3Pb5-6

Proceedings of Symposium on Ultrasonic Electronics, Vol. 33 (2012) pp. 489-490
13-15 November, 2012

Evaluation of a method for strain imaging in arterial wall by synthesizing ultrasonic echo based on strain distribution obtained by finite element analysis

有限要素解析で算出した動脈壁歪み分布から合成した超音波エコーによる歪み推定法評価

Kazuki Shiratori[1†], Hideyuki Hasegawa[2, 1], Hiroshi Kanai[1, 2] ([1]Graduate School of Eng., Tohoku Univ.; [2]Graduate School of Biomedical Eng., Tohoku Univ.)
白鳥　和紀 [1†]　長谷川　英之 [2, 1]　金井　浩 [1, 2] ([1] 東北大院 工, [2] 東北大院 医工)

1. Introduction

Mortality from myocardial infarction or stroke has been increasing due to the progress of the westernization of dietary life and the aging society. Its main cause is arteriosclerosis, which is characterized by changes in elastic modulus of the arterial wall. The progress of systemic atherosclerosis progression is often observed at the bifurcation of the carotid artery. Currently, ultrasonography is suitable to observe the shape of the plaque in real time and non invasively. In addition, the measurement of the strain distribution in the arterial wall is important for assessment of elastic properties of the arterial wall.

In the present study, a simulation model of the artery was constructed for evaluation of methods for measurement of the strain distribution in the arterial wall. The model is composed of a number of ultrasonic point scatterers to which the corresponding displacement due to the increase of internal pressure were applied. The displacement of the scatterers were obtained by finite element analysis.

2. Method

2.1 Finite element analysis

In this paper, the deformation of a vessel model was analyzed using the finite element analysis to estimate stain distribution. Finite element model is composed of two-dimensional elements in square shape with the number of nodes of 1300, 4 mm inner diameter, 10 mm outer diameter, and 120 mmHg change in pressure (external pressure were assumed to be 0). Parameters used in finite element analysis are shown in Table 1[1)]. Using an *in vivo* ultrasonic data, the waveform of the change in diameter was estimated to obtain blood pressure waveform.

E-mail address: shirato@us.ecei.tohoku.ac.jp

Table 1 Parameters used in finite element analysis.

Internal diameter [mm]	4.0	Outer diameter [mm]	10.0
Poisson's ratio	0.4999	Young's modulus [MPa]	0.1
Intraluminal pressure [mmHg]			120

2.2 Simulation of ultrasound transmission

Scatterers were randomly distributed to the model of the same size as the vessel model of the finite element method for simulation of ultrasound transmission and reception. B-mode images were constructed by simulating the ultyrasonic wave scattered from the target[2),3)]. Parameters used in ultrasound transmission and reception are shown in Table 2. A schematic diagram of a linear array transducer is shown in Fig. 1.

Table 2 Parameters used in ultrasound transmission and reception.

Number of elements	194	Active elements	64
Element pitch [mm]	0.20	Sampling frequency [MHz]	40
Element height [mm]	0.50	Center frequency [MHz]	10
Kerf [μm]	1.0	Speed of sound [m/s]	1540

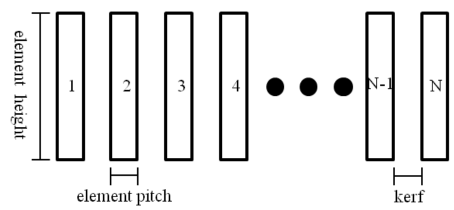

Fig.1. A schematic diagram of a linear array transducer.

2.3 Nodal displacement estimation

The displacements at nodes of elements by the finite element analysis was estimated, so that the strain distribution in the arterial wall due to the temporal change in blood pressure is simulated. In this process, it is necessary to determine to which element each scatterer belongs in the finite element model. The displacement of each scatterer is given by

$$u = \frac{\sum_{i=1}^{4}\left(\frac{u_i}{d_i}\right)}{\sum_{i=1}^{4}\left(\frac{1}{d_i}\right)} \quad (1)$$

where i (=1, 2, 3, 4) is the element node number, u_i is the displacement of node i, d_i is the distance between the i-th node and the scatterers.

3. Results

Figures 2(a) and 2(b) show a finite element model constructed in the present study and the corresponding estimated displacement distribution, respectively. In the case of a cylinder with homogeneous wall thickness and elastic property, the displacement distribution can be estimated analytically. In Fig. 2(c), the radial displacement obtained by finite element analysis is in good agreement with the analytical solution.

Figure 3(a) shows the distribution of ultrasonic scatterers at the internal pressure of 0 mmHg. The number of scatterers was 10,000. By simulating ultrasound transmission and reception, a B-mode image of the model is obtained as shown in Fig. 3(b). Also, the distribution of scatterers and the corresponding B-mode image of the internal pressure of 120 mmHg are shown in Fig. 4(a) and Fig. 4(b), respectively.

Furthermore, a blood pressure waveform and a M-mode image of an ultrasonic beam, which passes through the center of the artery, are also obtained as shown in Fig. 5(a) and Fig. 5(b), respectively. The frame rate was set at 50 Hz. The change in diameter due to the change in internal pressure can be observed in the M-mode image.

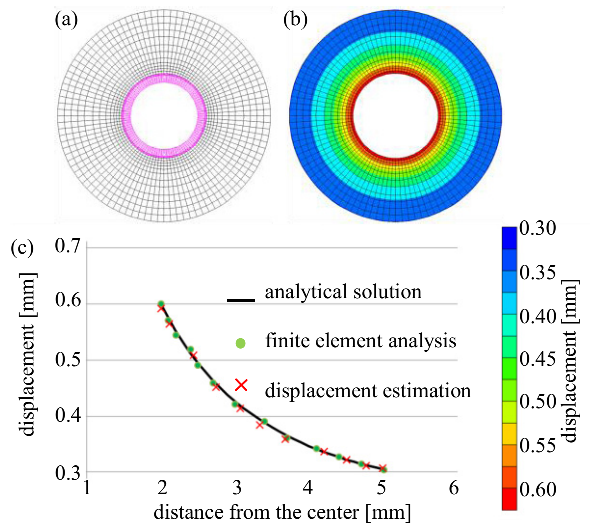

Fig. 2 (a) Constructed finite element model. (b) Estimated displacement distribution. (c) Radial profiles of displacement estimated by finit element analysis and analytical solution.

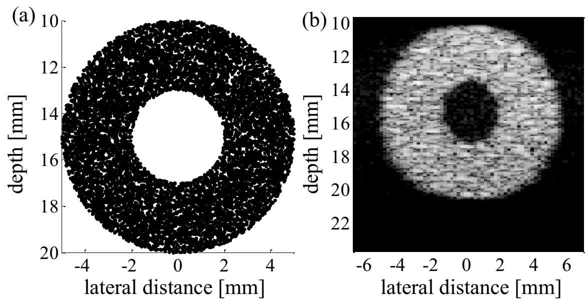

Fig. 3 (a) Scatterers distribution at internal pressure of 0 mmHg. (b) Corresponding B-mode image.

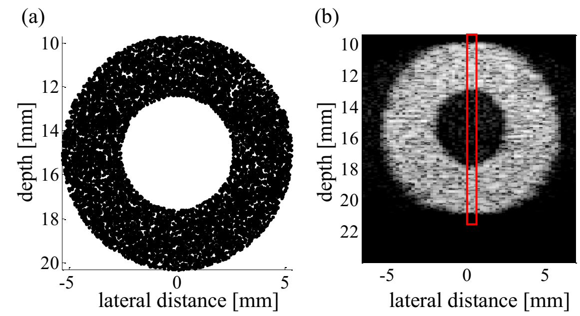

Fig. 4 (a) Scatterers distribution at 120 mmHg. (b) Ultrasonic echo image.

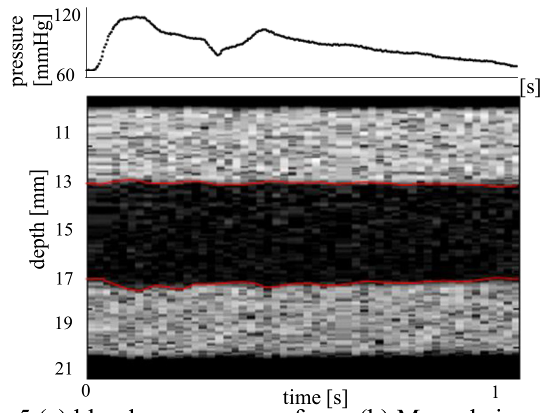

Fig. 5 (a) blood pressure waveform. (b) M-mode image.

4. Conclusion

In this study, a finite element model was constructed to obtain displacements caused by the pressure pulse of scatterers in the vessel wall model. In addition, by simulating pulse-echo measurements, B-mode and M-mode images of the model were obtained, and the motion of the model due to the change in internal pressure could be observed in the M-mode image.

References

1. R. A. Baldewsing, et al., Ultrasound Med.Biol., 30(6), 803–813, 2004.
2. J. A. Jensen , Med. Biol. Eng. Comput., 34 (1), 351-353, 1996.
3. J. A. Jensen and N. B. Svendsen, IEEE Trans., UFFC, 39, 262-267, 1992.