3P5-13

Proceedings of Symposium on Ultrasonic Electronics, Vol. 35 (2014) pp. 533-534
3-5 December, 2014

Visualization of Blood-Flow Dynamics with Motion Compensation in Contrast-Enhanced Ultrasonography for Differential Tumor Diagnosis

造影超音波を利用した体動補正に基づく腫瘍血流動態イメージング

Hideki Yoshikawa†, Zisheng LI, and Ken-ichi Kawabata (Hitachi, Ltd., Central Research Laboratory)
吉川秀樹†，黎子盛，川畑健一 (日立製作所 中央研究所)

1. Introduction

Contrast-enhanced ultrasonography (CEUS) is widely used to sensitively visualize small vessels of tumors. One uinque feature of CEUS is that all contrast agetns in the image plane can be eliminated instantly by a special pulse regime called flashing mode and replenishments of agents can be observed. The observing of the replenishment of contrast agents in tumor vascularity gives information on blood-flow dynamics of each vessles, which is useful for differential diagnosis[1,2]. For example, in liver observation, vessles to malignat and benign tumors are known to have different replenishment time. Vessles to malignant tumors tends to replenish in shorter period of time [3].

Inflow-time mapping (ITM) is an imaging technique to visually and quantitatively present such difference in replenishments. It maps time requred to replenish for each vessles on the imaging plane by analizing sequences of contrast images after flash.

For accurate performance of ITM based on a measurement of replenishing time, a motion compensation is necessary to prevent an artifact due to a tissue motion induced by respiratory, peristalsis and heart beat. Especially to obtain information on minute vessles, such compensation would be very important. The purpose of this study is development and evaluation of ITM with motion compensation to visualize blood-flow dinamics for differential tumor diagnosis.

2. Materials and Method

2-1. ITM with otion compensation

Flow chart of ITM with motion compensation (MC) is shwon in **Fig. 1**. CEUS images are obtained for several seconds from ultrasound scanner and stored in a memory. The image data are divided to several regions to measure non-rigid tissue motion. The region size is decieded to be small enough to include a few speckle patterns considering ultrasound frequency, focusing depth and aperture size of a probe. Tissue motion is measured by block-matching motion compensation algorithm with sum of absolute difference (SAD) in each region[4]. With a result of the motion measurement, non-rigid registration is executed to the obtained image data to compensate a position of a tumor. With the compensated image data, temporal change of brightness in each pixel is measured as time intensity course (TIC), and then inflow time to reach maximum brightness is estimated. Finally, a resulting image of ITM is constructed with color tones corresponding to the measured inflow time.

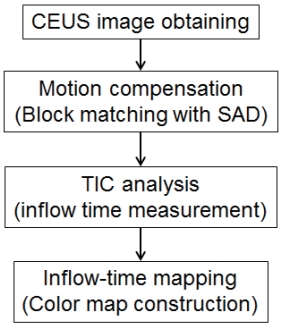

Fig. 1 Flow chart of inflow-time mapping with motion compensation.

2-2. In vivo experiment

Setup for experiments using rabbits with VX2 tumor implanted in a liver lobe is shown in **Fig. 2**. Sonazoid® was intravenously injected and then CEUS images were obtained with pulse inversion sequence for 10 s at the rate of 10 frames per second with ultrasound scanner EUB-8500 (Hitachi Aloka Medical, Japan). Central frequency of transmitting and receiving pulses from a probe EUP-L74M (Hitachi Aloka Medical, Japan) were 6 and 12 MHz, respectively. ITM with MC was executed for the obtained image data, in which region size for non-rigid motion measurement was 3 × 3 mm. Resulting images of ITM with and

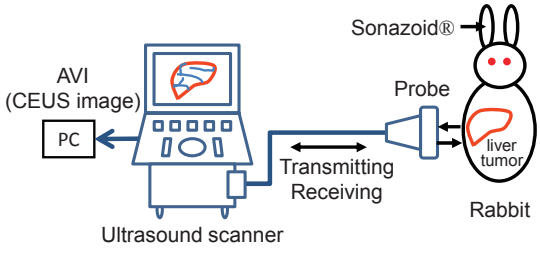

Fig. 2 Experimental setup with rabbit liver.

hideki.yoshikawa.zq@hitachi.com

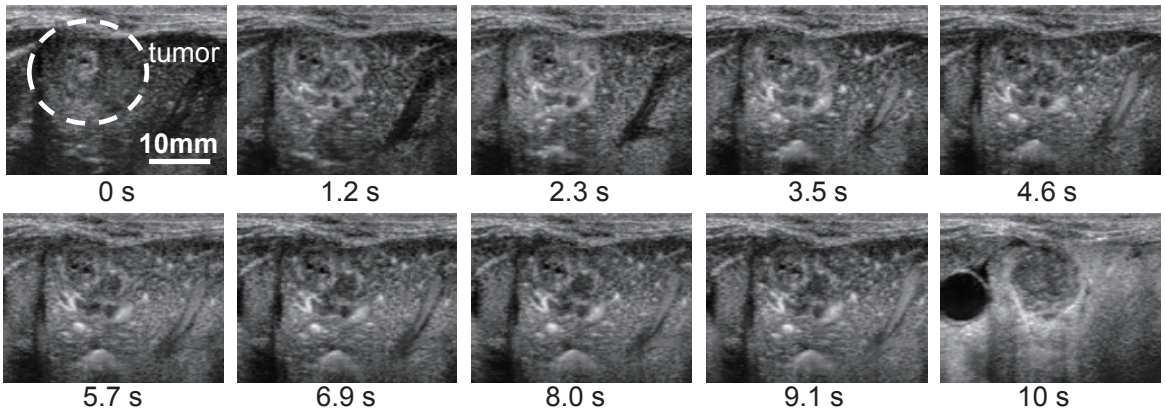

Fig. 3 CEUS images of a tumor of rabbit liver.

without MC was compared. Additionally, Time intensity courses of a typical feeding vessel were also compared and evaluated an effect of MC.

3. Results and Discussion

Obtained CEUS images of a rabbit liver are shown in **Fig. 3**. Surrounding area of the tumor becomes bright earlier than the other area. Comparing images in the upper row to those in lower one, it can be noticed that the tumor moves from left to right, and the amount of the displacement is approximately 2 mm in maximum between the images at 3.5 and 9.1 s.

The averaged images with and without MC are shown in **Fig. 4**-(a) and (b), respectivley. As shown in Fig. 4-(a), vessels around tumor can be clearly visualized, though, it is significantly blurred in Fig. 4-(b) especially in the circled vessels.

ITM with and without MC are shown in Fig. 4-(c) and (d), respectively. Red and blue color indicate early and late inflow time, respectively. As shown in Fig. 4-(c), inflow time around tumor is ealier than that in the other area. Central area of the tumor is not colored because vessels are shrinked by tumor growth and bubbles can not reach. Any motion artifact can not be recoginized in Fig. 4-(c), though it obviously appears in Fig. 4-(d). An abnormal color gradation is seen in many area similar to the circled area.

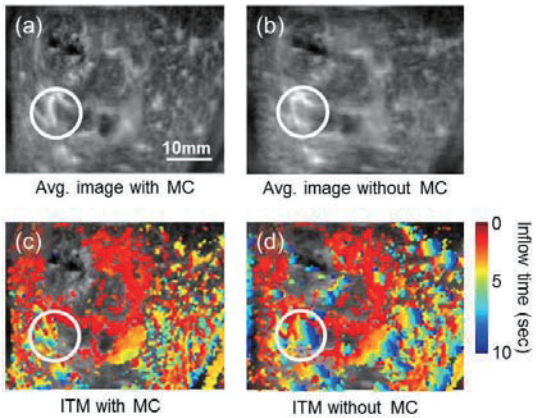

Fig. 4 Averaged image with (a) and without (b) MC. Color map of ITM with (c) and without (d) MC.

TIC analysis at the same pixel of the circled vessel in Fig.4 is shown in **Fig. 5**. TIC without MC is underestimated at late phase from 40 to 100 frames comparing to the one with MC. It is supposed that the target vessel deviated from the original position due to tissue motion, and leads to an obvious artifact in the color map of ITM.

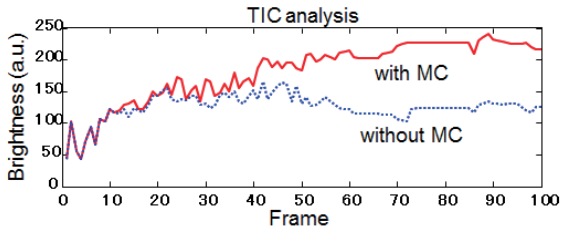

Fig. 5 TIC with and without MC of same pixel located on the same tumor vessel.

4. Conclusions

Motion compensation was applied to inflow-time mapping with liver tumor of rabbit. It was found that the artifact due to respiratory motion was effectively reduced. Robustness of the motion compensation algorithm for CEUS image is further studyed.

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