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Long Monitoring of Portal Vein with 3D Ultrasound: Image Tracking, Respiratory Motion Analysis and Diameter Measurement

3 次元超音波を用いた門脈の長時間モニタリング ～画像位置合わせ、呼吸解析、径計測～

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1. Introduction

Portal vein blood flow is reflected by not only hepatic but also gastrointestinal functions [1]. We have tried to develop a new ultrasound imaging system that can monitor blood vessels for a long time [2, 3] and focused on monitoring the portal vein [3] by the system. In this paper, 3D ultrasound image tracking was performed to decrease the respiratory motion of the portal vein. Also, the portal vein diameter was measured continuously through the all scan. Offline image processing and analysis were performed.

2. Material and Method

Experiments in this work were performed under the approval of the Medical Ethics Committee of Kyoto University (No. R0614).

2.1 Image Data acquisition

A healthy subject (53 y, male) was monitored with a LOGIQ7 ultrasound system (GE Healthcare, US) which employed a 3.3 MHz 4D3C-L probe, a mechanical 3D/4D convex type transducer. The subject was resting in the supine position with his breath free for about 60 min recording. We repeated 17 times of about 200 sec 3D imaging (10 volumes/sec) following about 13 sec intervals for data storage. The acquired data had totally 33586 volumes with a 336 x 115 x 216 matrix size and a 0.31 mm^3 voxel size.

2.2. Image tracking

The position of the portal vein in the 3D image data was tracked and co-registered to decrease the motion of the portal vein under the influence of respiration. Image tracking was achieved by the 3D template matching method. A reference volume was defined in the end-expiration phase and a template volume was extracted in the selected reference volume. The template volume included the main trunk and the junction parts of the portal vein. The center point of the portal vein junction was defined as a reference point of the portal vein.

2.3 Respiratory Motion Analysis

The portal vein displacement by the respiratory motion was analyzed by using the image tracking results. The portal vein displacement was measured in each volume from the reference volume. Respiratory rate was also estimated from the portal vein displacement.

2.4 Diameter Measurement

We measured the portal vein diameter through the all scan. Two templates were manually defined at opposite side walls of the portal vein main trunk in the reference volume. The templates in each volume were tracked and co-registered, and then the portal vein diameter was measured in each volume.

3. Results & Discussion

3.1 Image Tracking

The original and registered images are shown in **Fig. 1**. The left two images are B-mode long-axis images of the portal vein at 2 time points. The right image is an M-mode image for 20 sec at white lines on the B-mode images. In the M-mode

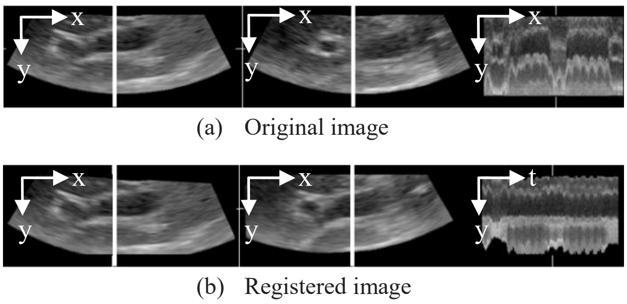

Fig. 1 Image tracking results

image after co-registration, the portal vein appeared as a straight black band. This result showed that the image tracking was performed well. Also, two clinicians confirmed that the image tracking was accurately performed by visual inspection of the registered 60 min image sequence.

3.2 Respiratory Motion Analysis

Figure 2 shows the trajectory of the reference point before co-registration. The reference point located relatively stable in the end-expiratory phase and moved largely along mainly x-axis in the inspiratory phase. This moving direction corresponded approximately to the craniocaudal direction.

Figure 3 shows the estimated displacement of the portal vein from the reference volume for all 60 min (a) and during 700-720 sec (b). The peak of the displacement corresponded to the respiratory motion. The displacement was small and stable in the end-expiratory phase. The respiratory rate by counting the peaks of the displacement was about 7-11 min^{-1} (about 0.11-0.18 Hz).

3.3 Diameter Measurement

Figure 4 shows the diameter change during the 60 min whole scan (a) and 700-720 sec (b). The diameter of the portal vein during 60 min was 10.7±1.0 mm (mean±s.d.). The repetitive waveform which might correspond to heartbeat was observed in the end-expiratory phase. On the other hand, the waveform was disturbed in the inspiratory phase. In the Fourier analysis of the diameter change, the power spectrum had two peaks. One was near 0.85 Hz which might synchronize heartbeat and the other was near 0.13 Hz which might synchronize the respiratory motion.

4. Conclusion

We recorded the 3D ultrasonography images of the portal vein during 60 min and analyzed the respiratory motion of the portal vein. The image co-registration and the diameter measurement of the portal vein were successfully performed during 60 min. Real time monitoring and more detail analyses will be performed in the next step.

Acknowledgment

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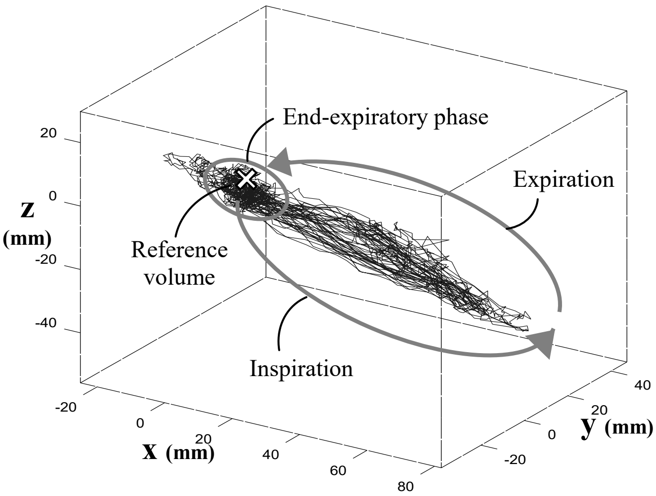
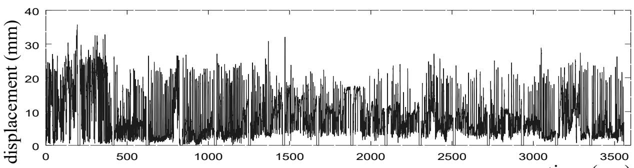
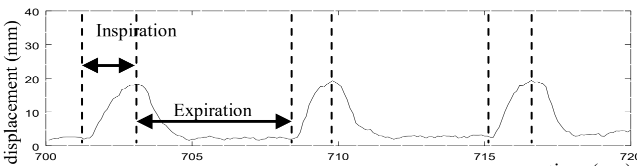


Fig. 2 Trajectory of the reference point

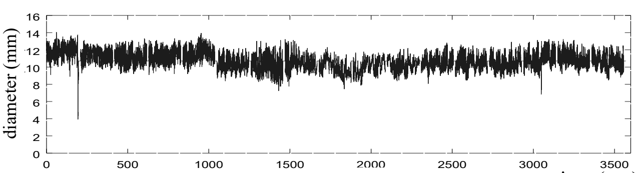


(a) Displacement during all 60 min



(b) Displacement during 700-720 sec

Fig. 3 Portal vein displacement



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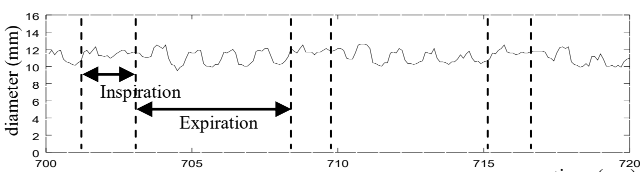

(b) Diameter during 700-720 sec

Fig. 4 Portal vein diameter