THE FRONTAL 3-D IMAGING FOR PTCA USING A RING ARRAY PROBE

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Commission V, Working Group V/4

KEY WORDS: ultrasound, 3-D imaging, PTCA, ring array probe

ABSTRACT

PTCA (Percutaneous Transluminal Coronary Angioplasty) is the most popular treatment for arteriosclerosis. In the operation by PTCA, to measure the size of a lesion quickly and accurately is very important. However, there is not any effective method to measure. Then we have proposed a method to measure the size of a lesion. This measurement method is called "the Instantaneous Frontal Imaging Method". We propose a new algorithm for the Instantaneous Frontal Imaging Method. In a conventional method, ultrasound is supposed to be reflected to a fixed direction corresponding to the normal of the reflector's surface. In the new algorithm, we set the model of reflection of the ultrasound that the ultrasound is reflected to the fixed direction at whole points of measurement domain. Inner products of measured and the calculated signals show the probability of reflector's existence at a point. In addition, we can reconstruct the 3-D image of reflector to display this probability. To use this new algorithm, we can obtain an image with high S/N ratio in the short time.

1 Introduction

The arteriosclerosis is one of important adult's diseases, and the main cause of myocardial infarction. In the arteriosclerosis, the cholesterol composed to the inside wall of the blood vessel, and the blood flow is interfered. When a stricture closes the blood vessel completely, the heart will necrotize, because the blood stops flowing into the heart. In the treatment of the arteriosclerosis, the PTCA (Percutaneous Transluminal Coronary Angioplasty) is usually performed. If this method is used, it is not necessary that the dangerous operation to open the chest of the patient.

The procedure of PTCA is shown in figure 1. First, the catheter is inserted to the blood bessel. Next, the guide wire which is mounted on the catheter pierces the stricture. Subsequently, the balloon which is also mounted on the catheter is inserted the hole which is opened by the guide wire. The balloon is expanded and crushes the stricture. Final, the blood flows smoothly again.

However, if the guide wire or the blood vessel is bent as shown in figure 2, the guide wire will pierce the blood vessel, and the operator must open the chest of patient urgently. The operator must know the size of a lesion or three dimensional structure of stricture and blood vessel.

However there is not any effective method to measure the size of a lesion or three dimensional structure of stricture and blood vessel in the operation. Therefore,

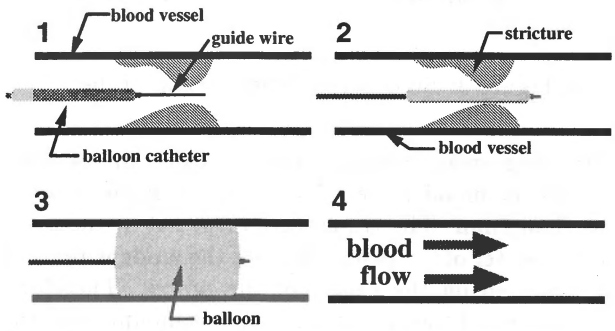

Figure 1: PTCA

we had developed the special ultrasonic probe which is called the ring array probe as shown in figure 3 and 4, and we have researched the measurement method called "the Instantaneous Frontal Imaging Method" [1],[2] and image reconstruction algorithms using this ultrasonic probe. We propose the new image reconstruction method using this ultrasonic probe.

2 Ring Array Probe

This ultrasonic probe has some ultrasonic transducers that are located circularly. The one transducer transmits the spherical pulsed ultrasound, and that is different from traditional ultrasonic measurement method which transmit the ultrasonic beam. The ultrasound is reflected by the object in the measurement region, and is recieved by all trancducers of the probe. The flight times of the ultrasounds are different each transducers. Therefore, we can recognize the position of the object from these differences. The specification

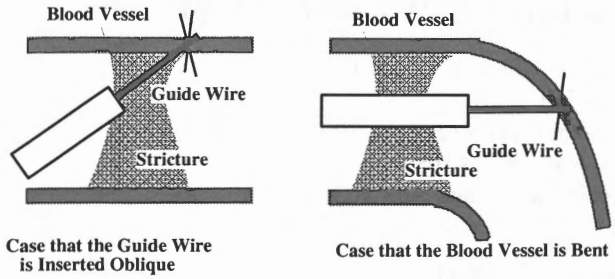

Figure 2: The Occurance of Accident

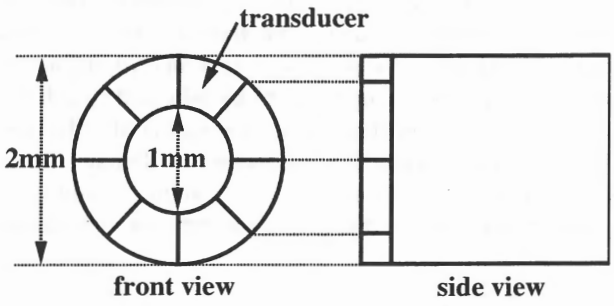

Figure 3: Structure of Ring Array Probe

of the ring array probe is limited because the probe is used in the blood vessel. The diameter of the probe is less than 2mm. The transducer must not be mounted on the center of the probe because the guide wire must be mounted on the center of the probe. Therefore, the number of the transducers that is mounted on the probe is about eight at most. Furthermore, the measurement must be carried out in a time as short as possible when the probe is used in the operation of PTCA.

3 Image Reconstruction

3.1 The Method we Proposed Before

As shown in figure 5, when the transducer t_i transmits the spherical ultrasound and the transducer t_j recieves the echo which reflected by reflecter, the echo is expressed as a vector $E_{i,j}(t)$.

In the measurement region, asuming a point reflecter located on a point (ξ, η, ζ) of measurement region, the assuming echo is expressed as a vector $T_{i,j}(t)$ which is called the table. The probability that a reflecter is exists at the position (ξ, η, ζ) of measurement region $\epsilon(\xi, \eta, \zeta)$ is estimated as

$$\epsilon(\xi, \eta, \zeta)$$

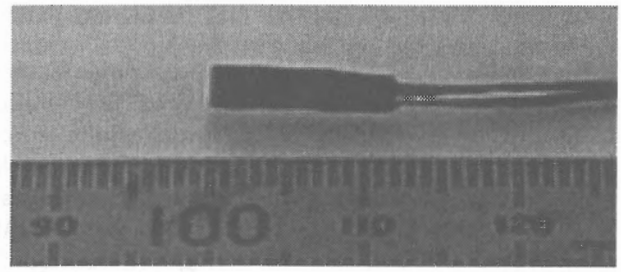

Figure 4: Photo of Ring Array Probe

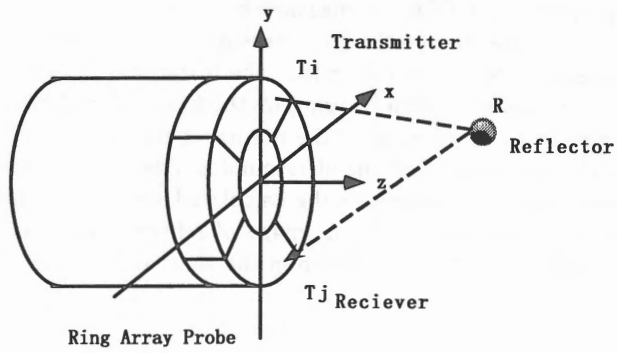

Figure 5: Transmission and Reception of Ultrasound

$$= \sum_{i,j} \frac{< |E_{i,j}(t)|, |T_{i,j}(t)| >}{< |E_{i,j}(t)|, |E_{i,j}(t)| >< |T_{i,j}(t)|, |T_{i,j}(t)| >} \quad (1)$$

where $< f(t), g(t) >= \int_0^{t_0} f(t)g(t)dt$.

To reconstruct the three dimensional image, the probability $\epsilon(\xi, \eta, \zeta)$ is mapped to reconstruction domain. This method is based on a simple expansion algorithm to the orthogonal basis. The imaging using this method is quite fast [4],[5], because only the inner product calculation is neccessary. However, the S/N ratio of the image which is obtained by this method is not so high, because basis are not orthogonal and imcomplete.

Therefore, we proposed the method for imaging with the high S/N ratio [5]. However the imaging using this method needs the long time, because the iteration and optimization are necessary for this method.

3.2 New Method

We porpose the new method. To improve the S/N ratio of image, more transducers are neccessary. However, it is difficult to increase the number of transduc-

ers, because the diameter of the probe is limitted less than 2mm. Therefore, we propose to make new tables. Generally, the ultrasound is reflected to fixed direction, because the reflectors are not points but plane in usual. Therefore we set the tables which correspond to the normal of reflection surface. Assuming that there are three different planes x, y, z that are orthogonal each other as shown in figure 6, we set the three different tables.

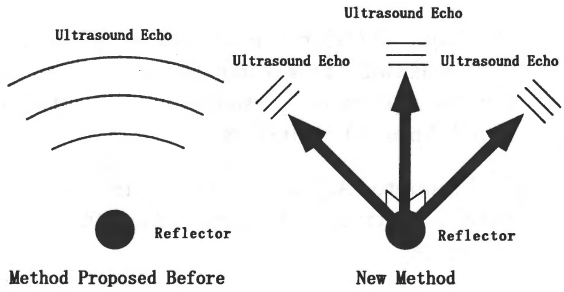

Figure 6: Model of Reflector

In other words, we set the tables $T_{i,j}(t)_x$, $T_{i,j}(t)_y$,$T_{i,j}(t)_z$. The propability of the existance of the surface at the point in the measurement space is assumed that:

$$\epsilon(\xi,\eta,\zeta)_x = \sum_{i,j} \frac{< |E_{i,j}(t)|, |T_{i,j}(t)_x| >}{< |E_{i,j}(t)|, |E_{i,j}(t)| >< |T_{i,j}(t)_x|, |T_{i,j}(t)_x| >} \quad (2)$$

$$\epsilon(\xi,\eta,\zeta)_y = \sum_{i,j} \frac{< |E_{i,j}(t)|, |T_{i,j}(t)_y| >}{< |E_{i,j}(t)|, |E_{i,j}(t)| >< |T_{i,j}(t)_y|, |T_{i,j}(t)_y| >} \quad (3)$$

$$\epsilon(\xi,\eta,\zeta)_z = \sum_{i,j} \frac{< |E_{i,j}(t)|, |T_{i,j}(t)_z| >}{< |E_{i,j}(t)|, |E_{i,j}(t)| >< |T_{i,j}(t)_z|, |T_{i,j}(t)_z| >} \quad (4)$$

The probability of the existance of a plane which has a fixed direction is the sum of these probability.

4 Experiment

To evaluate the new algorithm, a computer simulation was performed. The parametars of the simulation are shown in table 1. We set the four reflectors in front of the ring array probe at 10mm intervals as shown in figure 7. Points reflect the ultrasound to fixed direction.

Table 1: Parameters in the computer simulation experiment.

enviroment	in water
speed of ultrasound	1500m/s
central frequency	10MHz
number of transducers	8
diameter of the probe	2mm
measurement region	2x2mm plane
measurement depth	12mm
discretized elements	0.1mm pitch

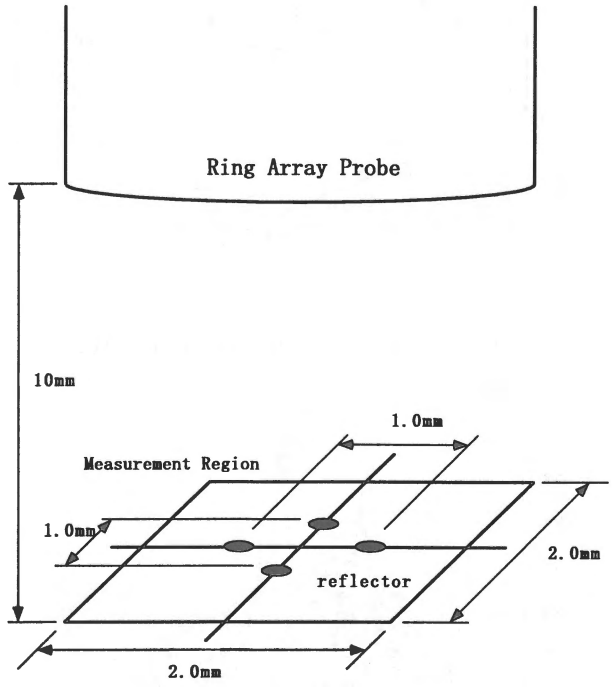

Figure 7: Arrangement of Ring Array Probe and Reflectors

5 Results and Discussions

Figure 8 shows the C-mode(Continuous depth mode) image which is obtained using the traditional method. Figure 9 shows the C-mode image which is obtained using the new method. In each images, the position of reflectors are reconstructed correctly. The S/N ratio of the image which is obtained using new method is two times higher than the image which is obtained using tradiotional method. We assume that the improvement of S/N ratio is derived from the increase of the table. The number of data which is used for the estimation of the reflector's position in new method was three times larger than the data of method that proposed before. The calculation time to obtain the image in new method is three times longer than traditional method. However, the calculation of the esti-

mation can be processed parallel. Therefore, the time to obtain the image can be reduced.

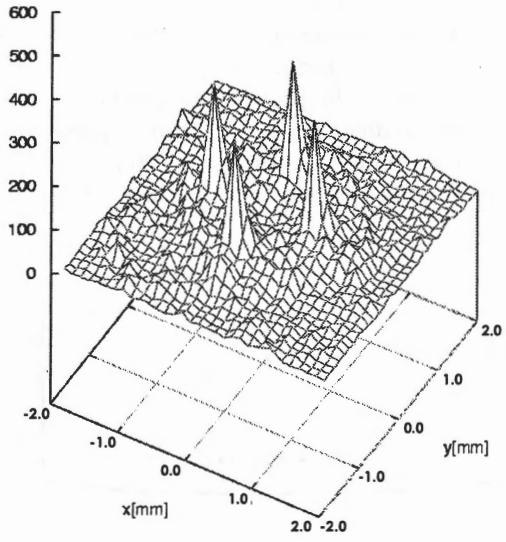

Figure 8: C-mode Image by Traditional Method

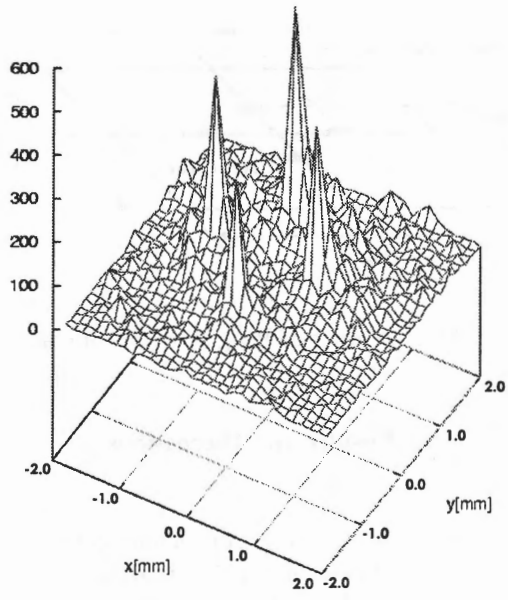

Figure 9: C-mode Image by New Method

6 Conclusion

We proposed a new method for image reconstruction using ring array probe. Using this reconstruction method, the S/N ratio of the image improved two times higher than the image which is reconstructed using the traditional method. The calculation time to reconstruction can be reduced with parallel calculation. Therefore, the new method is suitable to use in operation of PTCA.

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