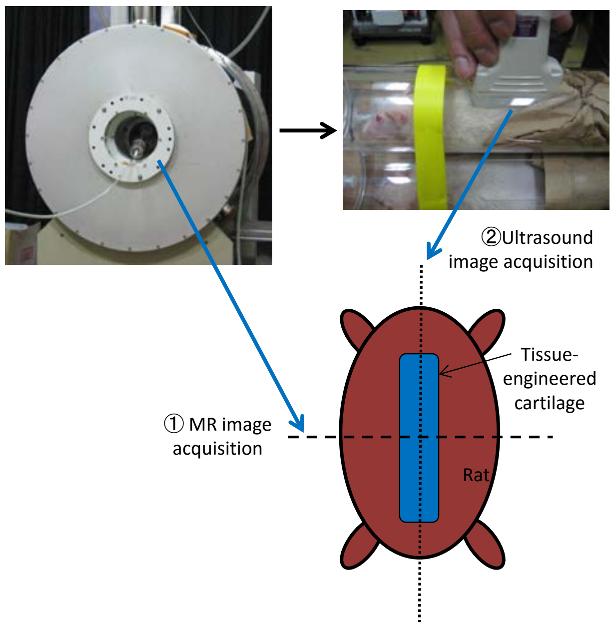

Fig. 1 Setup for acquiring images by using MRI and US devices.

3. Accuracy Improvement Based on Image Processing

Figure 2(a) and (b) show the T2-weighted MR image and the profile determination process for thickness measurement in the MR image. **Fig. 2**(b) is a sinogram, which is obtained by rotating profiles passing through the center of cartilage in the MR image. Here, high-contrast and horizontal band region around "Center" corresponds to the cartilage region. After obtaining the sinogram, a rotation angle is determined so that the thickness of cartilage is minimized, and then a profile for thickness measurement in the MR image is determined as shown in **Fig. 3**.

On the other hand, as shown in **Fig. 2**(c), the boundary of cartilage in the US image is unclear. Therefore, the displacement difference between skin and cartilage when the US probe moves on the skin laterally was utilized for the boundary detection. The displacements of skin and cartilage on the US image were measured by the sum of absolute difference (SAD) method, and traced and accumulated. As the result, the cartilage region is detected as large displacement and high-contrast region, as shown in **Fig. 2**(d). **Fig. 3** also shows the profile extracted from the accumulated displacement image shown in **Fig. 2**(d). The cartilage region was clearly extracted from the US images. Here, profiles of **Fig. 3** were interpolated and their amplitudes were normalized with the maximum amplitudes. Finally, the SOS is determined by the ratio of full width at half maximums (FWHMs) of profiles shown in **Fig. 3**.

Figure 4(a) shows comparisons of SOS measurement accuracy. Here, "manual" means the SOS measured by manual boundary detection, "auto" means the SOS measured by the proposed method, and "vitro" means the SOS measured by pulse transmission method in the extracted cartilage tissue. "T1", "T2", and "ADC" mean that T1-weighted, T2-weighted, diffusion weighted images are used as the MR image, and "ALL" means the average of these three results. **Figure 4**(b) shows errors of in vivo SOS measured as "manual" and "auto" to in vitro SOS. As the result,

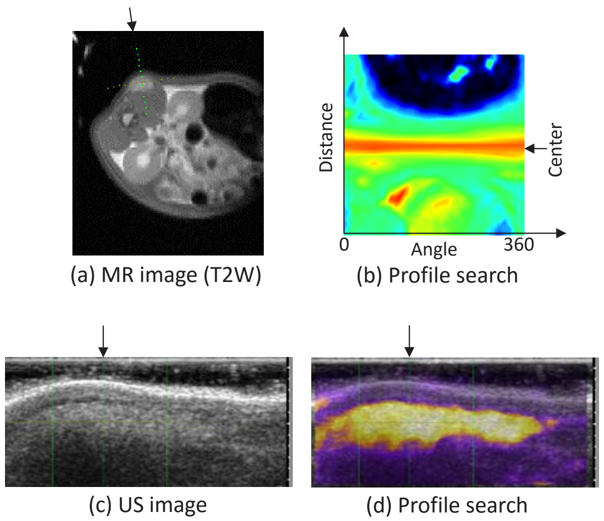

Fig. 2 Thickness measurement on the MR and US images.

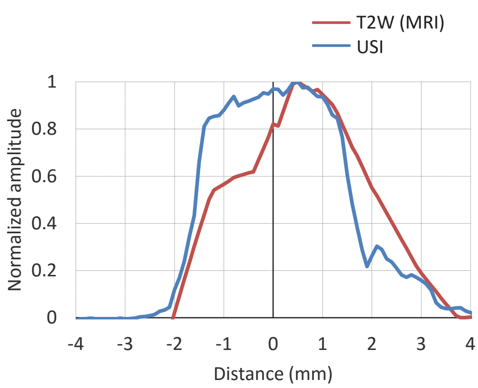

Fig. 3 Comparison of profiles obtained from the MR and US images.

the proposed method substantially reduces errors of in vivo SOS measurement.

4. Conclusion

In this study, accuracy improvement of multimodal measurement of SOS was investigated by using the data of tissue-engineered cartilages, and achieved by modifications of image processing for thickness measurements. As a future work, the accuracy improvement will also be investigated in the more general conditions.

Acknowledgment

This work was supported by JSPS KAKENHI Grant Number 16K01432

References

1. T. Aoki T, N. Nitta, A. Furukawa: Radiol. Phys. Tech. **6** (2013) 480.
2. Y. Fujihara, N. Nitta, M. Misawa, K. Hyodo, Y. Shirasaki, K. Hayashi, R. Kosaka, K. Homma, T. Numano, S. Kuribayashi, Y. Watanabe, J. Sato, K. Ohtomo, T. Takato, and Hoshi.: Tissue Eng. Part C: Methods. **22** (2016) 429.

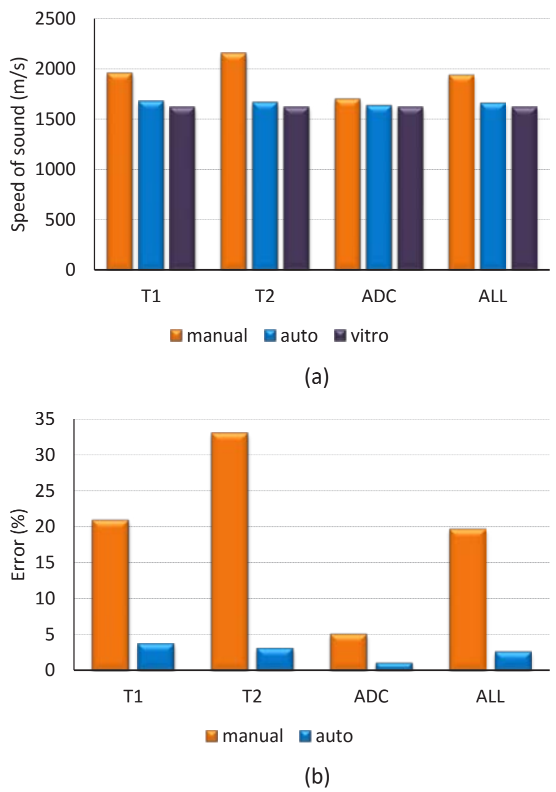

Fig. 4 Comparisons of SOS measurement accuracy. ("manual": SOS measured by manual boundary detection, "auto": SOS measured by the proposed method, "vitro": SOS measured in the extracted cartilage tissue.)