INTRAVENTRICULAR ELECTROCARDIOGRAPHIC STUDY
ON RIGHT VENTRICULAR HYPERTROPHY
ESPECIALLY IN PATIENTS
WITH CHRONIC OBSTRUCTIVE PULMONARY DISEASE

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ELECTROCARDIOGRAPHIC diagnostic criteria of right ventricular hypertrophy has been described by numerous reporters including *Meyers, Klein, Stoffer* and others (1948), *Sokolow* and *Lyon* (1949), *Goldberger* (1949), *Milnor* (1957), *Roman, Walsh* and *Massie* (1961), and others. But, how to grasp the characteristics of the right ventricular overloading in the cases complicated by left ventricular hypertrophy or bundle branch block, is not distinctly explained yet in some respects.

Especially, the right ventricular hypertrophy in the chronic obstructive pulmonary disease often fails to be satisfied with the above mentioned diagnostic criterias. The apparent failure of the ECG to be chronic obstructive pulmonary disease may be due to a lack of linear relationships between hypertrophy and action potential, the inability of the lead system to reflect these changes, or to improper selection of quantitative criteria.

The conventional intraventricular electrocardiographic studies of the right ventricular hypertrophy has been performed by analysis of the pattern and quantitative determination of the voltage of the QRS complex in unipolar lead. The results of the above determination will vary fairly much with the spatial orientation of the intraventricular electrode against the myocardium in connection with change, as a function

of time, of the active potential of myocardium. The technique, therefore, cannot very well be applied to the evaluation of different cases on comparative basis. However, in the bipolar lead electrocardiography wherein the intraventricular electrode is fixed at a certain position while the electrode on the precordial region are shifted from one position to another, since depolarization then proceeds from the endocardium to the epicardium, the local diagnosis in the sense of right or left predominance in the individual identical cases must be feasible to some extent. Under this notion, the author at the time of carrying out right heart catheterization used a catheter with a platinum electrode to record right intraventricle — precordial region bipolar electrocardiography for the study how the right ventricular overloading was reflected.

METHODS

Comprised in the present studies were 12 cases of chronic cardiac disease in whom right ventricular overloading was conceivable and 17 cases of chronic obstructive pulmonary disease. Prior to right heart catheterization, chest X-ray studies, standard lead electrocardiography and pulmonary function tests were performed. In the cases of chronic cardiac disease, phonocardiogram was also recorded.

At right heart catheterization, a catheter with a platinum electrode (made by USCI Company) was led in along the right ventricular outflow tract, mid and inflow tract under fluoroscopy. At each of those sites a simultaneous recording was performed of pulmonary arterial pressure, right

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TABLE I PULMONARY CIRCULATORY DYNAMICS, QRS ELECTROCARDIOGRAM AND A RATIO IN 12

Case No.					PAP (mmHg)			RVP (mmHg)		CI (l/min.M ²)
					s	d	m	s	d	
1.	U. K.	M	62	MI	65	37	46	70	8	2.56
2.	H. M.	M	34	MSI	44	23	34	45	7	—
3.	T. T.	F	21	MSI	44	23	29	45	3	5.28
4.	H. T.	F	40	MS	—	—	22	35	6	3.10
5.	K. F.	M	34	MS	57	31	40	67	9	2.42
6.	G. M.	M	21	MS	80	50	60	80	5	4.66
7.	R. O.	M	17	MI + AI	97	29	64	97	5	4.06
8.	T. I.	M	34	ASD	39	8	21	51	3	*20.98
9.	M. Y.	F	19	VSD	70	39	49	70	2	*16.44
10.	Y. Y.	M	43	VSD	78	25	49	78	5	*16.77
11.	S. F.	M	18	Eisenmenger's	163	87	116	163	13	* 4.39
12.	F. S.	M	17	Ebstein's + VSD	40	9	26	40	9	*11.26

*: Pulmonary blood flow

MI: Mitral insufficiency, MSI: Mitral steno-insufficiency, MS: Mitral stenosis,
 Eisenmenger's: Eisenmenger's syndrome. Ebstein's: Ebstein's disease,
 RVP: Right ventricular pressure (s; systolic, d; diastolic),

Fig.1.

ventricular pressure, max dp/dt, unipolar right intraventricular electrocardiography (RIVECG), and standard limb lead electrocardiography (I, II, or III lead). Next, the RA electrode of I lead of

the standard lead was connected with the intraventricular electrode. The point of frontal projection, on the precordial region, of the intraventricular electrode was dealt with as O, and center-

PATTERN IN THE RIGHT INTRAVENTRICULAR PATIENTS WITH CARDIAC DISEASE

TPRI (dyne.sec.cm ⁻⁵ /M ²)	QRS complex			A (A _R /A _L) ratio			Criteria of Roman
	outflow	mid	inflow	outflow	mid	inflow	
1436	rS	—	Qrs	1.70	—	0.70	negative
—	rS	—	—	1.10	—	—	negative
280	rS	—	—	2.26	—	—	negative
567	—	qr	—	—	1.00	—	negative
1320	rsR'S'	—	Qrs	1.36	—	1.00	negative
1126	rS	rS	QS	1.31	—	—	R/S _{V₁} 1.0
1260	—	rSr's'	—	—	2.30	—	compl. RBBB R/S 10.0
78	rsr'S'	rsr'S'	rsr'S'	1.81	1.47	1.43	negative
238	rs	—	—	1.20	—	—	R/S 1.3
234	rS	rS	rS	1.25	1.19	1.36	negative
2112	rS	—	—	1.44	—	—	compl. RBBB R/S _{V₁} 16.0
185	rS	—	rsr'S'	1.77	—	2.24	R/S _{V₁} 1.6

AI: Aortic insufficiency, ASD: Atrial septal defect, VSD: Ventricular septal defect,
 PAP: Pulmonary artery pressure (s; systolic, d; diastolic, m; mean),
 CI: Cardiac index, TPRI: Total pulmonary vascular resistance.

ing around that point LA lead were placed clockwise at 0°, 45°, 90°, 135° and 180° point, respectively, with 5 cm intervals. The respective points were designated A, B, C, D, and E. Simultaneously with the right intraventricular pressure curve, bipolar lead electrocardiography was performed of the right ventricular outflow tract, mid and inflow tract and at O, A, B, C, D and E on the precordial region corresponding to the above sites.

The highest height of the R wave of the bipolar lead electrocardiography obtained as stated above, was projected from O as the original point to the respective directions as shown in Figure 1; and the vector area surrounded by O, A, B, and C was dealt with as left ventricular element, and designated A_L. Likewise, the vector area formed by O, C, D, and E was dealt with as the right ventricular element, and designated A_R. The ratio A_R to A_L (A_R/A_L) was calculated, and the resultant figure was designated A ratio and used as an index and comparatively studied with circulation values.

RESULTS

With reference to the 29 cases under study,

their basic disease, pulmonary arterial pressure (PAP), right ventricular pressure (RVP), total pulmonary vascular resistance (TPRI), cardiac index (CI), the pattern of the QRS complex in the unipolar RIVECG (outflow, mid and inflow), and A ratios are presented in Table 1 and Table 2. The pattern of the QRS complex in the unipolar RIVECG, at the outflow tract in all the cases, rS, RS, rSR'S', rSR'S', rSR', etc. thus with a preceding positive deflection; but at the mid and inflow tract in some cases, qr, qrs, QS, etc. were observed, thus with a preceding negative deflection.

1) Relationship between A ratio and pulmonary arterial mean pressure (PAm):

The relationship between A ratio and PAm at the outflow tract or mid was found to be as follows. The A ratios of both sites were well correlated with PAm (Figures 2 and 3). The correlation coefficient at the outflow tract was 0.446 (p<0.02), at the mid was 0.828 (p<0.01). Their positive relationship was highly significant. The number of cases studied for the mid was small, therefore, their comparative study with A ratio, together with value at the outflow tract, showed a correlation coefficient of 0.531 (p<0.01), a significantly positive relationship

TABLE II PULMONARY CIRCULATORY DYNAMICS, RESPIRATORY FUNCTION, AND A RATIO IN 17 PATIENTS WITH CHRONIC OBSTRUCTIVE

Case No.	Diagnosis				PAP (mmHg)			RVP (mmHg)		CI (l/min.M ²)	TPRI (dyne.sec.cm ⁻⁵ /M ²)
					s	d	m	s	d		
1.	K. H.	M	57	CPE	22	10	14	25	4	4.38	255
2.	S. F.	M	70	CPE	30	15	22	30	6	2.35	248
3.	H. Y.	M	50	CPE	50	31	40	60	6	5.60	571
4.	T. T.	M	64	CPE	32	9	20	33	3	3.18	502
5.	M. Y.	M	49	CPE	25	8	15	26	2	3.32	361
6.	K. H.	M	58	CPE	28	12	18	30	4	3.27	440
7.	R. O.	M	64	CPE	21	9	12	24	4	2.24	428
8.	K. S.	M	64	CPE	39	14	18	41	4	4.42	524
9.	H. U.	M	55	CPE	39	23	29	41	4	4.42	524
10.	K. F.	F	68	CPE	39	14	21	40	3	2.91	540
11.	S. S.	M	69	CPE	29	19	25	31	4	3.04	657
12.	I. K.	M	61	chr. bronch.	21	6	14	24	4	4.25	263
13.	T. H.	M	53	chr. bronch.	22	8	15	35	5	4.24	283
14.	M. K.	M	56	chr. bronch.	39	12	18	46	11	2.76	160
15.	Y. O.	M	39	bron. asthma	19	9	13	25	4	4.50	231
16.	N. O.	M	23	bron. asthma	16	5	12	18	5	3.98	240
17.	N. I.	M	17	bron. asthma	20	10	14	20	2	2.20	509

CPE: Chronic pulmonary emphysema. chr. bronch: Chronic bronchitis. bron. asthma: Bronchial asthma. RVP: Right ventricular pressure (s; systolic, d; end-diastolic). CI: Cardiac index. TPRI: Total pulmonary %VC: Vital capacity/Predetermined vital capacity.

(Fig. 4).

The A ratios at both sites exceed 0.9 in all cases with PAm over 17 mmHg, with the exception of one case of chronic pulmonary emphysema. T-test by dividing the cases into two groups, one with over 0.9 as A ratio at the outflow tract or mid and the other with less than 0.9, showed the pressure of a significant difference ($p<0.01$) between the two groups. This shows that the A ratio of 0.9 at the outflow tract or mid can be taken as the critical value of the right ventricular pressure overloading (Fig. 5).

On the other hand, in the inflow tract, the relationship between A ratio and PAm showed a correlation coefficient of 0.214 thus without significant correlation.

2) Relationship between A ratio and cardiac index (CI):

The correlation coefficient at the outflow tract was 0.398, at the mid was 0.342, thus without a significant correlation observed.

On the other hand, the A ratio at the inflow

tract evidently tended to increase as the cardiac index increased. A correlation coefficient of 0.581 ($p<0.02$), a highly positive correlation, was observed (Fig. 6). Many cases with over 0.9 as the A ratio at the inflow tract showed the cardiac index within the normal range. Increase in A ratio at the inflow tract, however, was distinctly noted in the cases of congenital heart disease with left to right shunt.

3) Relationship between A ratio and total pulmonary vascular resistance (TPRI):

The relationship between the total pulmonary vascular resistance (TPRI) and the A ratio showed much scatter at the outflow tract, mid and inflow tract, failing to exhibit any consistent tendency.

4) Relationship between A ratio and Roman's and WHO's diagnostic criteria for right ventricular hypertrophy:

In the 12 cases of chronic cardiac disease under my study, comparative study was performed between the criteria described by Roman

QRS PATTERN IN THE RIGHT INTRAVENTRICULAR ELECTROCARDIOGRAM
PULMONARY DISEASE

FEV _{1.0} EVC	%VC	QRS complex			A (A _R /A _L) ratio			Standard leads	
		outflow	mid	inflow	outflow	mid	inflow	Roman	WHO
41	96	rS	QS	QS	0.82	0.49	0.62	negative	negative
32	52	—	QS	QS	—	1.16	0.90	negative	negative
—	—	rS	—	—	1.00	—	—	RAD 134° R/S _{V₆} 0.66	Predom. S R/S _{V₅} 0.8
36	774	RsR'S'	—	rS	1.12	—	0.98	negative	R/S _{V₅} 0.8
52	69	RS	—	—	0.73	—	—	negative	negative
46	78	—	RS	rS	—	0.93	0.53	negative	negative
25	109	RS	qS	rS	0.62	0.28	1.30	negative	negative
48	73	r	r	—	0.80	—	—	negative	negative
48	71	rS	—	—	1.12	—	—	RAD 124° R/S _{V₆} 0.7	incompl. RBBB R/S _{V₅} 0.6
27	93	rS	—	—	0.98	—	—	negative	negative
39	71	rS	—	—	1.05	—	—	negative	negative
50	98	rSR'	—	QS	0.50	—	0.68	negative	negative
68	100	rS	—	rSR'	0.66	—	0.52	negative	negative
42	127	rS	—	—	1.00	—	—	negative	negative
—	—	rSR'S'	—	Qr	0.10	—	—	negative	negative
75	104	RS	—	rS	0.77	—	1.25	negative	negative
67	116	r	qr	r	0.54	0.27	0.39	negative	negative

PAP: Pulmonary artery pressure (s; systolic, d; diastolic, m; mean)

vascular resistance. FEV/EVC: Forced expiratory volume in 1 second/Expiratory vital capacity.

et al. and A ratio at the right ventricular outflow tract or mid. In the 17 cases of chronic obstructive pulmonary disease, comparative study was performed between the criteria described by Roman et al. and WHO criteria of evaluation of right ventricular hypertrophy in cor pulmonale on one hand and the A ratio at the outflow tract or mid on the other (Table 3).

In the 12 cases with chronic cardiac disease, the A ratio at the outflow tract or mid exceed 0.9, PAm was invariably over 17 mmHg. The three cases of those cases satisfied with one or more of the criteria described by Roman et al.

In the 9 cases of the 17 cases with chronic obstructive pulmonary disease, PAm was over 17 mmHg. Excepting one (A ratio=0.80) of them, A ratio at the outflow tract or mid in 8 cases exceed 0.9. Furthermore, two cases (H.Y. and H.U.) in those 8 cases satisfied with the criteria described by Roman et al. and WHO criteria. Therefore, in 6 cases who did not satisfied with the conventional criteria of right

ventricular hypertrophy in the standard lead ECG, the A ratio at the outflow tract or mid was over 0.9.

DISCUSSION

Electrocardiographic studies for right ventricular hypertrophy have been performed by numerous workers by standard leads and intraventricular leads. Emslie-Smith¹ recorded, in his unipolar RIVECG, the presence of the late R in 33 of 50 cases of congenital and acquired heart disease. No significant relationship appears to exist between the occurrence or amplitude of this R and either the right ventricular systolic pressure or the QRS pattern in lead VI or aVR. Dickens and Goldberg *et al.*² pointed out that the variation in the precordial patterns with similar endocardial pattern was a reflection of the influence of cardiac position and the distal effects of left ventricular predominance on the precordial lead. They added that exact correlations between the endocardial patterns with

Fig.2. Relationship between pulmonary arterial mean pressure (PAm) and a ratio in right ventricular outflow.

respect to age, type of lesion, right ventricular pressure, an type of peripheral electrocardiogram could not be made. Thus one could not assumed that the precordial lead and right arm lead invariably reflected intraventricular active potentials. Among the present author's cases, too, even when the active potentials of the QRS complex in unipolar RIVECG was small, some cases exhibited pulmonary hypertension; thus, there was no correlationship observed between the active potentials of the QRS complex and the right ventricular pressure. Thus, by mean only of the unipolar RIVECG, it is extremely difficult to decide the relationship with right ventricular hypertrophy or right ventricular pressure overloading and the voltage or pattern of QRS complex.

The author, using the concept of right ventricular element and left ventricular element in individual cases, tried bipolar leads between within the right ventricle and on the precordial region; and, by the method already mentioned, examined the ratio of the right ventricular element to the left ventricular element, and, in this way, the author succeeded to some extent in quantitative judgment the right ventricular overloading. In other words, by converting the difference in active potentials in unipolar RIVECG in the individual cases to such a ratio as above mentioned, the difference between the cases could be reduced to a minimum.

*Cabrera et al.*³ who examined standard lead ECG from the hemodynamic standpoint, divided the right ventricular overloading into systolic

Fig.3. Relationship between pulmonary arterial mean pressure (PAm) and A ratio in right ventricular mid.

overloading and diastolic overloading. In the systolic overloading, they observed increases of voltage of the R wave, sometimes producing an initial slurring R, and if the systolic overloading was marked and long duration, it could produced a negative T wave in VI. In the diastolic overloading, they pointed out the presence of complete or incomplete right bundle branch block.

The systolic overloading can of course be comprehended as a pressure overloading. In the present author's studies, the increased A ratio at the outflow tract or mid reflected the pressure overloading, in which cases the A ratio at the both sites was over 0.9. This value may be taken to indicate that it shows the critical value of the pressure overloading of the right ventricle.

Using the cardiac index as one factor indicating diastolic overloading, i.e. volume overloading,

the cardiac index and A ratio were studied for relationship, when a positive correlation was noted at the right ventricular inflow tract. In other words, the increased A ratio at the inflow tract suggests that functional or morphological change (towards hypertrophy) of the inflow tract has come from increase in inflow overloading (volume loading).

Essentially, the right ventricular wall is thinner than the left ventricular wall and, consequently, the right ventricular wall is believed to be better able to adjust with volume overloading, without allowing the intraventricular pressure to rise even in the instance of fairly much dilatation. In short, the pressure overloading is considered to tend directly to produce hypertrophy than is inflow overloading. But pressure overloading is of course not equal to right ventricular hypertrophy. The persistence of pres-

Fig.4. Relationship between pulmonary arterial mean pressure (PAm) and A ratio in right ventricular outflow and mid.

sure overloading may, however, bring about centripetal right ventricular hypertrophy. In this sense, the A ratio at the outflow tract or mid may possibly be a more useful index for the early diagnosis of right ventricular hypertrophy.

Grant *et al.*⁴ pointed out that the right ventricular hypertrophy to start at the right ventricular outflow tract and Crista supraventricularis. The A ratio at the outflow tract may, therefore, represent the subtle electrical change by the hypertrophy of that site.

A question posed here must be what relationship there is between the pressure overloading grasped in the form mentioned above and the conventional electrocardiographic right ventricular hypertrophy. Relationship was studied between the criteria of Roman *et al.*⁵ which are the most simple, highest in probability, and often

used in daily clinical practice, and the A ratio at the outflow tract or mid. However, the criteria of Roman *et al.* which are very suitable for the diagnosis of right ventricular hypertrophy due to congenital heart disease are believed to have problems in the judgment of right ventricular hypertrophy due to chronic cor pulmonale.

In the electrocardiograms of cases with chronic pulmonary emphysema and chronic cor pulmonale, Scot⁶ studied the causes of the low QRS voltage, and found the following factors: (1) the electrodes are relatively far removed from the ventricles; (2) the emphysematous lung is a poor electrical conductor; (3) the spatial QRS vector tends to be posteriorly directed, with a resultant small projection on the frontal plane. It may be started that the electrocardiographic differentiation of cases of pulmonary emphy-

Fig.5. T test between the two groups of A ratio under 0.9 and over 0.9.

sema without cor pulmonale from cases with cor pulmonale is often difficult or impossible, Scot added.

As for the electrocardiograms of chronic pulmonary emphysema, numerous reports have been published by Wasserburger,⁷ Spodick,⁸ Littmann,⁹ Okafuji,¹⁰ Calataynd,¹¹ Kerr,¹² and others from the height and axis of P wave and VCG, etc. Concerning the emergence of right ventricular hypertrophy when converted to cor pulmonale, some workers have pointed out the presence of slurred in^{13,14} VI. What is the electrocardiographic standard for judging the conversion into cor pulmonale, is a highly controversial problem.

The change in myocardial action potentials and in the transmission process of excitement will vary with the individual cases, and, there-

fore, comparing the individual cases on the basis of the absolute value of the height of the QRS complex would pose a problem. In the study of right ventricular hypertrophy by unipolar RIVECG, higher electric potential of the QRS complex than normal has been described, but it has not indicated the electric potential in the absolute value, presumably because of the situation mentioned above¹⁵.

Among the three elements pointed out by Scot, in respect to situation of electrode, the point of frontal plane projection of the tip of the catheter with platinum electrode at the right ventricular outflow tract ranged from the vicinity of the left margin of the second intercostal sternum to the vicinity of the left margin of the fourth intercostal sternum in the cases with chronic obstructive pulmonary disease. The O

Fig.6. Relationship between cardiac index (CI) and A ratio in right ventricular inflow.

point was variable, so to say. In every case, however, the experiment was carried out with the right ventricular electrode fixed at the right ventricular outflow tract, mid or inflow tract. Then bipolar lead in the right ventricle and precordium is used as done under the present experiment, variability of the position of the electrode does not always constitute an important question, it seems.

As for the next question of the uniformity of the lung as a volume conductor, *Katz et al*¹⁶ stated that the presence of the lung will considerably distort the electric field produced by the action potential of myocardium. *Kaufman et al*¹⁷, on the contrary, believe that the degree of nonuniformity of the lung as a volume conductor

may be negligible. In this studies, one electrode was within the right intraventricular cavity while the other electrodes were placed clockwise at 5 cm intervals centering around the point of projection on the frontal plane, and, therefore, even though there was increased air content, comparison could be performed under fairly similar conditions, and, thus, the distortion of conductivity in the lung could be reduced to a minimum.

Thus, there are various difficult problems in the electrocardiographic judging criteria for right ventricular hypertrophy in chronic cor pulmonale. WHO expert committee directed its attention to the qR pattern of V_1 in chronic cor pulmonale and stated that this pattern alone

TABLE III RELATIONSHIP BETWEEN ROMAN'S OR WHO'S CRITERIA FOR RVH AND A RATIO

Cardiac disease				
		Cases	A ratio	
			> 0.90	< 0.90
Roman	(+)	3	3	0
	(-)	9	9	0
Total		12	12	0

Chronic obstructive pulmonary disease				
		Cases	A ratio	
			> 0.90	< 0.90
Roman	(+)	2	2	0
	(-)	15	6	9
Total		17	8	9

		Cases	A ratio	
			> 0.90	< 0.90
WHO	(+)	2	2	0
	(-)	15	6	9
Total		17	8	9

would strongly suggest the presence of right ventricular hypertrophy. The expert committee reported that in the absence of a qR pattern a combination of at least two of the following changes must be present for these alterations to be indicative of right ventricular hypertrophy: (1) Alteration in the ratio R/S in the left chest leads with R/S less than 1 in V₅. (2) Predominant S wave in standard lead I. (3) Presence of an incomplete right bundle branch block with QRS less than 0.12 second.

In this study, in the cases that satisfied with the criteria of Roman et al. for judgment of right ventricular hypertrophy and also with WHO criteria for judgment of right ventricular hypertrophy in chronic cor pulmonale, the A ratio at the outflow tract and mid was over 0.9. Even when the above mentioned criteria were not satisfied with, in the cases whose A ratio at the outflow tract and mid was over 0.9, the pulmo-

nary arterial mean pressure was over 17 mmHg. Thus, the increased A ratio at the outflow tract or mid does well represent pressure overloading that preceded right ventricular hypertrophy, and the increased A ratio seemed to be useful for early diagnosis of right ventricular hypertrophy.

As is well known, in chronic pulmonary emphysema, there is considered to be no correlation between its severity and cardiac index. That severity rather shows a better correlation with the degree of elevation in pulmonary arterial pressure, as has been clarified through studies conducted in our Department¹⁹. The examination of the A ratio in chronic pulmonary emphysema, especially increased A ratio at the outflow tract or mid, can well indicate the right ventricular pressure overloading that fails to be distinctly noted by means of standard lead electrocardiogram. In the above manner, the tendency towards right ventricular hypertrophy will become known at an early stage. In other words, the advance from chronic obstructive pulmonary disease without right ventricular hypertrophy to chronic obstructive pulmonary disease with right ventricular hypertrophy i.e. cor pulmonale is predicted by an increased A ratio at the outflow tract or mid. In knowing about clinical course and prognosis of chronic obstructive pulmonary disease, the above mentioned technique of RIVECG may be regarded to be very useful.

SUMMARY

At right heart catheterization, a catheter with a platinum electrode was used for recording bipolar electrocardiograms between each of the outflow tract, mid and inflow tract of the right ventricle and precordium. In the individual clinical cases including those of chronic obstructive pulmonary disease, the ratio right ventricular element to left ventricular element was calculated, which another named A ratio. Whether or not there was right ventricular predominance was examined by employing the A ratio as the index. Examination for correlation was made between the A ratio, pulmonary arterial mean pressure (PAm) and cardiac index (CI), and the following conclusions have been obtained.

1) At the right ventricular outflow tract or mid, between the pulmonary arterial mean pressure and A ratio there was observed a significant positive correlation (outflow, $P < 0.02$; mid, $P < 0.01$).

In all but one of the cases whose pulmonary

arterial mean pressure exceeded 17 mmHg, the A ratio at the outflow tract or mid was over 0.9. Dividing the cases into two groups, one showing over 0.9 as the A ratio at the right ventricular outflow tract or mid the other under 0.9, the T test, too, a difference of statistical significance ($p < 0.01$) was observed between two groups. Thus, the A ratio has become known as an useful critical value for judgment whether or not there is pulmonary hypertension and/or right ventricular systolic overloading.

2) The A ratio at the right ventricular inflow tract exhibits a positive correlation with cardiac index. Especially in the cases of congenital heart disease accompanied by left to right shunt that pulmonary blood flow increased, the A ratio at the inflow tract tended distinctly to rise.

3) All the cases satisfied with the conventional electrocardiographic criteria for right ventricular hypertrophy (Roman et al. and WHO) showed the A ratio over 0.9. The increased A ratio may be interpreted to precede the right ventricular hypertrophy. The A ratio at the right ventricular outflow tract or mid seems to be useful as an index for early diagnosis of right ventricular hypertrophy.

Increase in the A ratio at the outflow tract or mid may be interpreted to represent the right ventricular overloading in not only cardiac disease but also chronic obstructive pulmonary disease, making it possible to evaluate to the aggravation from chronic obstructive pulmonary disease without pulmonary hypertension to chronic cor pulmonale.

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