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Structure extension of 3D liver blood vessel with multiple ultrasound volumes and comparison with MRI
複数の超音波ボリュームを用いた 3 次元肝臓血管の構造拡張と MRI との比較

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1. Introduction

Recently, drug delivery systems (DDS), which aim to deliver and concentrate drugs to target areas in the human body, have been recognized as a new therapy method with reduced side effects. Our group has been developing a method of ultrasound DDS involving the physical control of microbubbles containing drugs through blood vessel in an internal organ using acoustic radiation force [1,2]. To apply this technique in a clinical situation, an intraoperative navigation system for the visualization of blood vessel network (BVN) in the body, as well as accurate positioning of ultrasound transducers on the body surface, is indispensable. Although many preceding studies have reported the reconstruction and classification of human blood vessels using CT or MRI data [3-5], the use of them is limited due to the deformation of the shape of BVN between the acquisition of images and the operation. Therefore, we have developed a therapeutic system using ultrasound alone, which includes the three-dimensional fusion imaging between B- and Doppler modes [6], and the spatial extension to obtain wider BVN using multiple volumes [7]. In this study, we attempted to validate the extended BVN by comparing with not only multiple ultrasound volumes but also MRI data of an identical subject.

2. Methods

After the fusion between B- and Doppler modes [6] and the spatial extension using multiple volumes [7] were applied, the centerline of obtained BVN was extracted to define the similarity between them. Then the common bifurcation points were chosen using the spatial registration method [6,7] to evaluate deformations between them as shown in **Fig. 1**. The Euclidean distances d_1, d_2,.. between the corresponding bifurcation points in the two trees of BVNs were measured to calculate the average distance, which is defined as eq. (1), where *num* represents the total number of corresponding bifurcation point between two BVNs.

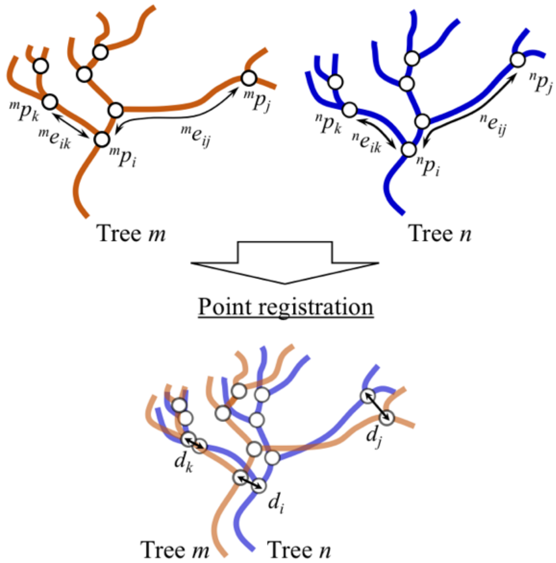

Fig. 1 Comparison between two blood vessel networks using spatial point registration.

$$d_{avg} = \frac{\sum(d_1 + d_2 + d_3 + \cdots + d_{num})}{num} \qquad (1)$$

We used an echography (Philips EPIQ Elite) with a three-dimensional probe (X6-1) to obtain multiple volumes to cover larger liver region from several different directions, including intercostal and sub-rib bows. The imaging conditions for ultrasound volumes were B-mode Gain = 60%, Doppler mode Gain = 45%, Depth = 100 mm, Mechanical Index = 1.0. The subject was a healthy female of 52 y.o. and ordered to lie in two different positions: Dorsal position and Left position. Regarding the respiratory state, the subject was ordered to exhale or inhale most deeply during the image acquisition time of about 10 seconds, where we defined the four situation of the subject's body position and respiratory state as shown in **Table I**.

Table I Definition of four situations.

	Exhaled state	Inhaled state
Dorsal position	DE	DI
Left position	LE	LI

3. Results

First, we reconstructed four BVNs corresponding to Table I using maximum 4 volumes including portal vein and hepatic vein. Common bifurcation points were extracted by analyzing tree structures to apply to spatial registration. **Fig. 2** shows the structures of extended BVNs and their superimposition, where the deformation of the BVN was visually suggested.

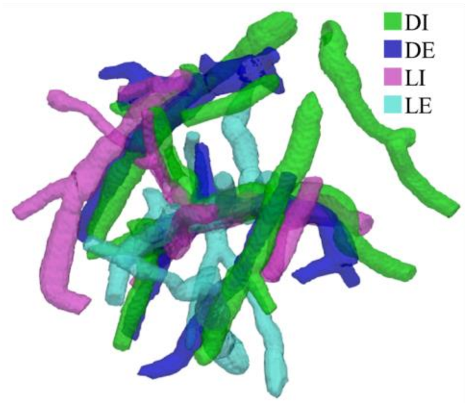

Fig.2 Comparison of ultrasound BVNs in four situations.

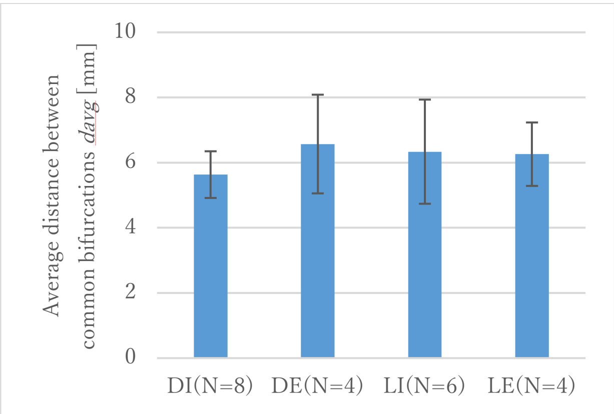

Fig.3 Comparison of average distance of common bifurcation points between the BVNs of extended ultrasound and MRI.

Fig. 3 shows a comparison of d_{avg}, which was calculated between each ultrasound BVN and that extracted from MRI, where *N* indicates the number of common bifurcation points. Although there was not so much difference among four situations, d_{avg} of DI shows the best similarity compared with MRI. **Fig. 4** shows the structural comparison between extended ultrasound in DI situation and MRI, where the correlation between them was qualitatively reliable except thinner blood vessels. **Fig. 5** shows a superimposed tree graph between DI of ultrasound and MRI as an alternative structure comparison. Because of the correspondence in upper bifurcation points, we confirmed a potential of the proposed method of structure extension using ultrasound volumes.

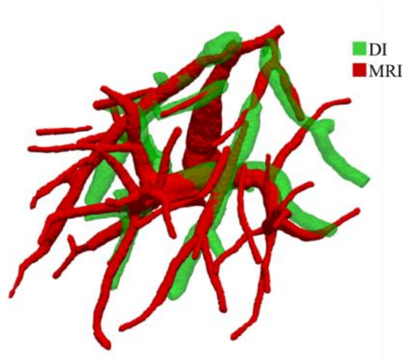

Fig.4 Comparison of BVNs between MRI and extended ultrasound volumes.

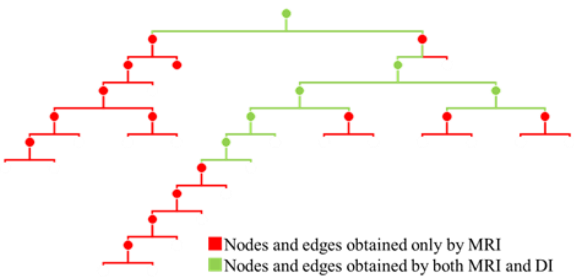

Fig. 5 Comparison of structure as tree graph between extended ultrasound of DI situation and MRI.

4. Conclusions

We have developed and verified the structure extension method of blood vessel network using multiple ultrasound volumes by comparing with MRI data derived from the same subject. We are going to enhance the accuracy in thinner blood vessel by improving the extension method.

References

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