Determinants of the First Derivative of Doppler Blood Flow Velocity in Common Carotid Artery

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Abstract

The aim of this study is determine first derivative of blood flow velocity (FDBFV) in common carotid artery (CCA) in order to evaluate cardiovascular functions. The extracted derivative features suggest the acceleration waves which able to provide aging index (AGI) in the cardiovascular system. In the study, acceleration wave derived from FDBFV consist of a, *b, c, d, e* and *f* waves. The waves of *a, b, c, d, e* and *f* represent the initial positive, early negative, re-increasing, late redecreasing, diastolic positive waves and diastolic negative waves, respectively. The FDBFV waveforms of 227 healthy volunteers are statistically analyzed in the study. As a result, AGI in FDBFV (r=0.727, p<0.0001) shows strong correlation and consistency as compared to the other previuos study. In particular, there are significant correlations between systolic blood pressure, gender and heart rate in f waves. We found that there are sensitive to blood pressure and unknown wave freatures in CCA. In conclusion, FDBFV in CCA is an effective method to evaluate the vascular aging.

Keywords – 1301A, 1302, 7102

1 Introduction

Pulse wave or blood flow analysis is well known as an important tool to evaluate the vascular effects of aging, hypertension and atherosclerosis [1]. There are two kinds of non-invasive technique to measure blood flow, one is a Doppler ultrasound method and the other is an optical one. The Doppler ultrasound method is widely used to measure hemodynamic in blood vessels as arteries exist in the deep place of the human tissue.

Analyses of the Doppler power spectrum and velocity waveforms are useful for assessing and diagnosing cardiovascular disease. Theoretically the first derivative of the velocity on the Doppler wave represents the acceleration of the flow. It was described to the automated boundary detection of the systolic Doppler flow [2] but has not yet describe in the aging index factor. Second derivative of photoplethysmogram (SDPTG) produces acceleration wave which has the same output as FDBFV. However, the signal produced in SDPTG is not contained the f wave. The aim of the study is to investigate the determinants of first derivative of Doppler blood flow velocity in CCA to evaluate the cardiovascular functions affected by gender, blood pressure and body fat.

2 Methods and Materials

In this study, blood velocity data from the CCA were collected using the developed wireless measurement system. Measurements of BFV were noninvasively detected by using Doppler ultrasound method. The measurement system consists of a probe, a Doppler signal discriminator (DSD), a transmitter, a receiver, an analog-digital converter and laptop personal computer.

The system has been developed to a miniaturized Doppler blood flow velocity (BFV) measurement device to monitor BFV at CCA with synchronization measurement of electrocardiogram and blood pressure at brachial artery. The systolic blood pressure (SBP) and the diastolic blood pressure (DBP) were measured for the left brachial artery using an automatic blood pressure monitor (Tango, SunTech Medical, US). The mean blood pressure (MBP) and the pulse blood pressure (PP) were calculated using DBP+(SBP−DBP)/3 and SBP-DBP, respectively.

Fig. 1 represents the envelope waveform of the flow velocity was extracted from the spectrogram using a threshold method. The velocity envelope was computed using an ensemble averaging technique for 30 consecutive cardiac cycles. The averaged velocity waveforms (Vp) were used to identify characteristic points in the blood velocity waveforms and to calculate blood velocity indices [3, 4]. Acceleration waveforms as illustrated in Fig. 1 are acquired from derivative of the Vp.

The FDBFV consists of six waves, represented *a, b, c, d, e* and *f* as the initial positive, early negative, re-increasing, late re-decreasing, diastolic positive waves and diastolic negative waves, respectively. To describe the FDBFV components quantitatively, the height of each wave was measured from the baseline as illustrated in Fig. 1. Using six waves of FDBFV, we

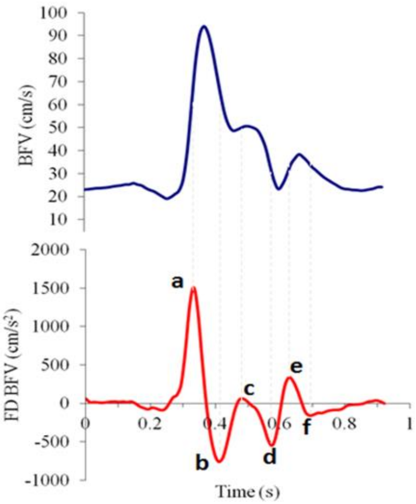

Fig. 1: An envelope velocity waveform and its first derivative of BFV

calculated *b:a*, *c:a*, *d:a*, *e:a* and *f:a* ratios to use for statistical analysis.

According to the previous study by Takazawa et al, aging index (AGI) was defined as *(b-c-d-e)/a* [6]. The AGI was considered as markers of the dispensability of large arteries, the intensity of reflected wave from periphery and vascular aging. As f wave can be measured clearly, we proposed to insert f value to the equation to evaluate AGI for further analysis.

Data were expressed as mean±standard deviation (SD). To provide an overall view, Pearson's correlation analysis was performed to confirm the relationship between all outcome variables and factors.

3 Result

The study was performed in a total of 227 healthy subjects (138 male, 89 female) between 20 and 70 years old which were normotensive. The measurement was taken from each subject for two minutes to detect the cervical arterial blood flow velocity at rest sitting posture.

Table 1. presents the gender-related differences in FDBFV ratio data in the subjects. There were significant ($p<0.05$) differences in the FDBFV of *f:a* ratio and significant ($p<0.001$) differences in *b:a*, *e:a* and *(b-c-d-e+f)/a* parameter with the gender. The f characteristic, data clearly show that there is a significant gender difference ($p<0.05$) in the FDBFV waveforms of the CCA.

Table 2. represents age-related increases in *b:a* and *f:a* ratios and decreases in *c:a, d:a,* and *e:a* ratio. The equation of *(b-c-de)/a* was defined as SDPTG aging index and age [6]. The parameter used by K. Takazawa et al. has been used in this study to measure AGI. Although the index value after considering the f wave *(b-c-d-e+f)/a* ($r=0.727$, $p<0.001$) was slightly lower than *(b-c-d-e)/a* ($r=0.737$, $p<0.0001$), but there were no large difference has been observed.

By using stepwise regression analysis, we found that the *f:a* was very significant correlated to the cardiovascular factor as we expected [5]. There were correlation with the systolic blood pressure ($\beta=0.507395$, $p<0.001$), sex ($\beta=-0.42695$, $p<0.001$), and heart rate ($\beta=-0.25036$, $p<0.001$). However, there is no significant correlation seen in others cardiovascular factors such as body mass index, body fat and weight.

4 Discussion

The major finding in this paper is the determinant of the FDBFV as an aging index in the hemodynamics system. This outcome of the flow velocity waveform may contributes to the improved of cardiovascular risk and autonomic nervous system. The correlations between gender of an early (*b:a, c:a*) and late (*d:a, e:a, f:a*) systolic phase were negative and positive respectively. The strength of this correlation increased gradually from early to late systole as show in the previous study [5]. To further investigate the evaluation of the vascular effect of aging by FDBFV, we calculate the acceleration wave correlation with age and do the multiple regression analysis.

By considering f wave in the newly proposed AGI calculation in the FDBFV we found that, there was strong correlation between age and FDBFV in CCA. Furthermore, the r value is not much different when comparing with the technique to derive AGI in SDPTG which is establishes method ($r=0.737$, $r= 0.727$ respectively). These observations support the validity of the current vascular aging index [6]. The results represent, there were significant correlation with systolic blood pressure, gender and heart rate in *f:a* ratio. We already expected to see the correlation of this FDBFV with some cardiovascular factor as its measurement done on CCA which is near to the heart [7]. Compare to the SDPTG, the measurement focusing on the small capillary instead directly to the artery. Thus it is not sensitive enough and cannot detect much of cardiovascular changes.

Table 1. Gender-related differences in FDBFV ratio data

Parameter	Female (n=89)	Male (n=138)
b:a	-0.379 ±0.128	-0.420 ±0.154*
c:a	-0.002 ±0.064	-0.006 ±0.064^NS
d:a	-0.329 ±0.082	-0.325 ±0.110^NS
e:a	0.129 ±0.055	0.150 ±0.058*
f:a	-0.104 ±0.025	-0.119 ±0.032**
(b-c-d-e+f)/a	-0.273 ±0.241	-0.354 ±0.277*
(b-c-d-e)/a	-0.169 ±0.231	-0.234 ±0.270^NS

Significances indicated as *p<0.05, **p<0.001, NS: not significant

Table 2. Acceleration wave change with age

ratio	r	p
b:a	0.729	<0.0001
c:a	-0.269	=0.004
d:a	-0.583	<0.0001
e:a	-0.236	=0.009
f:a	0.261	=0.005
index	r	p
(b-c-d-e)/a; (AGI)	0.737	<0.0001
(b-c-d-e-f)/a	0.727	<0.0001

AGI: aging index, r: correlation coefficients, p : significant coefficient

5 Conclusion

These data extend recent findings on the relationship between FDBFV and AGI measurement. We showed that the findings of the f wave in the FDBFV indicate the missing biological information in previous method. In addition, it can be monitored easily and non-invasively in the pulse wave acceleration art. For the further investigation, we will study the cardiovascular risk correlation in the FDBFV

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