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SEMI-QUANTITATIVE ANALYSIS OF CAROTID ARTERIAL WAVE FORM - ITS PHYSIOLOGICAL CHANGES WITH AGING IN NORMAL SUBJECTS

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Abstract

Materials: One-hundred and eighty-seven normal subjects were selected and classified into 5 groups according to their age.

Method: Carotid arterial pulse wave was obtained from each individual and various calculations were made in terms of its timing and amplitude.

Results and comments: As the age advanced, the following changes were found; decrease in amplitude of the percussion wave, increase in height of the tidal wave, increase in level of the dicrotic notch, indistinction of the dicrotic wave and widening in degree of the percussion to the tidal wave. These physiological alterations with aging process may be of value as bacic data when evaluating abnormal morphology to be found in hypertension or arteriosclerosis which being prepared.

INTRODUCTION

In the clinical application of the carotid arterial pulse (CAP) there are 1) the identification of two components of the second heart sound, 2) the auxilliary diagnosis of left ventricular out-flow tract abnormality by specific wave form, and 3) the measurement of the left ventricular systolic time interval by timing analysis. Among these categories the quantitative studies on the morphological analysis has been rarely reported[1,2] because subjective factors cannot be excluded in the diagnosis of the wave forms.

The CAP gives morphological changes[1] in the conditions such as arteriosclerosis and hypertension, but for the differentiation of normal waves from pathological ones it is indispensable to evaluate the changes

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of wave forms accompanying the aging process. Therefore, we have analyzed subjectively the changes brought about in the quantitative wave form by the aging dealing with many normal individuals as the subjects of our study.

SUBJECTS AND METHOD

The subjects consisted of 187 individuals selected from about 1,000 cases whose CAP was recorded at the cardiac laboratory of the Kawasaki Medical School Hospital during the period from 1974 to 1975. These were all normal individuals without any abnormality in their medical history, physical examinations, electrocardiogram, and chest X-ray findings, and they were classified into 5 groups according to age. The age group (5 groups of A-E) and sex are shown in Table 1.

TABLE 1

Number of cases, sex and age in 5 groups

	Cases	Age (ave.)		Cases	Age (ave.)
A	31 M 24 F 7	19> (13.26)	D	38 M 29 F 9	40-49 (44.29)
B	55 M 34 F 21	20-29 (22.62)	E	35 M 28 F 7	>50 (55.86)
C	28 M 25 F 21	30-39 (35.18)	total	187 M140 F 47	

The CAP were recorded with the subjects in supine position, after 15-minute rest, using a Perrotte-type pick-up apparatus applied to the pulsating site of the right common carotid artery by hand and it was recorded on a mingograph at the paper speed of 100 mm/sec. Simultaneously the phonocardiogram (at the left lower sternal border) and electrocardiogram (V_5 in the chest lead) were recorded.

MEASUREMENT AND ANALYSIS

The measurements of A) timing and B) amplitude were carried out from each CAP as shown in Fig. 1.

As for A) timing, the beginning of ejection of CAP (the beginning of upstroke), i.e. upstroke point was designated as US, the terminal point of ejection phase (dicrotic notch) as DN, the summit of the first peak in the ejection wave (percussion wave) as PW, also of the second

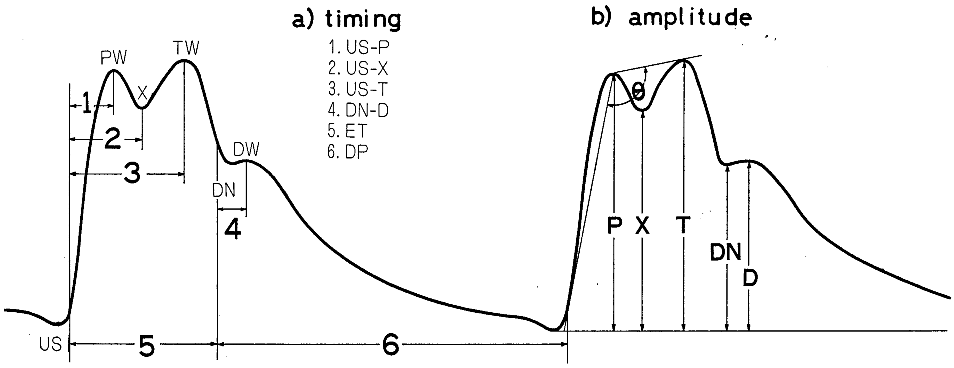

Fig. 1. How to measure a) timing and b) amplitude of the cacotid artery pulse wave. See the text for abbreviations.

peak (tidal wave) as TW, the trough between the two as X, and the peak of dicrotic wave at early diastole as DW. In addition, the ejection time was designated as ET, and the diastolic phase from DN to next US as DP. These six items were selected.

For the measurement of B) wave amplitude, the site where the recording is stable is selected, by taking the terminal point of the diastole as the base line, the distance from base line to PW was taken as P, that to X as X, to TW as T, and that to DN as DN, and that to DW as D. The angle formed by PW and TW was designated θ, as shown in the figure. These six items were selected.

Further, using the CAP with simultaneously recorded electrocardiogram, the total systole (Q-II : from the beginning of Q to the beginning of the second heart sound) and pre-ejection period (PEP : the difference between Q-II and ET) as well as ET/PEP were calculated.

With 9 items of the timing analysis such as ET, PEP, ET/PEP, (US-P)/ET, (US-X)/ET, (US-T)/ET, (DN-D)/ET, and (DN-US)/ET, and 8 items of the wave amplitude such as P/X, T/X, DN/X, D/X, T/P, DN/P, DN/T and θ, the average value and its one standard deviation in each age group, and the difference in their values of group A and each age group wave compared and studied their statistical significance.

RESULTS

Table 2 shows the average value and its one standard deviation of the timing analysis (2-a) and of the amplitude analysis (2-b).

Fig. 2-a and 2-b also show the average values of two kinds of analysis values connected by a line according to each age group.

TABLE 2

Calculated values of timing (2-a) and amplitude (2-b) analyses in 5 different age groups

	Heart Rate	ET (msec)	PEP (msec)	ET/PEP	value when ejection time=1.00				
					US-P	US-X	US-T	DN-D	DN-US
A	72.13 ±13.16	276.94 ±17.16	89.19 ±19.54	3.23 ±0.03	0.34 ±0.05	0.61 ±0.07	0.76 ±0.06	0.29 ±0.09	1.98 ±0.39
B	63.45* ±10.43	285.64 ±21.82	98.27 ±12.29	2.95* ±0.39	0.32 ±0.05	0.58 ±0.09	0.76 ±0.07	0.27 ±0.09	2.35* ±0.39
C	66.71 −11.89	276.96 ±16.74	101.79* ±15.23	2.78* ±0.44	0.31 ±0.05	0.51* ±0.09	0.73 ±0.08	0.21* ±0.06	2.25* ±0.43
D	68.55 ±12.04	280.00 ±20.24	98.55 ±15.59	2.92* ±0.50	0.29* ±0.05	0.43* ±0.07	0.69* ±0.07	0.17* ±0.06	2.12 ±0.36
E	65.00* ±10.92	279.57 ±25.25	100.44* ±11.96	2.81* ±0.42	0.30* ±0.05	0.45* ±0.11	0.71* ±0.08	0.19* ±0.07	2.32* ±0.38

	value when X=1.00				T/P	DN/P	DN/T	θ degee
	P	T	DN	D				
A	1.43 ±0.24	0.93 ±0.07	0.53 ±0.12	0.64 ±0,13	0.67 ±0.12	0.38 ±0.11	0.56 ±0.11	54.26 ±16.45
B	1.25* ±0.17	0.97 ±0.08	0.59* ±0.10	0.68 ±0.08	0.79* ±0.16	0.48* ±0.12	0.61 ±0.09	64.76 ±25.13
C	1.16* ±0.14	1.05* ±0.12	0.62* ±0.12	0.66 ±0.12	0.93* ±0.20	0.55* ±0.14	0.59 ±0.11	90.64* ±29.42
D	1.02* ±0.07	1.13* ±0.10	0.72* ±0.12	0.72 ±0.13	1.11* ±0.15	0.72* ±0.17	0.63* ±0.09	119.53* ±24.35
E	1.03* ±0.09	1.12* ±0.14	0.74* ±0.14	0.75* ±0.14	1.10* ±0.18	0.73* ±0.16	0.66* ±0.09	115.89* ±26.32

±=1 standard deviation
*=statistically significant difference ($p < 0.05$) against the value of group A

A) *Timing analysis :* Excepting ET, all the measured values showed a significant change in high age group when compared with group A. In the high age group PEP was lengthened significantly, and ET/PEP was similarly shortened, the ratio of ET to US-P, US-X, US-T as well as to DN-D all revealed a significant shortening.

B) *Wave amplitude analysis :* When compared to group A, in the high age group P/X was shortened, while T/X, DN/X and D/X were prolonged significantly. T/P, DN/P and DN/T were prolonged and θ was increased, all significantly.

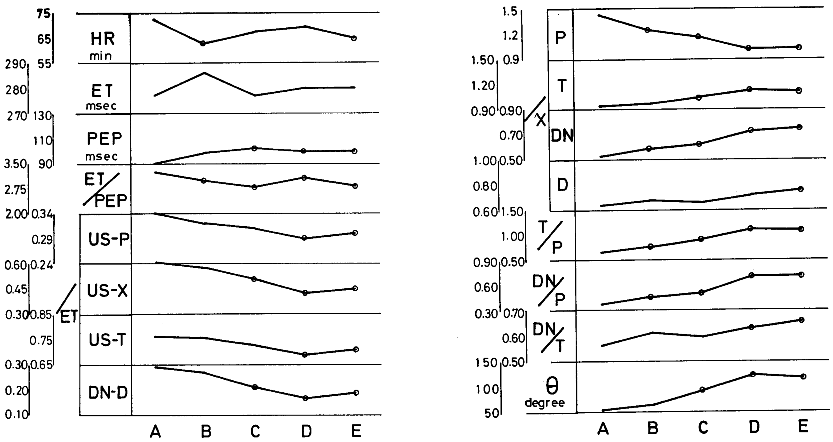

Fig. 2. Calculated average values of timing (2-a) and amplitude (2-b) analyses in 5 different age groups.
-●-=statistically significant difference ($p < 0.05$) against the group A

Fig. 3 shows schematically the pattern of CAP in each age group on the basis of timing and wave amplitude analysis. The main changes

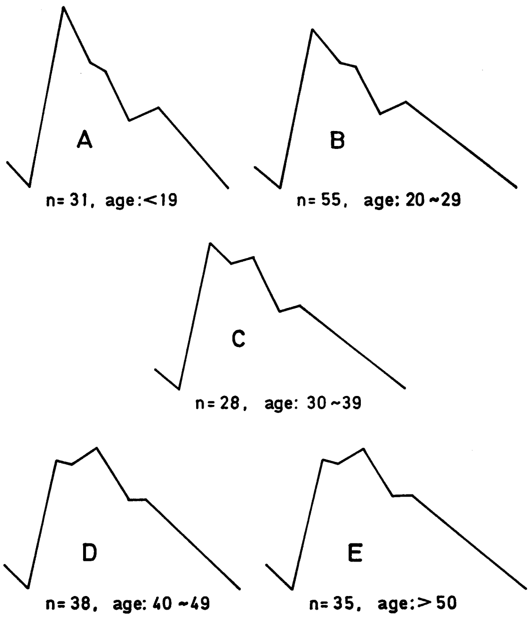

Fig. 3. Morphological presentations of 5 carotid artery wave forms, condtructed based on the mean values in 5 groups.

of wave shape due to advance in age were a shortening of PW, a lengthening of TW, an increase of DN level, an obscuring tendency of DW, and an obtusing tendency of θ.

DISCUSSION

The diagnostic significance of CAP wave forms can be seen in cockscomb type specific to aortic valvular stenosis, bisferious pulses observed in a high output state such as aortic valvular insufficiency or hyperthyroidism and also in the slow secondary wave specific to idiopathic hypertrophic subaortic stenosis as well as in anacrotic pulses observable in hypertension and arteriosclerosis. However, these are all the terms given to morphological features from a subjective viewpoint.

The shape of CAP seems to show changes with age in normal individuals. In comparing such a aging change by the timing analysis, US-P, US-T, and DN-D were all shortened significantly with advance in age (Table 2-a). In the wave amplitude analysis P decreased by aging, while T, DN, D as well as T/P. The DN/P and DN/T increased. Also the angle (θ) formed by PW and TW increased (Table 1-b). These results indicate that there were the decrease of PW, the increase of TW, the increase of DN level and an obscuring tendency of DW with advance in age (Fig. 3).

The percussion wave (PW) has been reported to be affected by the contractility and ejection condition of the left ventricle. Consequently, a greater decrease of PW seems to be mainly caused by the decrease in the contractility and ejection force. Clinically, the index of ET/PEP is often used as one of indices for the contractility and ejection force. ET/PEP was significantly decreased in all other groups than in the group A, but there was no significant difference among groups B to E. Therefore, the decrease in PW along with advance in age cannot be fully explained by only the foregoing factors and the other factors to be mentioned later should be taken into consideration. It is already found[1] that the tidal wave (TW) increases with aging.

The increase of TW, according to the model experiment of Masuda[3], occurs by arteriosclerosis or by the increase of peripheral resistance. This fact can be substaniated[1] by the behaviors of TW to various drugs, such as the decrease of TW on inhalation of amyl nitrite and the increase of TW by angiotension.

As mentioned above, the increase of TW seems to be caused by the raised peripheral resistance, and the increase in the vascular elasticity and in the pulse transmission velocity, hence even in healthy individuals as they grow older the tidal wave (TW) increases because of the degeneration occurring at vessel wall.

On the other hand, both PW and TW, mentioned here, are not an absolute values but a relative values between the two. Thus the changes occurring in PW and TW due to aging, i.e. the fall in PW and the rise in TW, are also the mutual changes. Therefore, the fall in PW due to aging as aforementioned cannot be induced only by the pathological decrease in the contractility or ejection force, but there seem to be other factors being involved such as the relative increase of TW.

As for the reasons for the fluctuations of DN level and TW in the same direction[5], aside from the conditions of the peripheral resistance just mentioned, it seems that DN exists right on the descending limb of TW so that DN rises or falls along with rise or fall or TW.

Dicrotic wave (PW) formed at an early phase in diastole decreased further from the young age group to older age groups. The increase of DW can be observed in cardiomyopathy having a low out-put state[6], while Masuda et al.[3] state that the decrease of DW is caused by arteriosclerosis. Our results likewise showed a similar decreasing tendency from the young age to the older age groups.

From the above findings it has been subjectively demonstrated that in both young and old age groups there occurs a significant difference in the shape of the carotid arterial pulse wave. Therefore, such findings may be quite useful as the basic data in evaluating the abnormality of the wave form in hypertension and arteriosclerosis.

Furthermore, by representing numerical values of the morphological analysis, that had been subjective, since it is now possible to take advantage of computer, these data would serve greatly in the future clinical practice.

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