Radial Pulse Type Changed by the Applied Pressure in Same Position

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Abstract— **It has been shown that the systolic augmentation index (AI) in the central arteries, including the aorta and carotid arteries, changes with age. The AI can also be obtained from the peripheral arteries. And recently some investigations prove that simple and easily-obtainable radial AI is also age-dependent and could be a useful index of vascular aging. A new method to measure pulse waveform by multi-step pressure applied on radial artery was developed by DAEYOMEDI Co., Ltd. This system borrowed a robot arm for applying precision pressure to take pulses stably and to find out a representative pulse waveform. Radial arterial waveforms were obtained from 45 subjects with no cardiovascular disease and from 56 subjects with hypertension by using radial tonometer (DMP-3000(with five pressure steps). In this study, it was founded that radial pulse waveform types could be changed by the applied pressure and that the waveform types were different between healthy young people and hypertension patients.**

Keywords— **augmentation index, radial AI, pulse diagnosis, radial artery, robot pulse detect device**

I. INTRODUCTION

The augmentation index (AI) is generally defined as an index of augmentation of central blood pressure in aorta and carotid arteries during systole, when pressure waves were reflected from the periphery (mainly from the lower body) [1]. Increased aortic and carotid arterial AI is associated with the risk of cardiovascular disease [2,3], mortality and morbidity [4,5]. The most widely used approach for determining central arterial AI is to calculate the aortic pressure waveform from radial arterial waveforms using a transfer function, because the measurement of aortic or carotid artery pulse waves by applanation tonometry requires technical expertise and can cause uncomfortable for patients. Because AI can also be obtained from radial arterial waveform, radial AI itself could provide information on vascular aging.

Several researchers have indicated that this transfer function (radial artery to aorta) has large variation between-subjects [6], and therefore, synthesized aortic AI from radial pressure waveforms using a transfer function had no significant correlation with AI from invasively measured aortic pressure waves [7]. A recent study reported that AI has significant variation with the measuring position even in the same person's radial artery.[8]

We thought this variation might be caused from measurement method. There are now two methods of measuring radial artery waveform. The first method is to use a hand-held pen-type tonometer and to self-evaluate the measured data from operator index. The second one is a semiautomatic method that is programmed to determine automatically the pressure against the radial artery to obtain the optimal radial arterial waveform. But both of them cannot recognize the change of waveform by the applied pressure and the pattern of change is relying on the subject's characteristics. In a previous study we used a new method to validate the device by measuring radial waveforms, and observed change of waveform and variation of radial AI in same position by the applied pressure.[9]

In this study we defined radial pulse types in view of peripheral reflected waves and observed them in two groups, young healthy group and elderly hypertension group.

II. METHODS

A. Subjects

For the healthy group, a total of 45 young healthy adults (30 men and 15 women, age 21-38 years, height 169.53 ± 7.89 cm, weight 62.91 ± 12.72 kg; mean $\pm$ SD) underwent seated radial waveform measurements. They had no history of cardiovascular disease, diabetes, or hyperlipidemia. This study was reviewed and approved by the local Institutional Review Board.

For the hypertension group, a total of 56 hypertensive adults (23 men and 34 women, age 40-78 years, height 161.05 ± 8.87 cm, weight 65.77 ± 10.97 kg; mean $\pm$ SD) underwent seated radial waveform measurements. This study was reviewed and approved by the Dongkuk University Hospital Institutional Review Board.

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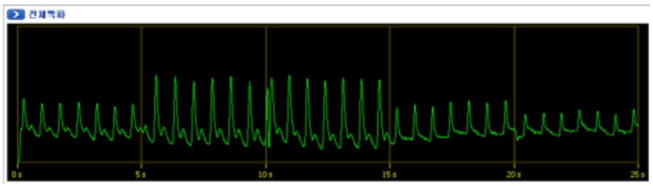
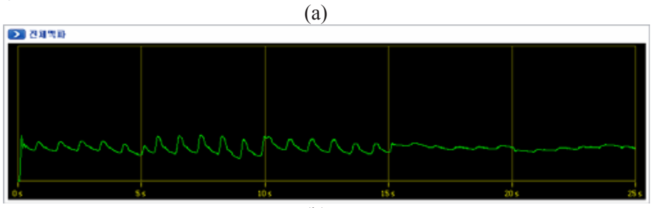
B. *Measurements*

Blood pressure (BP) was measured on the left upper arm using an oscillometric method after 5 min of rest in the sitting position (HEM-780; Omron Healthcare Co., Ltd., Kyoto, Japan). Immediately after measuring BP, the left radial arterial waveform was measured using the tonometric method. We used a multi-step pressure method (DMP-3000; DAEYOMEDI Co., Ltd. Ansan, Korea).

DMP-3000 has robotics mechanism to scan and trace automatically the blood vessel's position accurately and to apply pressure to take a multi-step waveforms in stable. The arterial tonometry sensor, incorporating an array of 5 piezoresistive semiconductor transducers, was designed to find out blood vessel's position accurately and take pulses. This device put the sensor on the left radial artery and applied pressure at multi-steps of 50g, 90g, 140g, 190g, and 240g.



(a)



(b)

Fig. 2 The measured pulse waveforms applied by multi-step pressure. Each step took pulses in 5 seconds. (a) Response patterns by multi-step pressure of 190g , and (b)50g. Each pattern has a relation with the subject's individual characteristics.

Radial arterial pressure waveforms were recorded for 5 seconds for each step. The first and second peaks of systolic and diastolic pressure were automatically detected using fourth derivatives for each radial arterial waveform and averaged. In DMP-3000 this procedure was repeated 5 times depending on five steps of the applied pressure. So we could obtain 5 different radial pulse waveforms for the same position of the same person at different applied pressure. The representative pulse waveform was selected by order of measured pulse height. This method is based on the measurement method of oscillometric blood pressure.

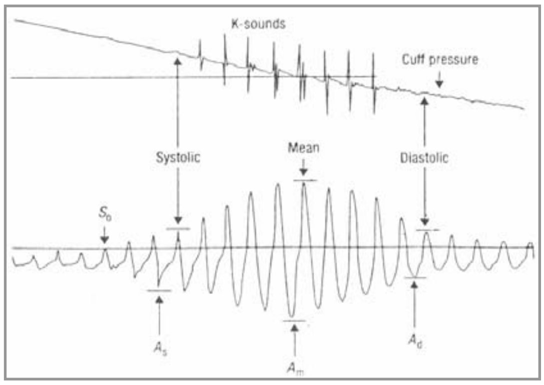
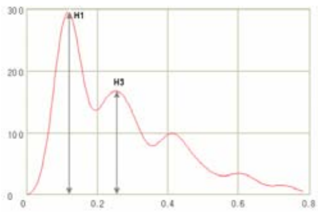


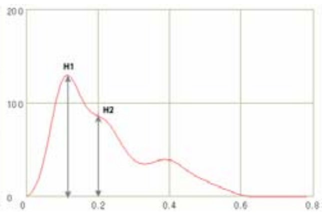
Fig. 3 Diagram of the general method of detecting oscillometric blood pressure .

In peak detecting process, the second peak could not be defined in some pulses, because of no significant peak evenly found using the fourth derivative method. So we defined radial pulse types in 3 categories to calculate Radial-AI.

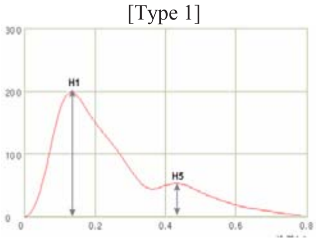
Type 1 has significant second peak, Type 2 has no significant second peak but has inflection point, and Type 3 has no significant second peak and no significant inflection point until the end of systolic period. All pulse types are shown in Figure 4. DMP-3000 automatically classifies pulse type and calculates Radial-AI.



[Type 1]



[Type 2]



[Type 3]

Fig. 4 Diagrams of the three defined pulse types.

C. *Statistical Analysis*

All values were expressed as mean $\pm$ SD, if not specified. The difference between men and women was evaluated by analysis of variance. Kruskal-Wallis test was performed to find out change of AI by the applied pressure. Pulse type occupancy was plotted in pie chart. All statistical analyses were performed using the Minitab statistical software package (MINITAB Corp., Pennsylvania, USA). A probability value of $P<.05$ was considered to be statistically significant.

D. Results

As shown in Table 1, in normal healthy group, height, body weight, BMI, and systolic blood pressures were lower in women than those in men (P<0.001 for all), and radial AI was higher in women than that in men (P<0.01 for all). Heart rate in men was higher than that in women and the applied pressure of the representative pulse in men was lower than that in women (p<0.05 for all).

Table 1. Selected physiological characteristics of normal healthy group

	Male	Female
Age(years)	25.80 ± 7.04	25.06 ± 3.68
Height(cm)	173.45 ± 5.74	160.80 ± 4.19 ***
Weight(kg)	68.90 ± 10.71	50.33 ± 4.34 ***
Body Mass Index	22.84 ± 2.94	19.45 ± 1.21 ***
Heart rate(beat min^{-1})	68.10 ± 12.04	74.40 ± 8.74 *
Systolic BP(mmHg)	119.47 ± 10.92	101.17 ± 9.62 ***
Diastolic BP(mmHg)	69.45 ± 8.06	66.60 ± 7.04
Radial AI (%)	45.69 ± 16.16	54.86 ± 12.89 **
Applied pressure (g)	184.77 ± 40.31	163.93 ± 33.96 *

Data are mean ± SD. *P<0.05; **P<0.01; ***P<0.001, versus male.

As shown in Table 2, in hypertensive group, height, body weight, and systolic blood pressure were lower in women than those in men (P<0.001 for all). Others have no significant differences between women and men in hypertensive group.

Table 2. Selected physiological characteristics of hypertensive group

	Male	Female
Age(years)	59.65 ± 11.24	58.64 ± 9.79
Height(cm)	169.65 ± 5.28	155.21 ± 5.28 ***
Weight(kg)	73.43 ± 9.18	60.67 ± 9.22 ***
Body Mass Index	25.48 ± 2.47	25.13 ± 3.09
Heart rate(beat min^{-1})	66.13 ± 9.56	62.70 ± 8.16
Systolic BP(mmHg)	133.74 ± 13.22	124.67 ± 12.19 *
Diastolic BP(mmHg)	81.22 ± 11.79	76.79 ± 8.12
Radial AI (%)	87.38 ± 11.04	93.24 ± 17.03
Applied pressure (g)	126.17 ± 36.48	108.67 ± 31.67

Data are mean ± SD. *P<0.05; **P<0.01; ***P<0.001, versus male.

Result of Kruskal-Wallis test of AI for the applied pressure is shown in Table 3, and we could find out that AI was inversely proportional to the applied pressure.

Table 3. Result of Kruskal-Wallis test in normal health group for all 5 step pressure. (H : test statistics , DF : degree of freedom)

Normal healthy	Median	Average rank	Z
Step 1 (50g)	64.50	306.3	6.42
Step 2 (90g)	56.95	277.9	4.28
Step 3 (140g)	50.20	228.8	0.23
Step 4 (190g)	45.50	182.9	-3.55
Step 5 (240g)	38.40	134.2	-7.36
	H = 101.55 DF = 4 P = 0.000		
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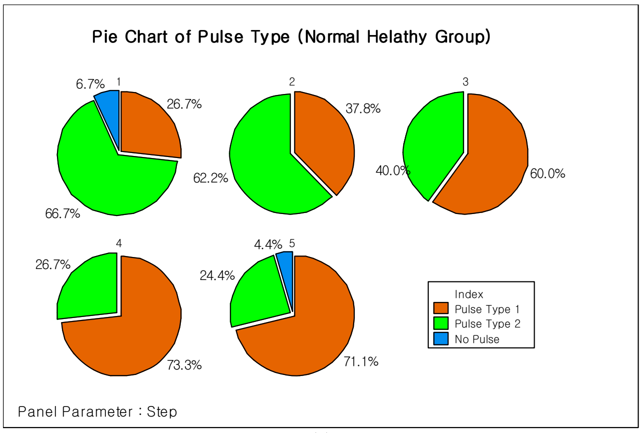
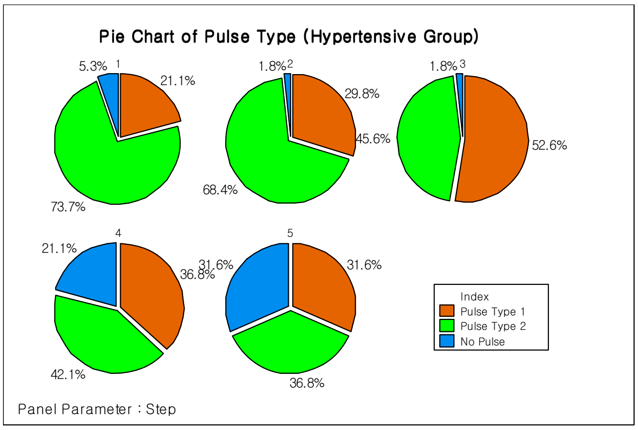
Hypertensive	**Median**	**Average rank**	**Z**
Step 1 (50g)	91.25	131.2	0.65
Step 2 (90g)	91.95	140.2	1.72
Step 3 (140g)	91.00	141.0	1.82
Step 4 (190g)	84.10	108.7	-1.72
Step 5 (240g)	84.20	93.7	-2.99
	H = 15.18 DF = 4 P = 0.004		
	H = 15.19 DF = 4 P = 0.004		

Pie charts of the pulse type occupancy are shown in Figure 5.



(a)



(b)

Fig. 5 Pie charts of pulse type occupancy in normal healthy group(a) and hypertensive group(b)

III. Conclusions

In the present study, we defined the radial pulse waveform types in view of peripheral reflected waves. All three types of pulses were defined and observed in normal healthy and hypertensive groups. Physical characteristics in the hypertensive group had no significant differences between women and men. We found out that the measured pulse types were changed by the applied pressure in the same position. Especially Type 3 was not observed all in sub-groups. Normal healthy group had more people of pulse Type 1 than hypertensive group did. Normal healthy group had a representative pulse near the applied pressure step of 3 or 4. In step 3 pulse Type 1 had 60.6% and in step 4 pulse Type 1 had 73.3% occupancy. In hypertensive group a representative pulse was shown in step 2 and 3. In step 2 pulse Type 1 had 29.8%, in step 3 pulse Type 1 had 52.6% occupancy. In hypertensive group, many cases showed no pulse detect in step 4 and step 5. Radial AI was inversely proportional to the applied pressure especially in young healthy population.

Further study is required to determine the optimal pressure applied for cardiac diseases, and to develop hemodynamic theory to analyze the change of pulse types and the pulse waveform characteristics in the same position of the same person.

Acknowledgment

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