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Effects of aging on carotid pulse waveforms

Kazumasa Matsubara[1 ‡], Mami Matsukawa[1], Daisuke Koyama[1], Miho Ohsaki[1], Kozue Saito[2], Hiroshi Yamagami[3] ([1]Doshisha Univ.; [2]Nara Medical Univ.; [3]Osaka National Hospital.)

1. Introduction

Arteriosclerosis often progresses without symptoms, which delays the diagnosis in the hospital. For simple and inexpensive screening of the carotid artery at home, we focused on the pulse wave. The pulse wave is a temporal variation of the displacement of the skin surface caused by pressure waves propagating in the artery. In this study, characteristic changes of pulse waveforms at the carotid artery were evaluated to know the aging effects on the arteries to brain, because the pulse wave reflects the elasticity of arteries and contains the effects of reflected waves from the brain.

We constructed a pulse wave measurement system using an inexpensive and commercially available piezoelectric sensor for ultrasound ranging [1]. This sensing system does not require a cuff as in pulse wave velocity (PWV) measurement or gel as in ultrasonic diagnosis system.

In this study, we measured pulse waves at the carotid arteries of healthy subjects and extracted dynamic features from pulse waveforms [2]. The classifier logistic regression, which was embedded in the system, clarified the effect of dynamic features. This study is permitted by the ethics committees at Doshisha university and Nara Medical university.

2. Measurement method and subjects

74 healthy subjects were measured (ages: 20s-80s). The subjects lay down in the spine position and in the resting state during measurements.

Pulse waves at the left common carotid arteries were measured using a piezoelectric transducer (MA40 E7R, Murata Manufacturing) [3]. The output of the transducer was amplified and digitized by a data logger (NR 500, NR-HA08 Keyence) or our handheld system (ProAssist). **Figure 1** shows the pulse wave measurement using a piezoelectric sensor. During measurements, the differential waveform of the skin surface displacement was observed. In practice, four stable and continuous waveforms were observed. They were then averaged and normalized and used as a measured wave.

ctwh0340@mail4.doshisha.ac.jp

Fig. 1 Pulse wave measurement using a piezoelectric sensor.

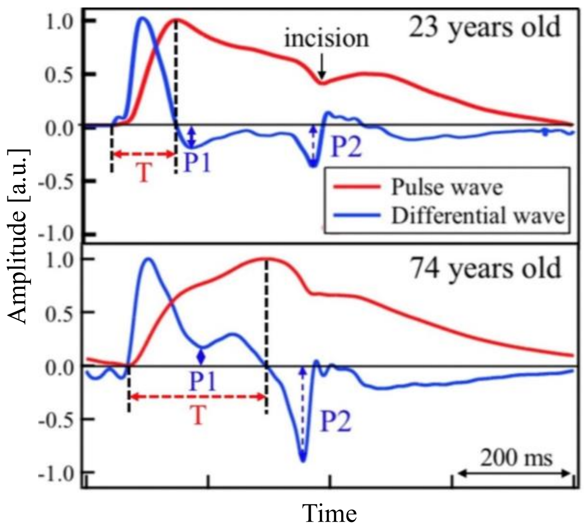

Fig. 2 Observed pulse waves (skin surface displacements) and differential pulse waves.

3. Waveform analysis

Figure 2 shows normalized pulse and differential waveforms of young and old subjects. The maximum value of the old subject waveform was found later than that of the young subject waveform. In hard cerebral arteries, strong reflected waves from the vascular bed are expected to superpose on the incident pulse wave. The degree of superposition of the reflected wave to the incident wave may change due to the age [4]. Considering this phenomenon, following three dynamic features (T, P1 and P2) were selected for the waveform analysis.

(1) Time difference T between wavefront and maximum amplitude of pulse wave.

(2) Amplitude P1 at the first negative peak of the differential pulse wave.

(3) Amplitude P2 at the negative maximum amplitude of the differential pulse wave.
The analysis was performed using the logistic regression model [5].

$$p = \frac{1}{1 + \exp[-(b_0 + \boldsymbol{b} \cdot \boldsymbol{x})]} \qquad (1),$$

Where p is the probability that the subject is specific age. $b=(b_1,b_2,b_3)$ is the weight of each dynamic feature and b_0 is intercept of the logistic regression model created, and $x=(x_1,x_2,x_3)$ is dynamic feature of pulse wave. Here b_1 is the weight coefficient for T, b_2 is for P1 and b_3 is for P2. To obtain a logistic regression model, 37 learning data and 19 test data were randomly selected and divided into training and test sets 20 times using data in four groups, ((1) 20- 30s, (2) 40 - 50s, (3) 60s, and (4) 70 - 80s). Accuracies and the weights of input variables of all trials were estimated.

4. Results and discussion

Figure 3, where data are plotted with the linear regression, shows relationship between age and the dynamic features T, P1 and P2.

The dynamic feature T seemed to be separated into two age groups with a border around 50 years old. Values T of 20-40s subjects seemed independent of age. If the reflected wave from the brain was strong and the attenuation was small in the brain artery, a strong reflected wave may superpose on the incident wave, which results in the late maximum peak as can be seen in the pulse wave of the old subject in Fig.2. The reflected wave seemed to become strong around 50 years old.

The dynamic feature P1 showed good correlation with age (R^2= 0.78). P1 values for most of young subjects were negative.

The dynamic feature P2 near the incision also showed correlation with age (R^2= -0.42). It is known that the pulse wave rises rapidly when the aortic valve opens, and decreases to the incision, when the aortic valve closes. It is interesting that superposition of the reflected wave occurs just before the incision. Reflected waves of young people are usually small because of the soft artery, so we can find a gentle slope just before the incision, whereas the slopes of old subjects were comparatively steep.

The accuracies obtained by the logistic regression model for four age groups were (1) 0.94, (2) 0.84, (3) 0.68 and (4) 0.76. In the youngest group, better accuracy was obtained. **Table 1** shows the weights of the three dynamic features obtained by the analysis. The dynamic features T and P1 showed higher weights than P2. For 40-50s subjects, all the dynamic features T, P1 and P2 were low.

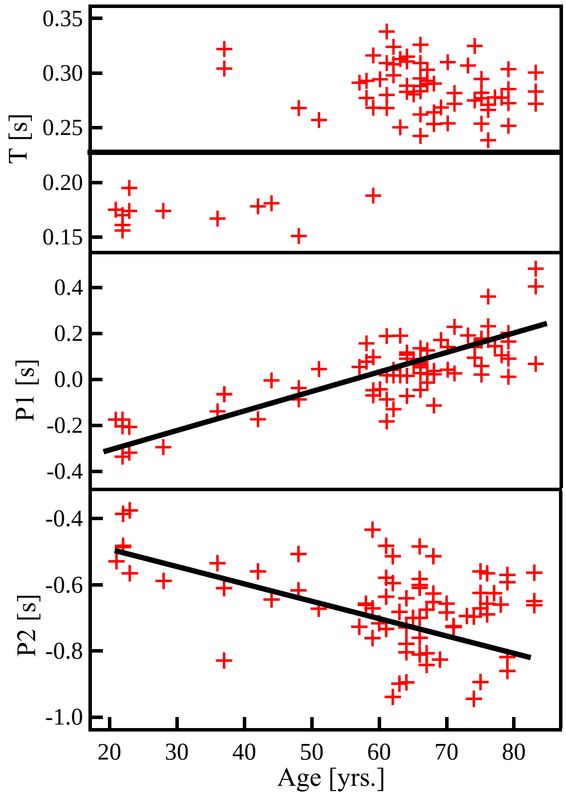

Fig. 3 Relationship between age and dynamic features T, P1 and P2.

Table 1 Weights of parameters.

	b_1		b_2		b_3	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
20-30s	-0.65	0.28	-0.81	0.19	0.26	0.24
40-50s	-0.34	0.34	-0.05	0.24	0.04	0.22
60s	1.09	0.21	-0.61	0.22	-0.15	0.26
70-80s	-0.22	0.20	1.55	0.21	0.08	0.29

5. Conclusion

The left carotid artery pulse waves of healthy subjects were measured by a simple system. To characterize the waveforms with age, 3 dynamic features were considered. Accuracy of 0.94 was obtained for the young ages group by the logistic regression 0.94. However, the accuracy of the middle age group (40-50 years old) was comparatively low. Additional dynamic features are expected to characterize the middle age group.

Reference

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