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A 3D Ultrasound Image Tracking of Brachial Artery for Flow-Mediated Vasodilation Analysis
３D 超音波像における血管追跡処理の FMD 検査への応用

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1. Introduction

The image registration and tracking in an ultrasound image sequence are important for a more effective assessment of the reaction of a living body in time series, sequential changes of lesioned part, therapeutic effects, and so on.

The 3D image registration and tracking have been received attention in the field of CT, MR, and PET and have been used widely in clinical. However, in the field of ultrasound, a few studies have been conducted although ultrasound is the useful diagnostic imaging device.

Recently, probes which are able to continuously obtain 3D volume images are developed. Therefore, it is thought that the 3D registration of ultrasound images have been received more attention hereafter.

In this paper, we focused on the Flow-Mediated Vasodilation (FMD) exnamination[1)] as an example of 3D registration application. According to the FMD examination guidelines[1)], a maximum long axis view of a brachial artery should be used and its diameter is measured at the same position. Therefore, a 3D probe and the 3D registration may be a useful tool for the FMD examination.

2. Materials and Method

A 3D ultrasound image sequences were obtained from a healthy normal subject (male, 50 years old, one of the authors) by using LOGIQ7 ultrasound system (GE Healthcare). Its 10MHz 4D10L probe, which could obtain volume sequence data by mechanically scanning 1D linear transducer, was employed.

In the FMD examination, the diameter of the brachial artery is continuously measured before and after avascularization performed by applying sphygmomanometer cuff to arm.

Following the FMD examination guidelines, B-mode ultrasound image sequence was acquired. The brachial artery was imaged at the antecubital fossa. Unlike a conventional method, only the 3D probe was fixed lightly with a clamp stand during the examination, and 3D image sequences were obtained. In the first step, rest images were recorded for about 15s as a baseline. In the next step, the cuff was inflated and was kept for 5min till the cuff deflation. Then, the recording of 3D images of artery was started from 30s before the cuff deflation and lasted for 5min. This scan protocol was performed several times. Each image sequence had about 850 volumes (about 2.8 volume/sec), 142 x 106 x 171 matrix size, and about $(0.2\text{mm})^3$ voxel size.

Time changes of the diameter was obtained in three steps. In the first step, the 3D registration in time series was performed in order to remove misalignment occured by the motion of the arm or the probe. In each sequence, a template volume of a part of the brachial artery was manually selected from an arbitrary volume. All the other volumes were registered to this template volume. In this paper, only the translational ajustment was considered. The normalized correlation was used as the metric in the registraion.

In the second step, a 2D tracking of the arterial wall was done. Firstly, a cross section of the maximum long axis view of the brachial artery was selected manually from an arbitrary volume in the registered 3D image sequence, and applied the section to the other volumes to acquire the 2D image sequence of the registered maximum long axis view of brachial artery. Secondly, the 2D image sequence was magnified by 5 times for obtaining tracking results in higher resolution. Finally, the upper and lower arterial walls were tracked by template matching to all the other frames in the 2D sequence, where the part of the each wall was manually selected as a template from an arbitrary frame in the 2D image sequence. The normalized correlation was used for the matching metric.

In the final step, the diameter of the brachial artery was measured using the coordinate of the arterial wall in the tracking result.

3. Result

The diameter measurement process was performed well in all scans. The results of each sequence were very similar in all trials. Therefore, one of them was shown in **Fig. 1**.

Figure.1 (a) and (b) show images of before and after registration respectively. The left two columns show the B-Mode long axis view of the brachial artery taken at two different time points. The long axis view was obtained from the 3D image. The right column shows virtually reconstructed M-mode image from the 3D sequence at the yellow line on the B-Mode images. In the B-Mode images of (a), the rumen of the right image is not clear, and different from the left. In (b), the right image is similar to the left. In the M-Mode image of (a), several blur are shown at the part of the rumen.

The measured diameter of the brachial artery in the sequence was plotted in **Fig. 2**. Both of the plot (a) and (b) start to increase gradually after cuff release, and to reach the peak at about 50s after cuff release. The plot of (b) is a smooth curve, on the other hand, (a) has sudden rises and falls.

The value of %FMD defined as

$$\%FMD = \frac{[\text{Maximum diameter}] - [\text{baseline diameter}]}{[\text{baseline diameter}]} \times 100\%$$

was 7% for this sequence. This is within the normal range.

4. Discussion

The FMD examination requires the diameter measurement at the same position. Therefore, in the conventional method, the tight fixture of the subject's arm and of the probe is necessary. However, if 3D imaging and post process of 3D registration are used, the tight fixation is not necessary because it is possible that all points in the object are registered as long as the object is included in FOV of the probe.

The arterial rumen on the M-Mode image after registration (Fig. 1 (b)) is more stable than before registration (Fig. 2 (a)). Due to this stability, it was possible to obtain 2D image sequence which includes the maximum long axis view and the same position of the brachial artery.

According to the FMD guidelines, the diameter of the brachial artery starts to increase gradually after cuff release, and to approach the peak at from 45s to 60s after cuff release. After that, it decreases to baseline which is a diameter of the brachial artery at rest. The curve in Fig. 2 (b) shows the tendency of that though the peak is not very clear.

To compare the plot of Fig. 2 (a) and (b), the plot in Fig. 2 (b) shows the curve which has less dispersion than (a). This is owing to registration, therefore, registration was effective in FMD examination.

5. Conclusion

In this experiment, proper time-diameter curve was obtained without tight fixation like the conventional method.

The possibility of applying the 3D registration to FMD examination was shown in this paper. It is expected that the 3D registration of the ultrasound images is might be a useful tool in many clinical situations.

6. Reference

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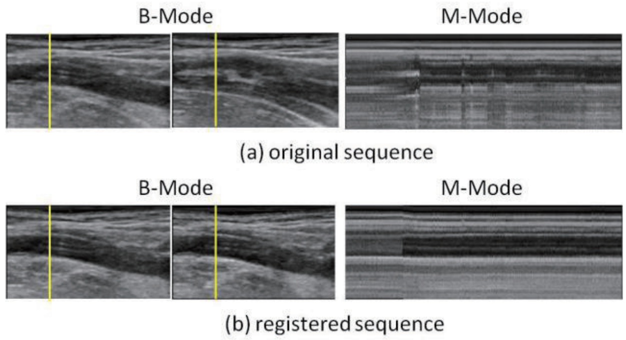

Fig. 1 The original sequence (a) and the registered sequence (b). B-Mode images of the brachial artery and M-Mode images at the yellow line.

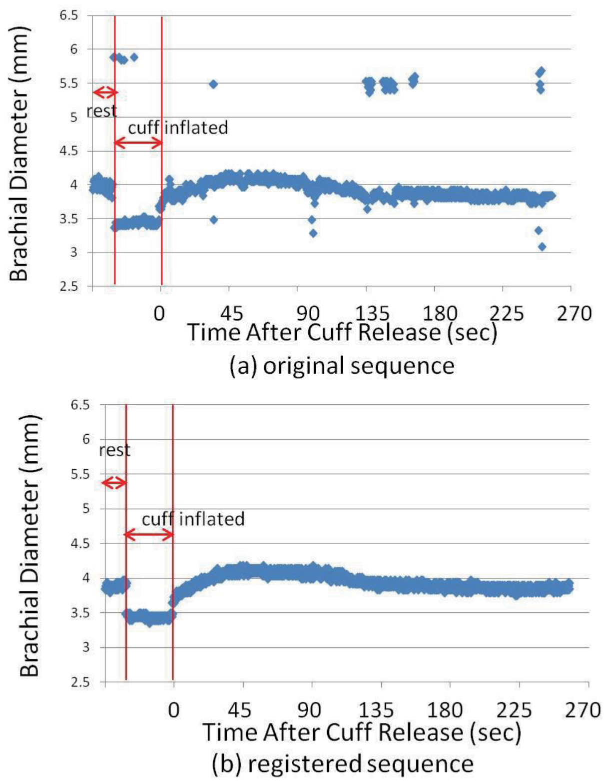

Fig. 2 Time course of the brachial artery diameter obtained from the original sequence (a) and the registered sequence (b).