**Fumio Otsuka: A Study of the Relationship between Pulse Wave Velocity of Human Aorta and its Postmortem Histopathology. Tokyo Jikkei Medical College Journal, 1973; 88:11-16**

Translated by

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## Summary

The purpose of this study is to clarify whether or not a hardness of aorta measured by a pulse wave velocity (PWV) method can be an index for pathological changes of the aorta.

Materials consisted of aorta samples from 72 patients whose antemortem pulse wave velocity had been measured. The pulse wave velocity was calculated from the length of the aorta and the transmitting time of the pulse wave. Pathological changes were examined with reference to non-fibrotic thickening, streaks and spots, diffuse fibrotic thickening, atheroma, ulceration and calcification of the intima by applying the point counting method. Histopathological specimens were taken from 4 portions of the aorta and stained with Elastica Van Gieson. Volume percentage of elastic fibers, collagens and muscle cells in the media were obtained by using a Karl-Zeiss' eyepiece I. The relationship between the pulse wave velocity and the pathological changes was examined by multivariate analysis.

Results obtained were:

Elasticity of the aorta measured by the PWV method was well correlated with the degree of pathological changes. A multiple correlation coefficient (R), 0.810, was obtained by regressing PWV on four intimal and two medial factors. This means that the elasticity decreases with progression in the pathological changes. The weight of each intimal factor for sclerosis successively increased in the order of the diffuse fibrotic thickening, formation of atheroma and calcification. The quantitative estimation of the pathological changes in the aorta is possible by the measurement of PWV.

Sclerosis in the aorta generally precedes to the cerebral and coronary arteries which often result in a fatal process. Accordingly, the measurement of aortic sclerosis using the PWV method has and important clinical significance in prediction of arteriosclerosis in cerebral and coronary arteries.

## Sample and Method

The aorta was excised from decreased patients whose PWV has been measured prior to death between 1964 and 1969. A total of 72 cases (47 males and 25 females) were the study sample ranging from 13 years to 86 years of age, as shown in Table 1.

The Fukuda Schwarzer Physiopolygraph Model ST-4, which was used as a PWV measurement device, was capable of synchronously recording electrocardiogram, cardiac sound and two channels of pulse wave patterns. For recording, the subject was first laid in the supine position; the cardiac sound pickup microphones is placed on the chest wall. Then, pulse wave pickup microphones are attached to the throbbing parts of both carotid and femoral arteries. Recognizing the precomponents of cardiac II sound, uprise of two pulse waves and the scar on the carotid artery, let the subject hold their breath slightly, and synchronous recording is made during 5 to 6 heart beats. Immediately after the recording, the blood pressure at the right brachial artery is measured.

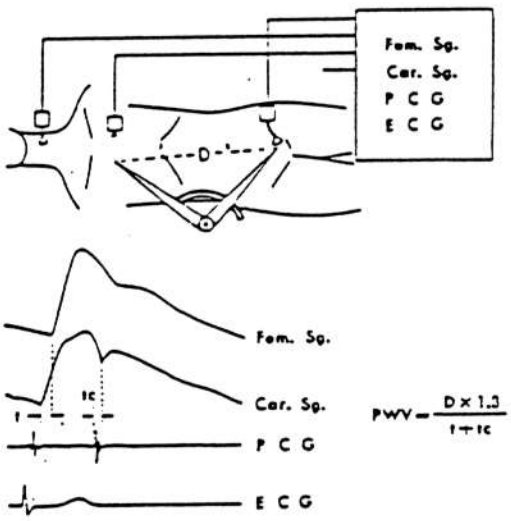



**Fig. 1 Method of registration and calculation of pulse wave velocity of aorta**

The time lag between the uprise of the carotid artery pulse wave and that of the femoral arterial pulse wave is measured as t. The time lag between the precomponent of the cardiac II sound and the scar of the carotid artery is measured at $T_c$. The actual length of the measuring portion of the aorta was obtained by multiplying the straight distance, D, between the second intercostal region of the right margin of the sternum and throbbing part of the femoral artery by the anatomical modification value, 1.3. The aortic pulse wave velocity (PWV), is expressed as:

$$PWV = [\ (D \times 1.3) / (t + T_c)\ ]_p$$

where p is the minimum internal pressure or diastolic blood pressure. PWV value was corrected for diastolic blood pressure at 80 mm Hg by using Table 6 of Hasegawa's paper (Appendix II).

Table 1. Materials and Findings

| No. | Sex | Age | Diagnosis | PWV (m/sec) (measured) | Intima (%) non-fib. | fib. | atheroma | cal | Core's Index | ASSA Index | PWV (m/sec) (estimated) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | F | 27 | Peritonitis carcinomatose | 5.1 | 100(17)* | 0 | 0 | 0 | 1 | 0 | 7.4 |
| 2 | M | 24 | Leukemia | 5.6 | 100 | 0 | 0 | 0 | 0 | 0 | 7.1 |
| 3 | F | 45 | Cholelithiasis | 5.8 | 100(40) | 0 | 0 | 0 | 1 | 0 | 7.2 |
| 4 | F | 31 | Cancer of stomach | 6.1 | 100(19) | 0 | 0 | 0 | 1 | 0 | 7.0 |
| 5 | M | 28 | Chronic nephritis | 6.2 | 100(35) | 0 | 0 | 0 | 1 | 0 | 7.3 |
| 6 | M | 55 | Malig. hypertension | 6.2 | 84(11) | 0 | 16 | 0 | 1 | 12 | 7.4 |
| 7 | M | 20 | Uremia | 6.3 | 98 | 0 | 2 | 0 | 1 | 2 | 7.4 |
| 8 | M | 52 | Chronic nephritis | 6.3 | 100(33) | 0 | 0 | 0 | 1 | 0 | 6.8 |
| 9 | M | 21 | Chronic nephritis | 6.4 | 100 | 0 | 0 | 0 | 0 | 0 | 7.0 |
| 10 | F | 22 | Malig. schwannoma | 6.4 | 100 | 0 | 0 | 0 | 0 | 0 | 7.2 |
| 11 | M | 45 | Cirrhosis of liver | 6.5 | 100(10) | 0 | 0 | 0 | 1 | 0 | 7.1 |
| 12 | F | 23 | Leukemia | 6.8 | 98(34) | 0 | 2 | 0 | 1 | 2 | 7.4 |
| 13 | F | 46 | Cancer of stomach | 6.9 | 88( 4) | 0 | 12(11)** | 0 | 1 | 9 | 7.6 |
| 14 | M | 18 | Chronic nephritis | 7.0 | 100(16) | 0 | 0 | 0 | 1 | 0 | 7.0 |
| 15 | M | 26 | Cancer of liver | 7.0 | 94(40) | 0 | 6 | 0 | 1 | 5 | 7.1 |
| 16 | M | 36 | Cancer of stomach | 7.1 | 98 | 0 | 2 | 0 | 1 | 2 | 6.9 |
| 17 | M | 51 | Cirrhosis of liver | 7.1 | 39 | 0 | 58( 2) | 3 | 11 | 46 | 7.8 |
| 18 | M | 64 | Cancer of lung | 7.1 | 73(22) | 0 | 27 | 0 | 2 | 20 | 8.0 |
| 19 | F | 43 | Periodic paralysis | 7.2 | 100(20) | 0 | 0 | 0 | 1 | 0 | 7.6 |
| 20 | M | 50 | Myocardial infarction | 7.2 | 92(13) | 0 | 8 | 0 | 1 | 6 | 7.6 |
| 21 | M | 57 | Mediastinal tumor | 7.2 | 92(15) | 0 | 8 | 0 | 1 | 6 | 7.4 |
| 22 | F | 58 | Cancer of stomach | 7.3 | 94 | 0 | 6 | 0 | 1 | 5 | 7.6 |
| 23 | M | 34 | Chronic nephritis | 7.4 | 70(43) | 0 | 30 | 0 | 4 | 23 | 8.0 |
| 24 | M | 38 | Cancer of liver | 7.4 | 80( 8) | 0 | 20 | 0 | 1 | 15 | 7.3 |
| 25 | F | 58 | Cancer of liver | 7.4 | 96(20) | 0 | 4 | 0 | 1 | 3 | 7.7 |
| 26 | M | 70 | Cholangioma | 7.4 | 99(25) | 0 | 1 | 0 | 1 | 1 | 8.1 |
| 27 | M | 13 | A.S.D. and A.I. | 7.5 | 100 | 0 | 0 | 0 | 0 | 0 | 7.2 |
| 28 | F | 50 | Liver atrophy | 7.5 | 100(21) | 0 | 0 | 0 | 1 | 0 | 7.4 |
| 29 | M | 64 | Cirrhosis of liver | 7.5 | 95( 8) | 0 | 5 | 0 | 2 | 4 | 7.8 |
| 30 | M | 35 | Chronic nephritis | 7.7 | 78 | 0 | 22 | 0 | 2 | 17 | 7.6 |
| 31 | M | 53 | Cancer of stomach | 7.7 | 100(67) | 0 | 0 | 0 | 1 | 0 | 7.3 |
| 32 | M | 61 | Leukemia | 7.7 | 100(18) | 0 | 0 | 0 | 1 | 0 | 7.4 |
| 33 | M | 52 | Cancer of liver | 7.8 | 67(27) | 0 | 33( 1) | 0 | 5 | 25 | 8.2 |
| 34 | M | 33 | Cirrhosis of liver | 7.9 | 97(11) | 0 | 3 | 0 | 1 | 2 | 7.2 |
| 35 | F | 65 | Cancer of bladder | 7.9 | 34 | 0 | 66(15) | 0 | 20 | 46 | 8.8 |
| 36 | M | 51 | Cirrhosis of liver | 8.0 | 100(34) | 0 | 0 | 0 | 1 | 0 | 6.7 |
| 37 | M | 29 | Chronic nephritis | 8.1 | 100(62) | 0 | 0 | 0 | 1 | 0 | 7.6 |
| 38 | F | 36 | Chronic nephritis | 8.1 | 109(15) | 0 | 0 | 0 | 1 | 0 | 7.4 |
| 39 | M | 53 | Cerebral hemorrhage | 8.2 | 0 | 51(6)* | 49( 1) | 0 | 11 | 75 | 9.6 |
| 40 | M | 57 | Cirrhosis of liver | 8.2 | 75 | 0 | 22 | 3 | 2 | 19 | 7.9 |
| 41 | M | 40 | Chronic nephritis | 8.4 | 0 | 56(23) | 34 | 0 | 9 | 75 | 9.0 |
| 42 | F | 47 | Cancer of bladder | 8.4 | 99(34) | 0 | 10 | 0 | 1 | 8 | 7.9 |
| 43 | M | 68 | Cancer of liver | 8.4 | 47( 8) | 0 | 49( 4) | 4 | 13 | 41 | 9.0 |
| 44 | M | 38 | Cancer of stomach | 8.5 | 98(29) | 0 | 2 | 0 | 1 | 2 | 6.9 |
| 45 | M | 56 | Cancer of lung | 8.5 | 67( 4) | 0 | 33 | 0 | 2 | 25 | 8.3 |
| 46 | F | 72 | Cancer of stomach | 8.5 | 43 | 0 | 55( 4) | 2 | 12 | 41 | 9.0 |
| 47 | M | 67 | Cirrhosis of liver | 8.6 | 0 | 17 | 82(13) | 1 | 23 | 75 | 9.6 |
| 48 | M | 43 | Chronic nephritis | 8.7 | 98 | 0 | 2 | 0 | 1 | 1 | 7.1 |
| 49 | F | 56 | Chronic nephritis | 9.1 | 100(22) | 0 | 0 | 0 | 1 | 0 | 7.4 |
| 50 | F | 73 | Cirrhosis of liver | 9.1 | 0 | 41( 2) | 36 | 23 | 31 | 82 | 11.5 |
| 51 | F | 56 | Cirrhosis of liver | 9.2 | 0 | 30 | 67( 5) | 3 | 18 | 70 | 9.6 |
| 52 | M | 84 | Encephalomalacia | 9.2 | 0 | 39 | 56( 5) | 5 | 20 | 76 | 9.5 |
| 53 | M | 58 | Cancer of lung | 9.4 | 0 | 49(17) | 50(10) | 1 | 21 | 76 | 9.4 |
| 54 | F | 62 | Myocardial infarction | 9.4 | 5 | 65(21) | 27( 2) | 3 | 14 | 71 | 9.3 |
| 55 | M | 52 | Cirrhosis of liver | 9.5 | 100(30) | 0 | 0 | 0 | 1 | 0 | 7.6 |
| 56 | F | 53 | Chronic nephritis | 9.5 | 98(44) | 0 | 0 | 2 | 2 | 2 | 7.8 |
| 57 | F | 70 | Subarachinoid hemorrhage | 9.5 | 0 | 39 | 61 | 0 | 10 | 75 | 9.8 |
| 58 | F | 76 | Cancer of bladder | 9.5 | 67 | 0 | 29 | 4 | 3 | 26 | 8.4 |
| 59 | M | 48 | Heart failure | 9.6 | 63(23) | 0 | 37 | 0 | 4 | 29 | 7.6 |
| 60 | M | 59 | Cancer of bladder | 9.6 | 0 | 62(36) | 38( 2) | 0 | 12 | 75 | 9.1 |
| 61 | M | 64 | Cancer of lung | 9.8 | 25( 1) | 0 | 74(23) | 1 | 29 | 57 | 9.0 |
| 62 | M | 72 | Heart failure | 10.0 | 0 | 36 | 63( 6) | 1 | 23 | 75 | 9.6 |
| 63 | F | 55 | Cholelithiasis | 10.1 | 52(17) | 0 | 48 | 0 | 5 | 36 | 8.9 |
| 64 | M | 72 | Cancer of bladder | 10.1 | 0 | 85(35) | 13 | 2 | 12 | 75 | 9.0 |
| 65 | M | 64 | Myocardial infarction | 10.3 | 0 | 20(11) | 51 | 29(9)** | 36 | 80 | 11.3 |
| 66 | F | 53 | Cancer of lung | 10.6 | 59 | 0 | 41 | 0 | 2 | 35 | 8.6 |
| 67 | M | 72 | Cancer of stomach | 10.6 | 0 | 39 | 49 | 12( 7) | 21 | 78 | 10.9 |
| 68 | M | 73 | Cancer of lung | 11.4 | 0 | 12 | 88 | 0 | 10 | 75 | 10.2 |
| 69 | F | 86 | Encephalomalacia | 12.3 | 0 | 19 | 64 | 17 | 26 | 80 | 11.2 |
| 70 | F | 74 | Cancer of lung | 12.4 | 0 | 13 | 57 | 30(20) | 37 | 83 | 11.0 |
| 71 | M | 62 | Cirrhosis of liver | 13.1 | 0 | 65( 3) | 11 | 24 | 32 | 81 | 11.3 |
| 72 | M | 80 | Cancer of stomach | 13.2 | 0 | 0 | 55 | 45(26) | 51 | 85 | 13.2 |

| No. | Sex | Age | Media vol % Elastic Fibre A | B | C | D | Collagen A | B | C | D | Muscle Cell A | B | C | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | F | 27 | 37.2 | 34.8 | 32.4 | 26.9 | 33.2 | 32.2 | 22.2 | 26.8 | 29.6 | 33.0 | 45.4 | 46.3 |
| 2 | M | 24 | 46.0 | 47.0 | 42.4 | 36.8 | 26.2 | 28.8 | 26.8 | 22.0 | 27.8 | 24.2 | 30.8 | 31.2 |
| 3 | F | 45 | 46.4 | 43.8 | 37.0 | 32.4 | 31.6 | 32.6 | 27.8 | 25.6 | 22.0 | 23.6 | 35.2 | 42.0 |
| 4 | F | 31 | 54.2 | 45.4 | 42.0 | 40.3 | 22.8 | 32.6 | 25.0 | 25.2 | 22.0 | 22.0 | 33.0 | 34.4 |
| 5 | M | 28 | 42.4 | 36.4 | 41.5 | 38.8 | 31.4 | 30.8 | 27.2 | 24.8 | 26.2 | 32.8 | 31.3 | 26.4 |
| 6 | M | 55 | 37.8 | 41.4 | 39.2 | 32.2 | 20.4 | 22.2 | 20.0 | 28.0 | 41.8 | 36.4 | 40.8 | 39.8 |
| 7 | M | 20 | 40.6 | 34.8 | 33.4 | 33.6 | 25.6 | 28.4 | 25.8 | 32.2 | 33.8 | 36.8 | 40.8 | 34.2 |
| 8 | M | 52 | 45.8 | 56.0 | 43.4 | 41.2 | 29.0 | 17.8 | 21.8 | 22.5 | 25.2 | 26.2 | 34.8 | 36.3 |
| 9 | M | 21 | 43.3 | 45.3 | 42.3 | 42.8 | 28.4 | 26.4 | 23.2 | 27.9 | 28.4 | 28.3 | 34.5 | 29.3 |
| 10 | F | 22 | 44.4 | 41.4 | 41.2 | 42.4 | 29.0 | 36.2 | 28.4 | 29.8 | 26.6 | 22.4 | 30.8 | 37.8 |
| 11 | M | 45 | 41.8 | 36.4 | 38.1 | 33.0 | 25.8 | 29.0 | 21.6 | 21.4 | 32.4 | 34.6 | 40.3 | 45.6 |
| 12 | F | 23 | 38.2 | 37.6 | 37.5 | 31.5 | 29.8 | 33.8 | 32.9 | 24.1 | 32.0 | 28.6 | 29.6 | 44.4 |
| 13 | F | 46 | 40.6 | 42.2 | 37.6 | 38.0 | 23.8 | 27.6 | 29.8 | 31.6 | 25.8 | 30.0 | 32.6 | 30.4 |
| 14 | M | 18 | 38.8 | 45.2 | 48.8 | 46.8 | 32.6 | 27.2 | 26.0 | 24.4 | 28.6 | 27.6 | 25.2 | 28.8 |
| 15 | M | 26 | 40.3 | 45.8 | 40.9 | 37.4 | 26.2 | 23.3 | 26.0 | 16.3 | 33.5 | 30.9 | 34.0 | 46.3 |
| 16 | M | 36 | 44.8 | 51.4 | 54.2 | 45.2 | 30.6 | 28.6 | 21.4 | 25.2 | 24.6 | 20.0 | 24.4 | 29.6 |
| 17 | M | 51 | 50.5 | 57.1 | 53.5 | 51.8 | 14.2 | 15.7 | 14.7 | 17.1 | 35.3 | 27.2 | 31.8 | 31.1 |
| 18 | M | 64 | 37.0 | 31.6 | 37.8 | 37.0 | 33.0 | 32.2 | 24.4 | 26.4 | 30.0 | 36.2 | 37.8 | 36.6 |
| 19 | F | 43 | 33.9 | 35.2 | 37.0 | 36.7 | 40.1 | 35.0 | 32.0 | 31.5 | 26.0 | 30.0 | 31.0 | 31.8 |
| 20 | M | 50 | 35.9 | 36.3 | 39.6 | 31.6 | 33.5 | 33.0 | 25.0 | 30.3 | 30.6 | 30.7 | 35.4 | 38.1 |
| 21 | M | 57 | 36.4 | 37.2 | 35.3 | 33.9 | 28.5 | 27.5 | 26.1 | 21.0 | 35.1 | 35.3 | 38.6 | 45.1 |
| 22 | F | 58 | 36.0 | 36.2 | 27.4 | 29.0 | 30.8 | 28.4 | 26.2 | 28.8 | 33.6 | 35.4 | 46.4 | 42.2 |
| 23 | M | 34 | 30.0 | 31.6 | 34.4 | 39.5 | 22.6 | 33.2 | 23.6 | 18.7 | 37.4 | 35.2 | 42.0 | 41.8 |
| 24 | M | 38 | 37.6 | 41.3 | 28.2 | 41.2 | 18.0 | 22.2 | 19.3 | 22.2 | 44.4 | 36.5 | 42.5 | 36.8 |
| 25 | F | 58 | 28.5 | 29.4 | 31.0 | 28.8 | 34.0 | 27.7 | 27.6 | 29.9 | 37.5 | 42.9 | 41.4 | 41.3 |
| 26 | M | 70 | 29.4 | 28.4 | 23.6 | 24.0 | 39.8 | 35.0 | 37.2 | 35.6 | 30.8 | 36.6 | 39.2 | 40.4 |
| 27 | M | 13 | 49.2 | 47.6 | 50.6 | 37.1 | 30.0 | 40.6 | 24.2 | 31.3 | 20.8 | 11.8 | 25.2 | 31.6 |
| 28 | F | 50 | 34.2 | 37.2 | 35.8 | 31.2 | 29.4 | 27.6 | 30.2 | 25.4 | 36.4 | 35.2 | 34.0 | 43.4 |
| 29 | M | 64 | 21.1 | 33.1 | 26.6 | 24.2 | 31.0 | 31.1 | 30.3 | 29.1 | 37.9 | 35.8 | 43.1 | 46.7 |
| 30 | M | 35 | 41.0 | 29.2 | 38.2 | 37.2 | 27.2 | 28.0 | 19.2 | 23.3 | 31.8 | 32.8 | 42.6 | 39.5 |
| 31 | M | 53 | 35.0 | 32.4 | 33.8 | 34.3 | 28.9 | 22.4 | 25.4 | 19.4 | 36.1 | 34.2 | 40.8 | 46.3 |
| 32 | M | 61 | 22.7 | 41.8 | 33.6 | 28.0 | 31.8 | 30.0 | 27.0 | 27.3 | 35.5 | 28.2 | 39.4 | 44.7 |
| 33 | M | 52 | 39.0 | 35.0 | 27.8 | 37.2 | 31.4 | 35.2 | 29.6 | 33.6 | 29.6 | 29.8 | 32.6 | 29.2 |
| 34 | M | 33 | 42.1 | 48.8 | 32.0 | 44.7 | 31.1 | 27.2 | 31.0 | 27.9 | 25.8 | 24.0 | 37.0 | 27.4 |
| 35 | F | 65 | 36.0 | 32.1 | 40.5 | 36.5 | 30.3 | 28.2 | 16.5 | 21.8 | 33.7 | 29.7 | 43.0 | 41.7 |
| 36 | M | 51 | 47.1 | 52.1 | 50.5 | 51.3 | 26.1 | 25.5 | 21.0 | 18.0 | 26.8 | 22.4 | 28.5 | 30.7 |
| 37 | M | 29 | 29.2 | 29.8 | 24.8 | 28.4 | 29.0 | 31.8 | 22.6 | 21.9 | 41.8 | 38.4 | 51.6 | 49.7 |
| 38 | F | 36 | 39.2 | 28.8 | 34.8 | 37.2 | 31.4 | 32.0 | 23.8 | 26.8 | 29.4 | 38.2 | 41.4 | 35.4 |
| 39 | M | 53 | 31.0 | 33.4 | 25.4 | 27.8 | 22.0 | 34.4 | 37.6 | 30.2 | 37.0 | 32.2 | 47.0 | 42.0 |
| 40 | M | 57 | 40.0 | 37.8 | 26.6 | 35.4 | 28.0 | 24.4 | 20.8 | 28.6 | 31.6 | 37.8 | 42.6 | 33.0 |
| 41 | M | 40 | 38.6 | 34.6 | 38.4 | 28.2 | 31.2 | 31.2 | 25.2 | 30.2 | 30.2 | 34.2 | 36.4 | 41.6 |
| 42 | F | 47 | 35.4 | 37.4 | 29.0 | 30.2 | 44.4 | 22.0 | 32.6 | 32.6 | 20.2 | 40.6 | 38.4 | 37.2 |
| 43 | M | 68 | 29.5 | 28.7 | 33.4 | 27.9 | 27.5 | 28.0 | 22.4 | 27.3 | 43.0 | 43.3 | 44.2 | 44.8 |
| 44 | M | 38 | 47.4 | 41.7 | 47.6 | 35.4 | 19.4 | 24.3 | 29.3 | 18.2 | 33.2 | 34.0 | 33.1 | 43.4 |
| 45 | M | 56 | 37.8 | 30.6 | 36.4 | 29.2 | 38.1 | 32.4 | 24.2 | 29.6 | 24.1 | 37.0 | 39.4 | 41.2 |
| 46 | F | 72 | 31.2 | 41.2 | 32.8 | 30.5 | 29.6 | 27.0 | 26.4 | 33.6 | 39.2 | 31.8 | 40.8 | 35.6 |
| 47 | M | 67 | 33.0 | 35.0 | 23.6 | 17.8 | 30.5 | 18.2 | 18.2 | 22.5 | 36.5 | 46.8 | 58.2 | 59.7 |
| 48 | M | 43 | 43.6 | 41.2 | 37.0 | 26.2 | 25.0 | 21.6 | 20.4 | 26.0 | 31.4 | 37.2 | 42.6 | 47.8 |
| 49 | F | 56 | 38.2 | 32.4 | 35.8 | 33.5 | 22.4 | 30.2 | 24.8 | 27.8 | 29.4 | 37.4 | 39.4 | 38.7 |
| 50 | F | 73 | 31.4 | 28.0 | 28.2 | 22.2 | 39.8 | 42.6 | 35.2 | 37.2 | 28.8 | 28.4 | 36.6 | 39.6 |
| 51 | F | 56 | 33.8 | 29.9 | 37.6 | 37.6 | 37.4 | 30.4 | 26.5 | 26.8 | 28.8 | 29.7 | 35.9 | 33.6 |
| 52 | M | 84 | 45.4 | 36.4 | 38.4 | 33.2 | 29.2 | 26.2 | 24.8 | 32.2 | 25.4 | 37.4 | 36.8 | 34.6 |
| 53 | M | 58 | 34.0 | 36.4 | 25.6 | 29.2 | 24.8 | 28.4 | 31.6 | 30.2 | 41.2 | 35.2 | 42.8 | 40.6 |
| 54 | F | 62 | 42.2 | 29.0 | 39.0 | 29.4 | 31.4 | 24.2 | 27.6 | 32.0 | 25.4 | 36.8 | 33.4 | 38.6 |
| 55 | M | 52 | 32.7 | 31.6 | 29.3 | 29.4 | 32.7 | 31.8 | 24.2 | 28.9 | 33.6 | 36.6 | 46.5 | 41.7 |
| 56 | F | 53 | 29.4 | 25.0 | 36.2 | 31.1 | 32.2 | 31.6 | 23.0 | 32.4 | 38.4 | 43.4 | 40.8 | 36.5 |
| 57 | F | 70 | 27.1 | 34.0 | 24.8 | 22.6 | 35.8 | 27.4 | 30.6 | 32.8 | 36.4 | 38.6 | 44.6 | 44.6 |
| 58 | F | 76 | 22.9 | 31.4 | 29.7 | 27.4 | 24.4 | 22.3 | 27.5 | 24.1 | 42.7 | 46.3 | 42.8 | 48.5 |
| 59 | M | 48 | 43.4 | 43.0 | 45.9 | 41.1 | 19.7 | 18.8 | 19.2 | 24.6 | 36.9 | 38.2 | 34.9 | 34.3 |
| 60 | M | 59 | 25.7 | 26.5 | 39.8 | 35.9 | 29.8 | 31.0 | 28.5 | 31.9 | 34.5 | 32.5 | 31.7 | 32.2 |
| 61 | M | 64 | 25.6 | 42.0 | 24.0 | 31.2 | 22.6 | 24.0 | 26.4 | 24.4 | 41.8 | 34.0 | 39.6 | 44.4 |
| 62 | M | 72 | 36.8 | 18.2 | 21.0 | 20.0 | 24.4 | 24.2 | 16.8 | 23.6 | 38.8 | 57.6 | 62.2 | 56.4 |
| 63 | F | 55 | 27.6 | 22.6 | 26.6 | 28.5 | 34.0 | 36.8 | 30.2 | 29.5 | 38.4 | 30.6 | 41.2 | 42.0 |
| 64 | M | 72 | 34.0 | 32.8 | 33.0 | 28.2 | 20.6 | 29.4 | 25.4 | 26.0 | 45.4 | 37.8 | 41.6 | 45.8 |
| 65 | M | 64 | 38.6 | 40.8 | 40.4 | 32.4 | 34.3 | 24.6 | 19.2 | 29.1 | 27.1 | 34.6 | 40.4 | 38.5 |
| 66 | F | 53 | 36.6 | 33.4 | 33.8 | 23.4 | 34.4 | 35.0 | 25.4 | 30.5 | 29.0 | 31.6 | 40.8 | 44.1 |
| 67 | M | 72 | 28.0 | 21.0 | 32.2 | 22.6 | 25.6 | 29.6 | 35.2 | 42.4 | 33.4 | 39.4 | 32.6 | 35.0 |
| 68 | M | 73 | 24.0 | 25.6 | 32.6 | 29.9 | 40.8 | 29.6 | 39.0 | 31.3 | 35.2 | 34.8 | 28.4 | 38.8 |
| 69 | F | 86 | 32.2 | 23.0 | 27.0 | 21.2 | 37.2 | 36.0 | 22.2 | 34.4 | 30.6 | 41.0 | 50.8 | 44.4 |
| 70 | F | 74 | 29.4 | 40.4 | 29.6 | 31.9 | 35.8 | 35.6 | 28.0 | 28.1 | 34.8 | 24.0 | 42.4 | 40.0 |
| 71 | M | 62 | 35.4 | 32.4 | 28.4 | 30.2 | 40.2 | 40.4 | 36.6 | 38.8 | 24.4 | 27.2 | 35.0 | 31.0 |
| 72 | M | 80 | 35.3 | 27.3 | 30.4 | 24.9 | 36.0 | 37.9 | 33.9 | 34.7 | 28.7 | 34.8 | 35.7 | 40.4 |

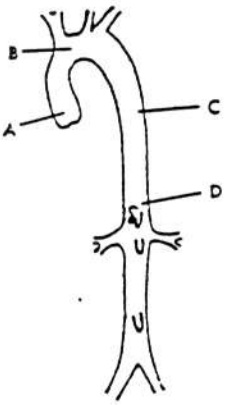
non-fib : non-fibrotic thickening
fib : diffuce fibrotic thickening
cal : calcification
( )* : streaks spots
( )** : ulceration

The quantitative measurement of pathological changes in the intima of the aortic artery was done by Mitchell and Cranston's point counting method[1], as shown in Figure 2. After opening the aortic artery, needles were placed in every 10 mm interval. Changes in each needle point were evaluated by classifying into six components: (1) non-fibrotic thickening; (2) streaks and spots; (3) diffuse fibrotic thickening; (4) atheroma; (5) ulceration; and (6) calcification. The area occupied by each component was expressed by percentage.

With regard to the measurement of changes in the media, a horizontally sliced sample was taken from each of the four part: A. ascending aorta; B. aortic arch; C. descending aorta; and D. upper abdominal aorta (Figure 3). Each sample was colored by the Elastica Van Gieson. Microscopic observation was conducted for each sample by the Karl Zeiss Integrating Eye Piece I (Figure 4). There components of the media (elastic fiber, collagen and muscle cell) were measured by points and were expressed as volume %.

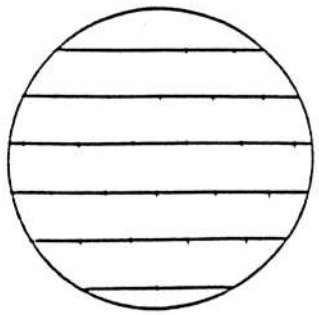
Intima (Macrotic)
Non-Fibrotic Thickening
(Streak. Spot)
Diffuse Fibrotic Thickening
Atheroma
(Ulceration)
Calcification

Fig. 2 Mitchell & Cranston's point counting method




A ASD. AORTA
B AORTIC ARCH
C DESC. AORTA
D UPPER ABD. AORTA

Fig. 3 Portions Sampled for Medial Examination



Elastic Fiber

(Muscle Cell)

Collagen

Fig. 4 Counting Method of the Media using the Eye-Piece I of Karl Zeiss

To examine the relationship between PWV and pathological changes in the aorta, the Pearson product-moment correlation coefficient was obtained between PWV and each component of changes in the intima and the media. In addition, a multiple correlation coefficient (R) was computed by regressing PWV on multiple components related to changes in the aortic artery (See Figure 5).

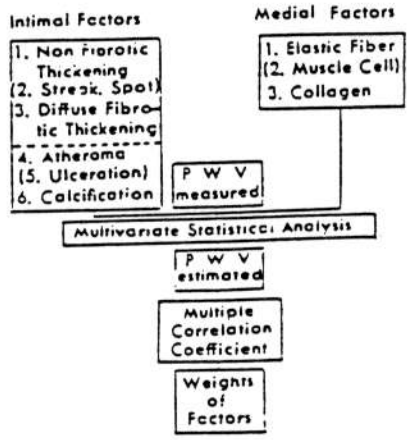



**Fig. 5 Blockdiagram to obtain Correlation between PWV and Pathological Findings of the Aorta**

## Results and Discussion

The validity of PWV, if a hardness of aorta measured by the PWV method is an appropriate index for pathological changes of the aorta, was examined by using postmortem aorta samples from 72 patients. Table 2 and figures 6 and 7 show the relationship between PWV and two major arteriosclerotic components; the intima (non-fibrotic thickening, diffuse fibrotic thickening, atheroma, and calcification) and the media (elastic fibre, collagen, and muscle cell). It was observed than as PWV increases in the order of 6.9, 7.0-7.9, 8.0-8.9, 9.0-9.9, and 10.0 m/sec or greater: (1) the corresponding value (%) of nonfibrotic thickening decreases in the order of 97.5, 86.4, 63.1, 35.2, and 10.4%, respectively; (2) the corresponding diffuse fibrotic thickening value increases in the order of 0, 0, 9.7, 25.0, and 26.5%, respectively; (3) the corresponding area affected by atheroma increases in the order of 2.5, 13.6, 26.2, 36.6, and 49.2%, respectively; (4) the corresponding area affected by calcification increases in the order of 0, 0, 1.0, 3.2, and 13.9%, respectively; (5) the corresponding elastic fiber volume decreases in the order of 39.9, 37.2, 35.3, 33.8, and 29.9%, respectively; (6) the corresponding collagen fiber value increases in the order of 27.6, 28.1, 26.8, 29.0, and 32.2%, respectively; (7) the corresponding muscle cell volume increases in the order of 32.5, 34.7, 38.0, 37.2, and 37.9% respectively. Despite the difference in atherogenesis involved with each component of the aortic artery, these results demonstrate that the PWV value remarkably reflects the changes in such arterial components.

Table 2. Correlation between PWV and pathological findings

| PWV(m/sec) | Non-fib(%) | Fib (%) | Atheroma (%) | Cal (%) | Elastic Fibre(vol%) | Collagen Fibre (vol%) | Muscle Cell (vol%) |
|---|---|---|---|---|---|---|---|
| 6.9 | 97.5 | 0 | 2.5 | 0 | 39.9 | 27.6 | 32.5 |
| 7.0–7.9 | 86.4 | 0 | 13.6 | 0 | 37.2 | 28.1 | 34.7 |
| 8.0–8.9 | 63.1 | 9.7 | 26.2 | 1.0 | 35.3 | 26.8 | 38.0 |
| 9.0–9.9 | 35.2 | 25.0 | 36.6 | 3.2 | 33.8 | 29.0 | 37.2 |
| 10.0 | 10.4 | 26.5 | 49.2 | 13.9 | 29.9 | 32.2 | 37.9 |
| mean | 58.5 | 12.3 | 25.6 | 3.6 | 35.2 | 28.7 | 36.1 |

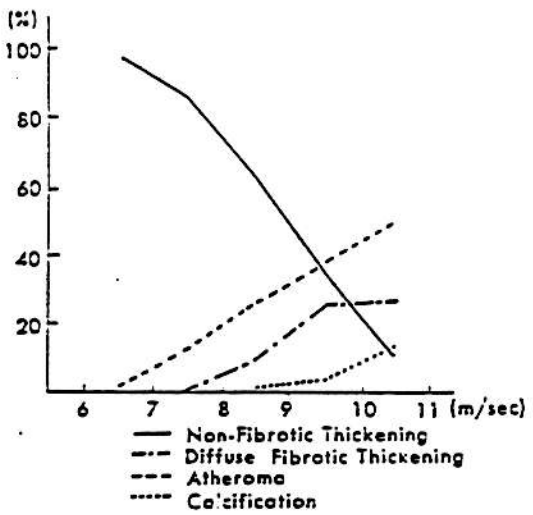



Fig 6 Correlation between PWV and Percentage of Intimal Findings.

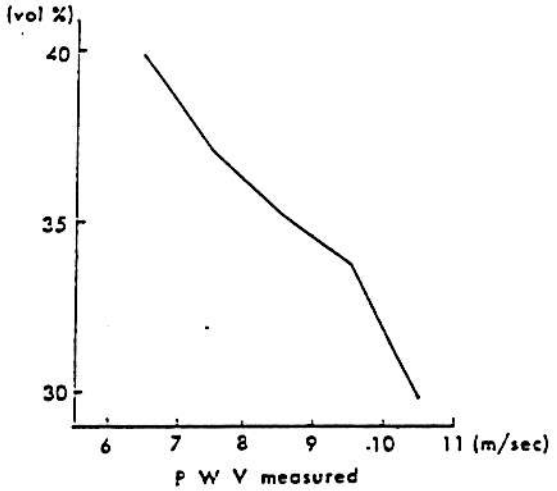



Fig. 7 Correlation between PWV and Elastic Fibre.

Figure 8 shows the relationship between PWV and Gore's Index[2] which was based on observation of changes in the intima. The correlation coefficient was 0.736 (Figure 8). Another similar atherosclerosis indicator, ASSA's Index (which was suggested by the Committee on Lesions of The American Society for the Study of Arteriosclerosis)[3], was counted and compared with PWV values among 72 samples. The correlation coefficient was 0.744 (Figure 9). PWV is fairly well associated with both indices. However, the subjects with both indices lower than 10 have PWV values ranging from <6 to 11 m/sec. Possible reasons are:

(1) Both Gore's Index and ASSA's Index are based on visual observations of changes in the intima only, while PWV reflects changes both in the intima and in the media, as shown in Table 2 and Figures 6 and 7; and

(2) PWV is considered to show both pathological and functional changes in the aortic artery, while both Gore's Index and ASSA's Index indicate pathological changes in the intima only.

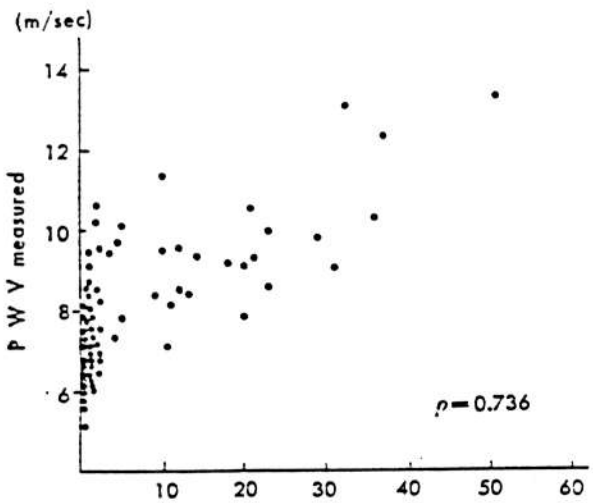



Fig. 8 PWV vs GORE's Index counted by MITCHELL & CRANSTON'S Method

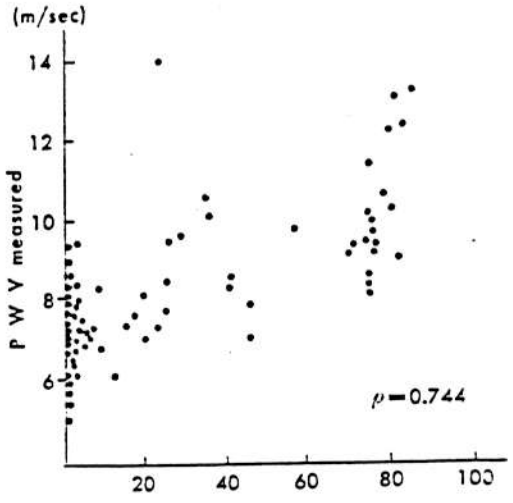



Fig. 9 PWV vs A.S.S.A's Index counted by MITCHELL & CRANSTON's Method (A.S.S.A.: The Committee on Lesions of the American Society for the Study of Arterosclerosis)

Multiple regression analysis was conducted to examine if PWV values can be predicted by changes in components in the intima and the media.

Multiple correlation coefficient, R, is a correlation coefficient between actually measured PWV values and predicted PWV values from regression analysis. As shown in Figure 10, R is 0.810 which is fairly high. In other words, PWV is considered to be a good indicator of arteriosclerosis in the aorta, because predicted PWV values were based on measured changes in the non-fibrotic thickening, diffuse fibrotic thickening, atheroma, and calcification in the intima, and elastic fiber and collagen in the media.

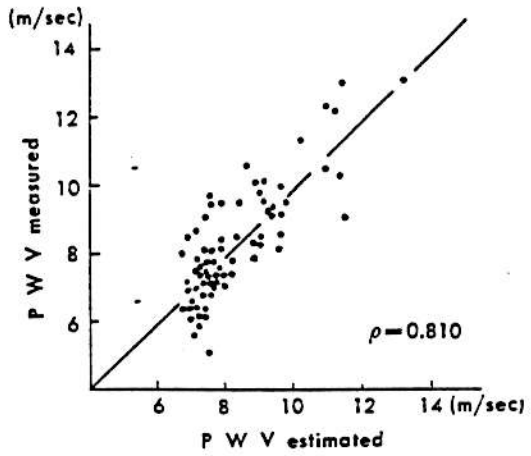



**Fig. 10 Correlation between PWV measured and PWV estimated by Multi-variate Statistical Analysis of 6 Factors of Aortic Intima and Media**

Table 5 shows the association between changes in PWV values and in each of five arteriosclerotic factors in the aorta, based on individual observations (Table 1) and results of pathological analysis in Table 2. By using the criteria in Table 5, it is possible to estimate the degree of changes in each factor according to a person's PWV value. For example, the person who has 9.0 m/sec of PWV is estimated to have 38% of non-fibrotic thickening, 25% of diffuse fibrotic thickening, 35% of atheroma, 3% of calcification and 30% of elastic fiber volume.

**Table 5. Estimation of Aoritic Change from PWV**

| P W V m/sec | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|
| non-fib % | 100 | 80 | 60 | 40 | 20 | 0 |
| fib % | 0 | 10 | 25 | 26 | | |
| Atheroma % | 0 | 10 | 20 | 30 | 40 | 50 60 |
| cal % | 0 | 1 | 2 | 3 | 10 | 15 |
| elas. fib. vol % | 40 | 37 | 35 | 33 | 30 | |

non-fib : non fibrotic thickening
fib : diffuse fibrotic thickening
cal : calcification
elas. fib : elastic fibre

As a noninvasive technique, the PWV method is extremely effective to evaluate the degree of arteriosclerosis in the aorta. The method can be used for the population screening and provide preventative measures of atherosclerotic diseases for persons with a high PWV value.

## Reference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