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Evaluation of Diseases Associated with Cardiac Enlargement Using Principal Component Analysis of Plain Chest X-Ray Films

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胸部単純X線写真を用いた各種心拡大疾患の主成分分析による計量評価

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胸部単純X線写真上で，心拡大を示す疾患の心形態の特徴および疾患較差を，主として主成分分析を用いて計量評価した．

対象は，成人正常群（163例）と各種心拡大疾患群（本態性高血圧症群59例，陳旧性心筋梗塞症群34例，慢性腎不全群28例，肥大性心筋症群11例）である．解析項目として，胸部単純X線写真正側面像の心大血管陰影計測値，身体計測値等計16項目を用い，これをMicro Computerに入力し，症例別，性別の平均値，標準偏差値を求めた．更に各項目間の関連性整理のため主成分分析を行い，主な主成分2～4個間の構造ベクトル分布，男女別の個人評点分布を求めた．

正常上限は，Heart Volume/BSA：男364ml，女299ml，Transverse diameter：男14.2cm，女11.7cm，CTR：男0.528，女0.583，Ungerleider-Gómez式：男1.14，女1.11であり，それ以上は，心拡大と判定できた．構造ベクトル分布より，16項目は，心の大きさ，心形態，体型，大動脈幅，血圧，年齢の6因子に要約され，その相互関係により疾患の特徴，較差を評価できた．すなわち，高血圧群では，左室圧負荷のため，心影の左方後方拡大，大動脈幅拡大を示し，これらは血圧値と平行した．心筋梗塞群では，左心系拡大指標と梗塞の大きさとの関係が密接であった．腎不全群では，容量負荷のため，心拡大が疾患群中最大であり特に正面心影の拡大が著明であった．また肺うっ血所見が，同疾患の重症度の決定因子の1つとなった．心筋症群では，心円形々態を示した．更に，高血圧群，心筋梗塞群で，体型に男女差を認めた．このように主成分分析を用いることにより，心大血管影の客観的評価が可能であった．

1.0 Objective

It is well known that various conditions which cause hemodynamic changes in the heart and great vessels, also affect their shape accoring to the location and degree of the change. Similarly, variations in the left heart load which accompany many of the diseases of adulthood, are associated with changes in the cardiac shadow on plain chest X-rays[1]. To objectively evaluate this change, the size of the shadow of the ventricle, atria and thoracic aorta from plain chest X-rays was measured; other values were also measured by physical examination. The relationship between these values and the type and degree of the disease and load was examined by Principal Component Analysis. This quantitative approach may have great value in the diagnosis of, as well as the assessment of severity and prognosis of, diseases associated with cardiac enlargement.

2.0 Study Group

All the subjects of the study were adults. The breakdown according to subgroup, sex and age is shown in Table 1.

The control group consisted of 163 healthy subjects with no past medical histories nor any pathological findings from chest X-rays, ECG or blood pressure.

The patient group consisted of 132 subjects with cardiac enlargement, including 59 patients with essential hypertension (HT), 34 patients with prior myocardial infarction (MI), 28 patients with chronic renal failure (CRF), and 11 patients with hypertrophic cardiomyopathy (HCM).

The HT group included only patients who had not received any prior anti-hypertensive therapy or had not been taking any anti-hypertensive medication for at least one week. Furthermore, their arterial blood pressure equaled or exceeded that of borderline hypertension as defined by the WHO Classification of Arterial Hypertension: systolic pressure equal to or exceeding 141 mmHg and diastolic pressure equal to or exceeding 91 mmHg[2].

The MI group included only patients for whom at least one month had passed since the infarction, and in which the site of the infarction had been ascertained by a ^{201}T1 myocardial scintigram.

The CRF group included only patients whose condition was relatively stable and who were on long-term hemodialysis therapy.

The HCM group included only patients who met the criteria defined by the Idiopathic Cardiomyopathy Research Committee of the Japanese Ministry of Health and Welfare[3].

3.0 Methods

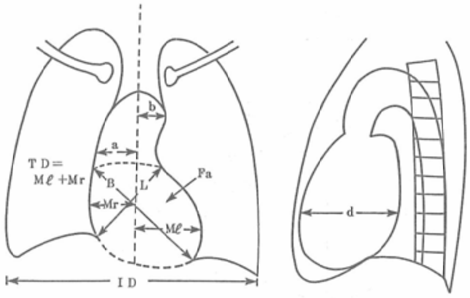
3.1 Plain Chest X-ray and Physical Examination Values Measured

The outline of the myocardial shadow was traced from upright posterior-anterior and left lateral plain chest X-rays, (Fig. 1) and six measurements taken:

1) Ml Mid-left distance.

Table 1 Number of Cases and Age Distribution

	No. of Cases	Male		Female	
		No. of Cases	Age	No. of Cases	Age
Control	163	126	44.5 ± 8.9	37	42.9 ± 7.2
Essential Hypertension	59	30	44.8 ± 13.6	29	52.1 ± 12.1
Prior Myocardial Infarction	34	28	57.7 ± 10.4	6	56.1 ± 10.6
Chronic Renal Failure	28	16	48.4 ± 13.3	12	44.3 ± 16.4
Hypertrophic Cardiomyopathy	11	6	34.7 ± 13.2	5	30.3 ± 11.7
Total	295	206	46.4 ± 11.6	89	46.4 ± 12.7



Abbreviation	
Mℓ (cm)	Mid-left distance
Mr (cm)	Mid-right distance
d (cm)	Depth diameter
Fa (cm²)	Frontal area
TD (cm)	Transverse diameter=Mℓ+Mr
a+b (cm)	Width of the aortic arch
CTR	Cardiothoracic ratio=TD/ID
U-G Formula	Ungerleider-Gómez Formula $TD/2\sqrt{Weight (kg)/Height (m)}$
HV (ml)	Heart volume=0.63×Fa×d
HV/BSA (ml)	Heart volume/Body surface area
L/B	Long diameter/Broad diameter

Fig. 1 Measured and Calculated Items of Heart and Great Vessels Derived from Plain Chest X-ray Films

Table 2 Scoring Method of Pulmonary Congestion Presence of any one of the conditions from 1.-6. is equivalent to 1 point.

1. Distended upper lobe veins
2. Septal edema (A, B and C lines)
3. Perivascular edema (hilar and peripheral haze)
4. Subpleural edema (thickened interlobar fissures)
5. Alveolar edema
6. Miscellaneous findings
   a) Pleural effusion
   b) Pulmonary hemosiderosis
   c) Pulmonary ossification
   d) Pulmonary fibrosis
   e) Aneurysmal dilatation of pulmonary veins
   f) Secondary pulmonary arterial hypertension

2) Mr Mid-right distance.
3) d depth diameter.
4) Fa Frontal area measured by a planimeter.
5) TD Transverse diameter =Ml + Mr.
6) a + b Width of aortic arch used as an index of aortic size.

Five items were also computed from the tracings:

1) CTR Cardiothoracic ratio=TD/ID =(transverse diameter)/(intrathoracic distance)
2) U-G Ungerleider-Gómez formula=$TD/2\sqrt{Weight (kg)/Height (m)}$
3) HV Heart volume=0.63 × Fa × d as defined by the Rohrer-Kahlstorf method[4)5)].
4) HV/BSA=(heart volume)/(body surface area)
5) LB =(long diameter)/(broad diameter)

In addition, five other items were evaluated:

1) Age Age.
2) BSA Body surface area.
3) mBP Mean blood pressure.
4) Score Score of pulmonary congestion obtained from plain chest X-rays counting one point for each item of Meszaros' classification (Table 2)[7)] to obtain an index of the degree of pulmonary congestion and edema present.
5) %DS %Defect Segment defined as the percentage of myocardium which has become ischemic due to infarction as calculated from a ^{201}Tl scintigram[8)].

A total of sixteen items were included in the analysis. The plain chest X-rays were non-triggered exposures taken in slight inspiration. Variation in the heart volume due to the respiratory and cardiac phases was found

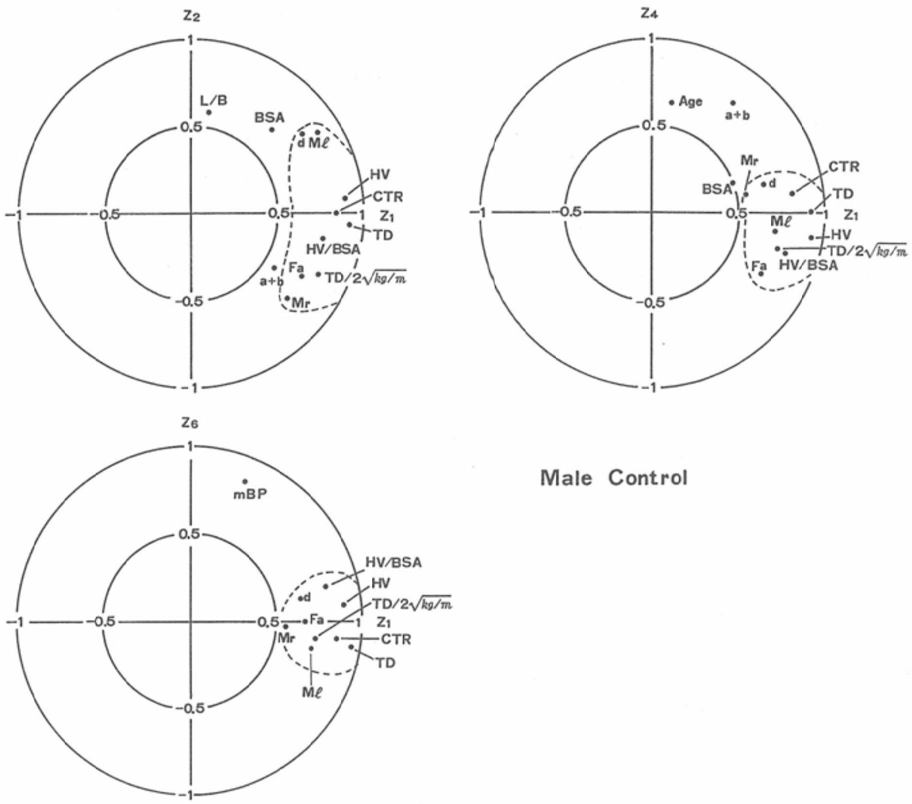


Fig. 2 Distribution of the Structure Vector in Control Group (Male)

Z_1-Z_6 are the first through the sixth principal components. Z_1 corresponds to HV, TD and CTR, the items indicative of heart size. Z_2 Corresponds to L/B. Z_4 corresponds to age. Z_6 corresponds to mBP. These are the main Principal Components. The items HV, CTR, and TD (inside the dotted line) which are indicative of heart size show a strong correlation.

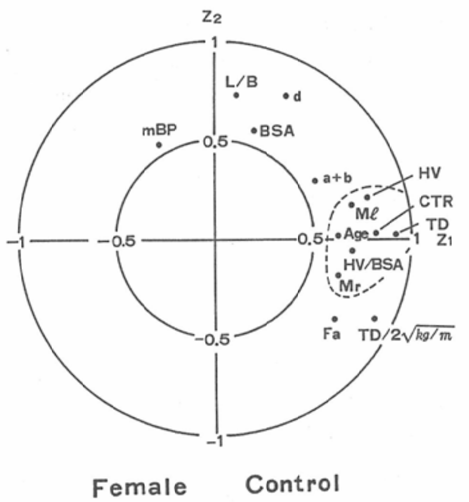


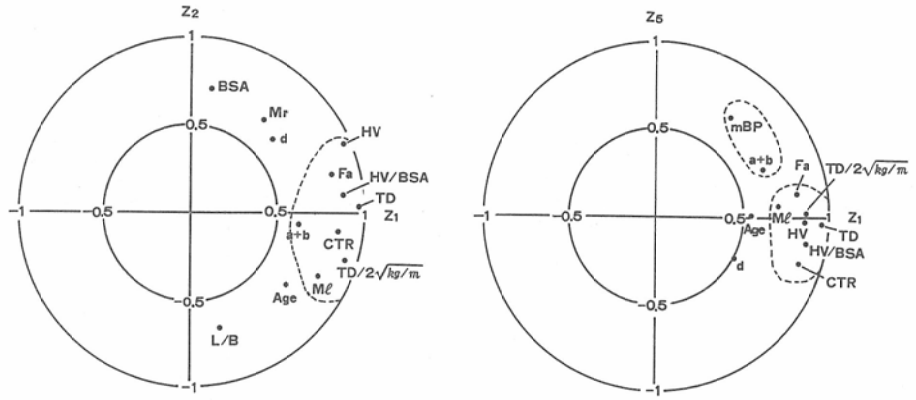
Fig. 3 Distribution of the Structure Vector in Control Group (Female)
HV, CTR and TD show a favorable correlation with age.

to be insignificant; the heart volume calculated by computerized tomography was within ten percent that calculated by the Rohrer-Kahlstorf method[6].

3.2 Statistical Analysis

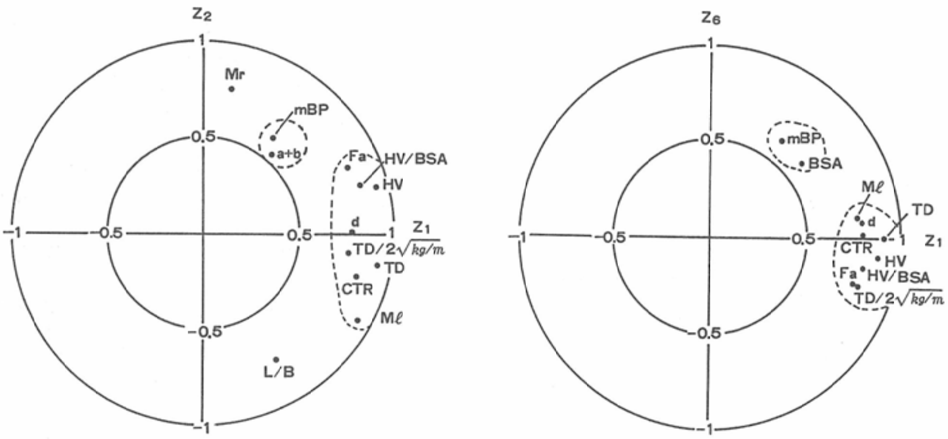
The values of the sixteen items were obtained for all subjects and the data stored on a microcomputer. The mean value and standard deviation were then computed by subgroup and sex.

The Principal Component Analysis method was used to examine the degree of correlation among the various items. The four to five most important principal components were derived by applying the iterative approximation method to a martrix composed of the correlation coefficients for all sixteen items. The structure and weighting vectors were also computed. The weighting vectors were multiplied by a normalized value for each item and the elements summed to compute a numerical grade for each subject-component



Male　　Essential Hypertension

Fig. 4　Distribution of the Structure Vector in Essential Hypertension Group (Male)
The items Ml and a + b indicate heart size. mPB is closely related to a + b but is not directly related to cardiac enlargement.



Female　　Essential Hypertention

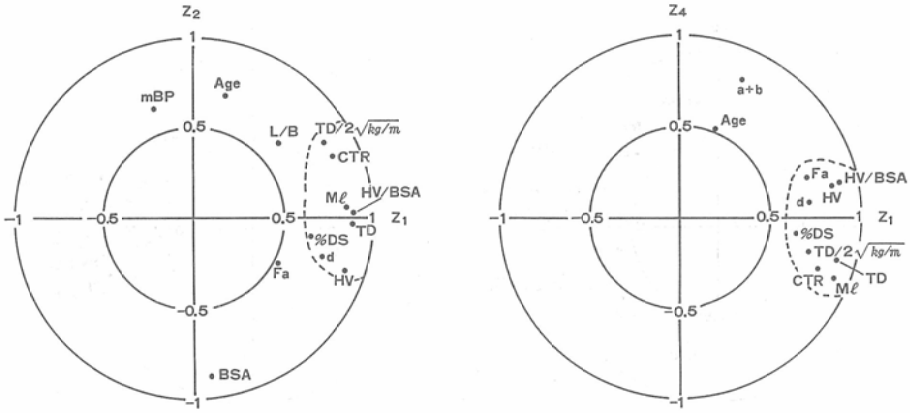
Fig. 5　Distribution of the Structure Vector in Essential Hypertension Group (Female)
Ml and d are closely related to the items indicative of cardiac enlargement. mBP is positively correlated with a + b and BSA.

combination. The characteristics of the heart shadow for each subject were then evaluated from the distributions of the structure vectors (Figs. 2—11) and numerical grades (Figs. 12—14).

4.0 Results

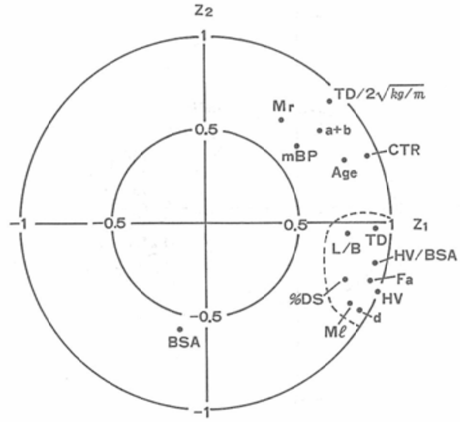
4.1 Sex-Related Differences and Degree of Cardiac Enlargement

The mean value and standard deviation for each of the sixteen items by group and sex is shown in Table 3. Many of the control group values for males exceeded 10% of the values for females, excluding Age and mBP; in particular, the HV and HV/BSA male values exceeded the female values by 35.8% and 18.9% respectively.



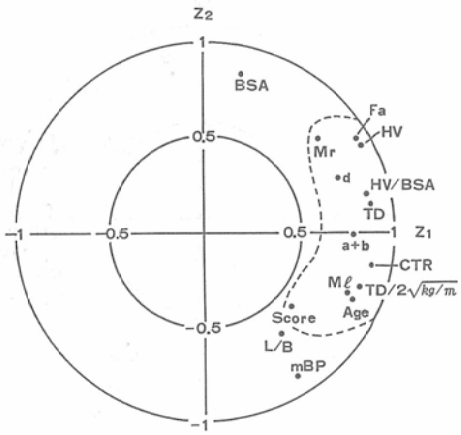
Male Myocardial Infarction

Fig. 6 Distribution of the Structure Vector in Prior Myocardial Infarction Group (Male)
Ml, d and %DS are directly proportional to the items indicative of cardiac enlargement. a + b is unrelated.



Female Myocardial Infarction

Fig. 7 Distribution of the Structure Vector in Prior Myocardial Infarction Group (Female)
The female group showed the same tendencies as the male group.



Male Chronic Renal Failure

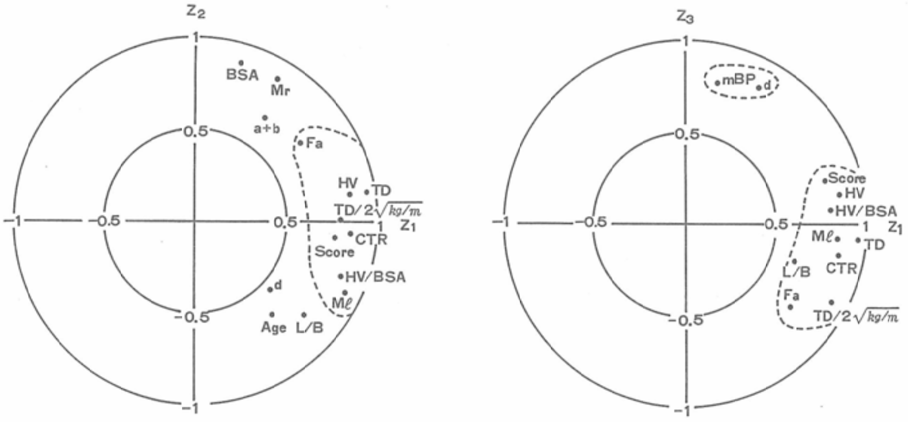
Fig. 8 Distribution of the Structure Vector in Chronic Renal Failure Group (Male)
The items indicative of cardiac enlargement are related to Mr, and closely related to Fa and Score.

If we regard HV/BSA as an index of cardiac enlargement, then among the male groups, the CRF group value was the largest (52% greater than the control group), followed by the MI group (40.1%), HCM group (35.6%), and HT group (28.9%); among the female groups, the MI group value was the largest (71.7% greater than the control group), followed by the CRF group (71.2%), HCM group (48.8%) and HT group (36.8%). These results indicate a greater degree of cardiac enlargement in the patient groups than in the control group.

4.2 Characteristics of and Differences Among the Groups Observed Through Principal Component Analysis

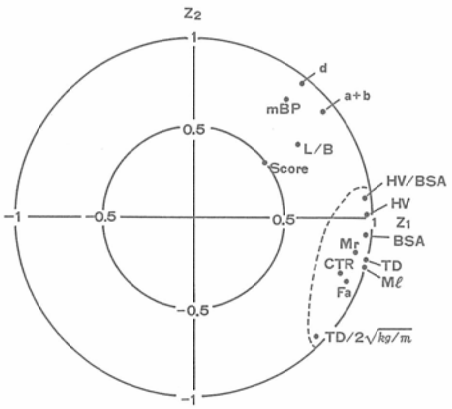
4.2.1 Distribution of the Structure Vector

A total of ten (five male and five female groups) Principal Component Analyses were performed. The structure vector distributions for the principal components are shown in Figs. 2—11. The structure vector can be regarded as a correlation coefficient corresponding to the principal component; the closer the value is



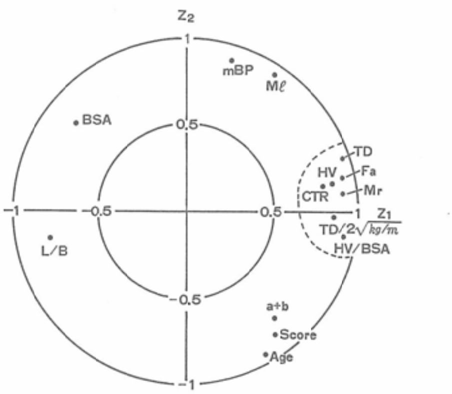
Female Chronic Renal Failure

Fig. 9 Distribution of the Structure Vector in Chronic Renal Failure Group (Female)
The cardiac enlargement index is closely related to Score.



Male Hypertrophic Cardiomyopathy

Fig. 10 Distribution of the Structure Vector in Hypertrophic Cardiomyopathy Group (Male)
The cardiac enlargement index is closely related to Mr.



Female Hypertrophic Cardiomyopathy

Fig. 11 Distribution of the Structure Vector in Hypertrophic Cardiomyopathy Group (Female)
The cardiac enlargement index is directly proportional to Mr, and inversely proportional to L/B.

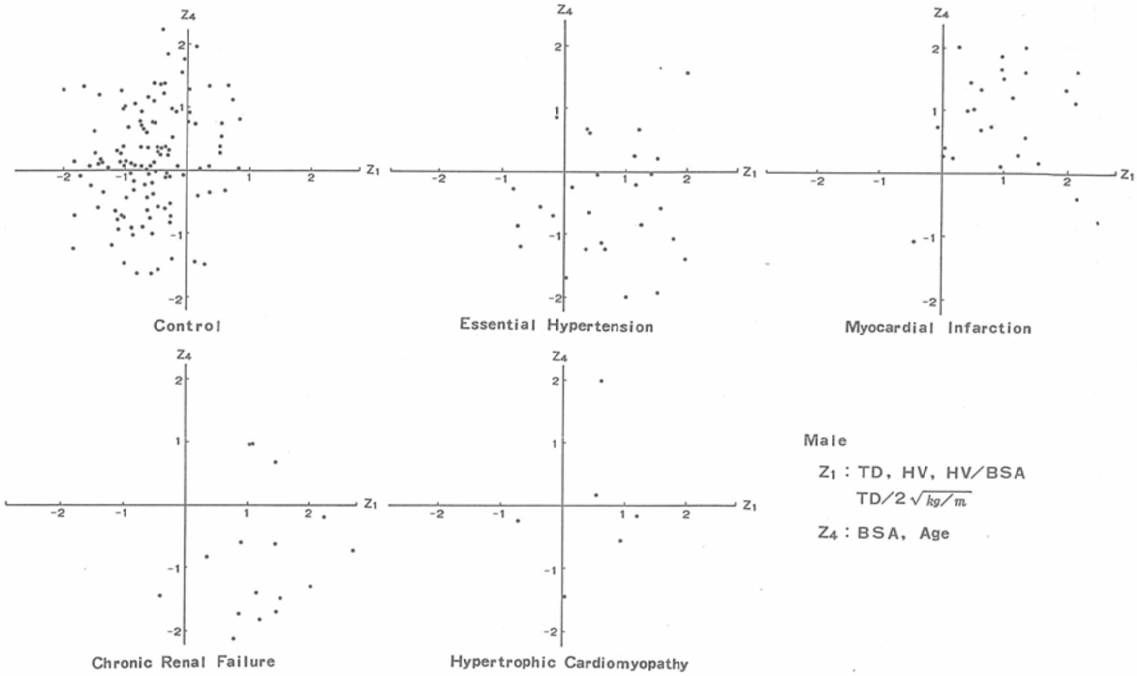


Fig. 12 Distribution of the Grades for the Five Study Subgrpups (Male)
The HT and CRF groups exhibit cardiac enlargement and a slim body build. The MI group exhibits cardiac enlargement and obesity.

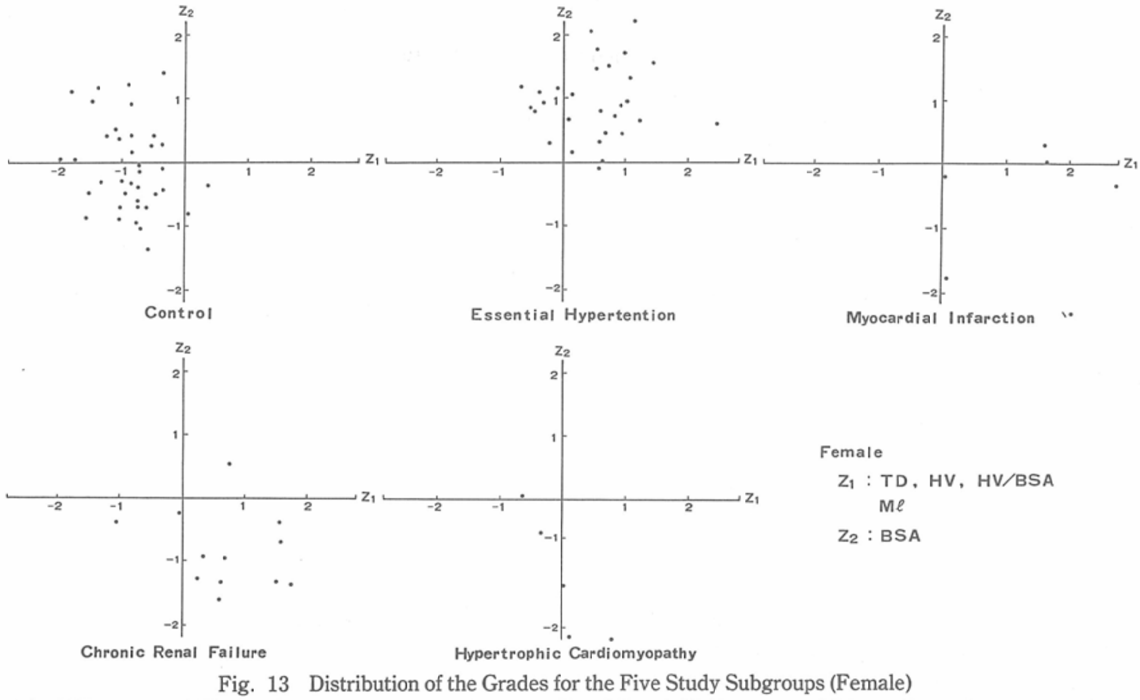


Fig. 13 Distribution of the Grades for the Five Study Subgroups (Female)
The HT group exhibits cardiac enlargement and obesity. The MI and CRF groups exhibit cardiac enlargement and a slim body build.

Table 3 Mean and Standard Deviation Values of 16 Items for Five Study Subgroups

	Control				Essential Hypertension				Prior Myocardial Infarction				Chronic Renal Failure				Hypertrophic Cardiomyopathy			
	Male (126)		Female (37)		Male (30)		Female (29)		Male (28)		Female (6)		Male (16)		Female (12)		Male (6)		Female (5)	
	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
Age	44.5	8.9	42.9	7.2	44.8	13.6	52.1	12.1	57.7	10.4	56.1	10.6	48.4	13.3	44.8	16.4	34.7	13.2	30.3	11.7
B.S.A. (㎡)	1.654	0.118	1.451	0.097	1.640	0.122	1.572	0.098	1.636	0.114	1.449	0.133	1.644	0.107	1.378	0.086	1.726	0.140	1.432	0.116
Mℓ (cm)	8.08	0.97	7.58	0.86	9.19	1.14	8.99	1.23	9.43	1.12	9.30	1.04	9.83	0.91	8,85	0.69	9.31	1.22	8.25	0.18
Mr (cm)	3.71	0.74	3.08	0.64	3.95	0.82	3.55	0.71	4.31	0.71	4.04	0.75	4.13	0.70	3.81	0.79	4.21	0.25	3.93	0.54
d (cm)	7.74	0.85	6.99	0.77	9.14	0.85	9.27	1.03	9.79	0.97	8.92	1.32	9.88	1.01	9.13	0.52	9.36	0.92	8.03	0.56
Fa (㎠)	96.09	10.63	78.50	7.66	103.85	14.09	88.52	11.93	108.06	12.66	103.28	12.98	114.22	14.38	97.46	14.88	113.18	15.28	99.44	7.57
TD (cm)	11.76	1.21	10.66	1.08	13.17	1.27	12.54	1.15	13.74	1.33	13.35	1.24	13.95	1.15	12.66	1.11	13.51	1.45	12.18	0.65
a + b (cm)	5.62	0.68	5.07	0.55	6.95	1.21	6.79	0.79	6.93	0.91	6.83	1.20	6.63	0.67	5.92	1.14	5.67	0.50	4.87	0.33
HV (ml)	468.96	74.87	345.36	45.22	599.48	103.54	520.52	113.37	669.59	124.51	589.21	154.78	708.33	99.37	563.80	108.10	668.67	119.42	503.37	58.49
HV/BSA (ml)	283.65	40.03	238.55	30.45	365.63	58.13	326.44	64.63	397.37	68.96	409.49	118.86	431.05	55.11	408.39	71.12	384.49	39.12	354.85	55.65
TD/2$\sqrt{kg/m}$	0.989	0.074	0.948	0.080	1.111	0.095	1.023	0.068	1.123	0.099	1.156	0.115	1.176	0.080	1.167	0.090	1.105	0.065	1.092	0.089
CTR	0.442	0.043	0.461	0.061	0.481	0.046	0.498	0.043	0.492	0.054	0.549	0.066	0.520	0.046	0.527	0.041	0.479	0.042	0.498	0.055
L/B	1.261	0.079	1.238	0.076	1.322	0.109	1.322	0.097	1.328	0.083	1.368	0.160	1.326	0.090	1.326	0.060	1.272	0.033	1.226	0.045
mBP (mmHg)	85.5	7.3	83.2	7.1	122.3	12.0	121.4	11.2	88.7	10.6	93.9	15.7	114.8	15.8	109.7	14.9	85.6	8.8	84.1	14.3
% DS									30.3	14.2	29.4	24.3								
Score									1.83	0.90	1.71	0.70	2.25	0.97	2.25	1.01	1.14	1.12	1.83	1.34

to one, the more strongly correlated the principal component is.

The first principal component (Z1) for all groups contained the items related to and heart size and shape. The remaining principal components (Z2-Z6) contained the BSA, a + b, mBP and Age items. The interrelationship of these six factors (Z1-Z6) revealed differences among the groups.

Control Group: With the X-ray heart shadow exhibiting no cardiac enlargement for the male group, the normal heart volume (HV) was strongly correlated with TD, CTR, HV/BSA and U-G Formula (Fig. 2). These five items were deemed an index of heart size. In the female group, (Fig. 3) HV was found to be strongly related to Age as well.

HT Group: The relationship of the heart size index items were similar to the control group (Figs. 4-5). However, heart size was also directly proportional to M1 and d, and related to a + b. In the male group, Age was related to heart size, and mBP was strongly related to a + b but not directly related to heart size. In the female group, mBP was strongly related to BSA.

MI Group: As in the HT group, Ml and d were closely related to the items indicative of left heart enlargement (Figs. 6-7). In contrast to the HT group, a + b was not proportional to heart size. %DS was directly proportional to the heart size items.

CRF Group: The distribution of the heart size items were closely related to Fa (Figs. 8-9). In addition, Mr was more closely related to heart size than in the MI group. Score (pulmonary congestion) was also found to be closely related to the heart size items. Although the value of mBP was high, it was not correlated with a + b.

HCM Group: The heart size items were distributed over a relatively narrow range (figs. 10-11). The Mr item, which is indicative of right heart enlargement, was strongly correlated, in the same manner as left heart enlargement, with the items indicative of cardiac enlargement. In the female group, L/B was inversely proportional to the heart size items and the heart shape was characteristically round.

4.2.2. Distribution of Individual Grades

Principal Component Analysis was performed by group and sex for all subjects. A distribution of the individual grades (Figs. 12-13) was graphed using the first component (Z1), indicative of HV and heart size, and the component in which BSA is the main factor (Z4 for males, Z2 for females). Since all subjects were adults, it can be considered that BSA is strongly related to obesity. The distribution graphs of the grades clarified the relationship between cardiac enlargement and body build (BSA), not otherwise apparent from the structure vector distributions. Among the males, the HT group exhibited cardiac enlargement and a slim body build, and the MI group cardiac exhibited enlargement and obesity; in contrast, among the females, the HT group exhibited cardiac enlargement and obesity, and the MI group exhibited cardiac enlargement and a slim body build. The CRF group exhibited cardiac enlargement and a slim body build for both males and females. These factors appeared to be unrelated for the male and female HCM groups.

5.0 Discussion

CTR has long been well known among the means for evaluating the heart shadow from plain chest X-rays[9)10)]; other methods of evaluation include the Ungerleider-Gómez formula 3U-G)[11)12)13)] in which the transverese diameter (TD) is normalized for height and weight, as well as other methods of computing the heart volume[4)5)14)15)]. The mid-left diameter (Ml) is also used as an index of left heart enlargement[16)].

Plain chest X-rays, as the simplest repeatable non-invasive procedure available, is even today, indispensable to the diagnosis of heart disease. We can surmise the hemodynamic condition of the heart according to changes in the shape and size of the heart shadow which, surrounded by the lung field, can be observed readily. In this reserach, the heart shadows of a control group and patient group were measured; by quantifying the shadow size and shape, their mean values were used to make an objective evaluation of the disease state; by making a cross-comparison of the patient groups, various characteristics of cardiac enlargement were revealed.

The sixteen items analyzed were subdivided into six factors: heart size, heart shape, body build, aortic size, blood pressure and age. The characteristics degree of severity of disease can be determined by evaluating the distributions of the structure vector and individual grades related to these six factors.

The factors which describe the control group heart size (and their respective upper limits for the male and female groups) are HV (619 ml, 436 ml), HV/BSA (364 ml/m^2, 299 ml/m^2), TD (14.2 cm, 11.7 cm), CTR (0.528, 0.583) and the U-G Formula (1.14, 1.11). Values greater than these were judged to indicate cardiac enlargement.

Cardiac enlargement was least prominent in the HT group because essential hypertension is largely due to pressure overload[17)]. This makes it difficult to detect this condition based on heart volume (HV) alone. However, essential hypertension can be detected from the characteristic left side and posterior enlargement. Moreover, hypertensive patients exhibit aortic elongation and dilatation which increases with the blood pressure value. We can therefore consider that aortic enlargement due to high blood pressure characterizes the heart shadow of essential hypertensive patients. Essential hypertension can thus be strongly suspected in subjects greater than forty years old who exhibit large values for these items.

In the female HT group, the close relationship between blood pressure and body build, especially the tendency toward obesity, suggests that the condition is one of increased cardiac output similar to hyperkinetic hypertension, rather than increased capillary resistance.

The MI group exhibited the same left side and posterior enlargement as the HT group, but an important difference observed was that aortic enlargement was minimal. It is well known that for MI patients who exhibit cardiac enlargement, the left ventricular function is diminished[18)] and the survival rate is low[19)20)21)22)]. Further, a high mortality rate among obese patients is also recognized[23)]. The degree of damage to the myocardium can be evaluated concretely by the %DS item[8)]; the extremely close relationship of %DS to the heart size items indicates the tendency toward cardiac enlargement is strongly related to the severity of the disease. The correction of obsity, particularly prevalent among males, improves the prognosis of heart disease.

The CRF group is characterized mainly by cardiac enlargement on the left side, but exhibits right side enlargement as well. In contrast with the HT and MI groups, posterior enlargement was minimal. Aortic enlargement was also small in view of the high blood pressure value. The disease is due primarily to volume overload which we presume induces hypertrophy and dilatation of all four chambers, especially the left ventricle; pericardial effusion may also affect the heart shadow. This may explain why the degree of arteriosclerotic lesions of the aorta is less than in the HT group. A noteworthy finding was the close relationship between the pulmonary congestion Score and cardiac enlargement. We can consider that the pulmonary congestion Score reflects the increased circulating blood volume in the body, and is thus an index which parallels the appearence of cardiac enlargement. The Score is an important factor in determining the degree of pulmonary congestion.

In general, it is thought that about half of hypertrophic cardiomyopathy patients have cardiac enlargement; evaluation of the CTR yielded similar results for the HCM group. However, most of the HCM group also exhibited an HV value surpassing that of the control group, confirming the presence of cardiac enlargement. The heart shadow showed equal enlargement of the right and left side resulting in a characteristic round shape when vierwd from the front.

By using the Principal Component Analysis method to quantitatively evaluate the shape of the enlarged hearts of all the subjects in the study, diagnosis and assessment of the degree of severity of heart disease was facilitated.

References

1) Hoffman, R.B. and Rigler, L.G.: Evaluation of left ventricular enlargement in the lateral projection of the chest. Radiology 85: 93—100, 1965
2) WHO Exoert Committee: Arterial Hypertension. World Health Organization, pp. 1—58, 1978, Geneva
3) Toshima, H., et al.: Annual Report of the Ministry of Health and Walfare: Idiopathic Cardiomyopathy Reseach Committee, pp. 234—235, 1979, Japan
4) Rohere, F.: Volumbestimmung von Körperhöhlen und Organen auf orthodiagraphischem Wege. Fortschr Rötgenstr 24: 285—294, 1916
5) Kahlstorf, A.: Über eine orthodiagraphische Herzvolumenbestimmung. Fortschr Rötgenstr 45: 123—147, 1932
6) Shiraishi, T.: Evaluation of disease associated with cardiac enlargement using plain chest X-ray films. J. Kansai. Med. Univ. 33: 604—622, 1981
7) Meszaros, W.T.: Lung changes in left heart failure. Circulation 47: 859—871, 1973
8) Shiraishi, T., Kobatashi, A., Hasegawa, T., Akagi, K., Nakazawa, M., Kasahara, A., Tanaka, Y., Watanabe, Y., Seo I., Sakai, A.: A study of the quantification of T1-201 myocardial scintigrams of prior myocardial infarction and their influence of left ventricular function. Radioisotopes 29: 479—483, 1980
9) Danzer, C.S.: The Cardiothoracic ratio: an index of cardiac enlargement. Am. J. M. Sc. 157: 513—521, 1919
10) Hammermeister, K.E., Chikos, P.M., Fisher, L. and Doge, H.T.: Relationship of cardiothoracic ratio and plain film heart volume to late survival. Circulation 59: 89—95, 1979
11) Ungerleider, H.E. and Clark, C.P.: A study of the transverse diameter of the heart silhouette with prediction table based on the teleoroentgenogram. Am Heart J. 17: 92—102, 1939
12) Gómez, G.E.: Importance of the relation between the anthrpometric index and the transverse cardiac diameter for appraising the size of the heart. Radiology 57: 217—226, 1951
13) Kobayashi, A.: Studies on roenthenographic detection of cardiomegaly with biplane filmes. J. Kansai Med. Univ. 31: 102—129, 1979
14) Jonsell, S.: A method for the determination of the heart size by teleroentgenography. Acta Radiol 20: 325—340, 1939
15) Muramatsu, J.: Heart size on the chest X-ray. Kokyu to Junkan 29: 229—236, 1981
16) Kazamias, T.M., Gander, M.P., Gault, J.H., Kostuk, W.J. and Ross, Jr J.: Roentgenographic assessment of left ventricular size in man: a standardized method. J. Appl Physiol 32: 881—884, 1972
17) Cohn, J.N., Limas, C.J. and Guiha, N.H.: Hypertension and the heart. Arch Intern Med. 133: 969-979, 2974
18) Feild, B.J., Russell, Jr R.O., Moraski, R.E., Soto, B., Hood, Jr W.P, Burdeshaw, J.A., Smith, M., Maurer, B.J. and

Rackley, C.E.: Left ventricular size and function and heart size in the year following myocardial infarction. Circulation 50: 331—339, 1974
19) Waris, E.K., Siitonen, L. and Himanka, E.: Heart size and prognosis in myocardial infarction. Am. Heart J. 71: 187—195, 1966
20) Shanoff, H.M. and Little, J.A.: Heart size and ten-year survival after uncomplicated myocardial infarction. Am. Heart J. 78: 608—615, 1969
21) Kostuk, W.J., Kazamias, T.M., Gander, M.P., Simon, A.L. and Ross, Jr J.: Left ventricular size after acute myocardial infarction. Circulation 47: 1174—1179, 1973
22) Battler, A., Karliner, J.S., Higgins, C.B., Slutsky, R., Gilpin, E.A., Froelicher, V.F. and Ross, Jr J.: The initial chest X-ray in acute myocardial infarction. Circulation 61: 1004—1009, 1980
23) Bray, G.A., Davkdson, M.B. and Drenick, E.J.: Obesity: a serious symptom. Ann. Intern. Med. 77: 779—795, 1972