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Precise Vascular Visualization in Power Doppler Imaging with Motion Compensation

位置補正処理によるパワードプライメージングの高精細血管描出法

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1. Introduction

Ultrasonic power doppler imaging (PDI) is widely used as a non-invasive tool for visualizing vascularity. PDI is sensitive enough to detect signals from a blood flow in minute vessels. Such a high sensitivity, though, also detects unwanted signals from tissue motion induced by respiration or heart beat, loading to artifacts in a PDI image. The signals from tissue motion usually have lower frequency components than the signals from blood flow. Thus, a clutter filter, in which high frequency components are passed, is effective in reducing the artifact, but the filter is not enough to eliminate the artifact.

Image persistence, in which consecutive PDI images are temporally averaged, is utilized along with the clutter filter to reduce motion artifacts. The brightness of the motion artifacts in a PDI image is relatively lower than that of the blood flow. In addition, the motion artifacts randomly appear in various areas in each consecutive PDI image. Therefore, image persistence enables decreasing the brightness of the motion artifact somewhat in comparison with the brightness of the vessels.

However, image persistence causes images of the vessels to blur because the positions of the vessels are displaced due to the tissue motion between consecutive PDI images.

We investigated a motion compensation (MC) method for image persistence and applied the method to contrast images and B-mode images[1][2].

In a single contrast image, a small vessel can not be clearly imaged because of the low density of the contrast agent. Using image persistence with MC enables a line-like structure of a vessel in each of the contrast images to be accurately overlapped and the small vessel to be smoothly imaged as a line structure without blur.

When applying image persistence with MC to a B-image of a human carotid artery, the inner membrane could be clearly imaged, but it could not be imaged in a single B-mode image.

Our purpose in this study was to achieve motion compensated PDI (MC-PDI). The feasibility for reducing image blurring was found in a test of image persistence with a PDI image using a rabbit liver.

2. Materials and Method

2. 1 Motion Compensation

PDI images (f_1-f_n) for image persistence were stored in a memory. Then, the latest image (f_n) was set as a base image, and the other images (f_1-f_{n-1}) were set as reference images for the MC. The base image was divided into $ROI_{i,j}$ (**Fig. 1**), where (i, j) is the number of ROI in the width (x) and depth (y) directions, and MC and image persistence were performed in each ROI. This approach can also be used to compensate for non-rigid tissue deformation.

On the same position to $ROI_{i,j}$, the search-region ($SR_{i,j}$) shown in Fig. 1 was set in a reference frame (f_{n-1}) to search the best-matched region to $ROI_{i,j}$. The ROI was 3.2 × 3.2 mm, and the $SR_{i,j}$ was 6.4 × 6.4 mm, which assumed the tissue displacement was smaller than 1.6 mm between images for persistence.

The best-matched region to $ROI_{i,j}$ was found from $SR_{i,j}$ by searching the minimum value of the sum of absolute difference (SAD) defined by equation (1),

$$SAD = \sum_{x=1}^{x_{\max}} \sum_{y=1}^{y_{\max}} \left| SR_{i,j}(x, y, t - \Delta t_{n-1}) - ROI_{i,j}(x, y, t) \right| \quad \cdots(1)$$

where ($x_{\max}$, $y_{\max}$) and Δt_{n-1} are $SR_{i,j}$ size and the delay time between the base image (f_n) and reference image (f_{n-1}). The best-matched region with a minimum SAD was extracted from the reference image (f_{n-1}), then averaged to the $ROI_{i,j}$ in the base image (f_n). These processes were carried out in all ROIs set in the base image (f_n) and all reference images(1-f_{n-1}).

The flow diagram of MC-PDI is shown in **Fig. 2**.

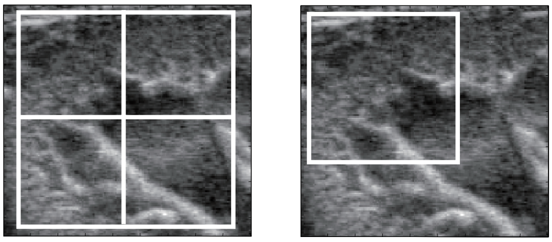

Figure 1. ROI on base frame and search area in reference frame

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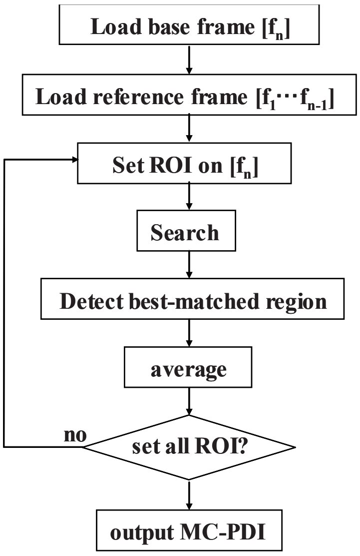

Figure 2. Flowchart of motion compensation

2. 2 In vivo experiment

An in vivo experiment was performed using a normal rabbit. PDI images for image persistence were obtained from an ultrasonic scanner EUB-8500 (Hitachi Medical Corp., Chiba, Japan) and a hand-held fixing linear array probe EUP-L54M (Hitachi Medical Corp., Chiba, Japan). The obtained images were loaded into a stand-alone PC.

First, conventional PDI images of the rabbit liver were obtained. Second, PDI images without image persistence were obtained. Finally, for the reference of the vessel size, a contrast agent was injected into the rabbit, and a contrast image was obtained. For obtained PDI images without image persistence, an MC-PDI image was constructed with Matlab®. The effect of the MC in image persistence was evaluated by comparing the vessels between the conventional PDI image and the MC-PDI image.

3. Results and Discussion

The vessel in the conventional PDI image and the MC-PDI image under the tissue motion of 0 and 22 mm/sec are shown in **Fig. 3**. The vessels in the MC-PDI images are not as blurred at 22 mm/sec as they are at 0 mm/sec. However, the vessels in the conventional PDI image are obviously more blurred in the image at 22 mm/sec than they are at 0 mm/sec. The size of the vessels in the conventional PDI image and in the MC-PDI image is quantitatively compared in **Fig. 4**. In the conventional PDI image, the vessels increased from 1.5 to 3.5 mm. Thus, the vessels were blurred by 2.3 times between stable and moving cases. In the MC-PDI image, the vessels increased from 1.2 to 1.4 mm. Thus, the size of the vessels was blurred 1.2 times between stable and moving cases. These results suggest that the image blur caused by image persistence can clearly be reduced using MC.

The size of the vessels in the contrast image was approximately 0.8 mm. Comparing the size of the vessels in the contrast image to conventional PDI and MC-PDI in the tissue motion at 22 mm/sec, the blur was 4.4 times and 1.8 times, respectively. The spatial resolution in the PDI was potentially worse than that in the contrast image. However, the extent of the blur was obviously better using MC than using the conventional PDI.

The tissue motion at 22 mm/sec is almost equivalent to the liver motion in humans, where motion is the most drastic in the abdominal tissue.

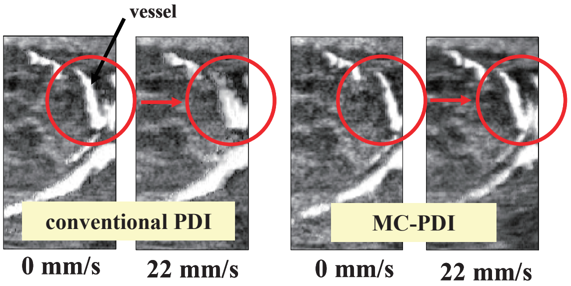

Figure 3. Comparison of vessels in conventional PDI with MC-PDI

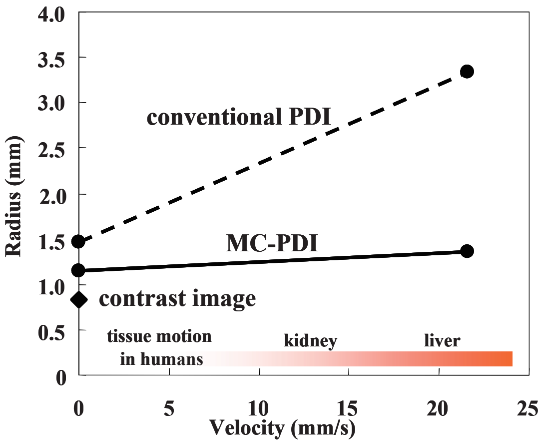

Figure 4. Relationship between tissue velocity and radius of vessel on conventional PDI and MC-PDI.

4. Conclusion

MC-PDI is effective in reducing the image blur caused by image persistence.

References

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2. H. Yoshikawa et al.: Jpn. J. Appl. Phys. **45** (2006) 4754.