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小児における右室収縮時相の評価：右心機能指標との対比

Evaluation of right ventricular systolic time intervals in children: Their correlation with indices of right ventricular function

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Summary

Systolic time intervals of right side of the heart (R STIs) were obtained from pulmonary artery pressure recordings by the catheter-tip micromanometer during cardiac catheterization in 293 infants and children (157 males and 136 females; ages from one day after birth to 17 years; mainly with congenital heart disease) and were analyzed their relations to other indices of cardiac performance of the right heart. Volume data were also obtained from biplane cineangiography of the right heart in 90 cases.

Among the R STIs, the ratio of pre-ejection period to ejection time of the right ventricle (R PEP/ET) was mainly analyzed. R PEP/ET was somewhat dependent on heart rate. The most definite correlation was observed between R PEP/ET and pulmonary artery diastolic pressure (RADP) irrespective of disease (R=0.88); the correlation of R PEP/ET with the other indices were less masked [right ventricular end-diastolic pressure (RVEDP): R=0.23, right ventricular ejection fraction (RVEF): R=−0.30, and maximal first time derivative of right ventricular pressure (RV P-dP/dt): R=0.46].

Key words

RV STIs　Catheter tip manometer　RV function

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Introduction

Systolic time intervals (STIs) are now well accepted as indices of cardiac performance. They are most properly obtained from pressure recording of the aorta or main pulmonary artery, while they might be obtainable noninvasively by means of external arterial pressure recording or ultrasound[1~3].

As to STIs of right side of the heart (R STIs), where external pressure recording is technically difficult, many reports have come out which deal with R STIs obtained through methods using ultrasound[3~6]. However, the investigations on R STIs obtained from direct pulmonary artery pressure recording are still insufficient.

Herein we report on R STIs, especially on the ratio of pre-ejection period to ejection time of the right ventricle (R PEP/ET), obtained from pressure recording of the pulmonary artery, and discuss on their relations to various indice^(s) of the function of right side of the heart.

Materials

The subjects of this study were 293 infants and children, 157 males and 136 females, suffering mainly from congenital heart disease. Their ages ranged from one day to 17 years. All were performed cardiac catheterization at the hospital of National Cardiovascular Center

Table 1. Subjects

Ventricular Septal Defect	68
Patent Ductus Arteriosus	26
Atrial Septal Defect	40
Pulmonary Stenosis	12
Valvular Heart Disease in the Left Heart	39
Myocardial Disease	11
Miscellaneous	10
History of MCLS	53
No Organic Heart Disease	34
Total	293

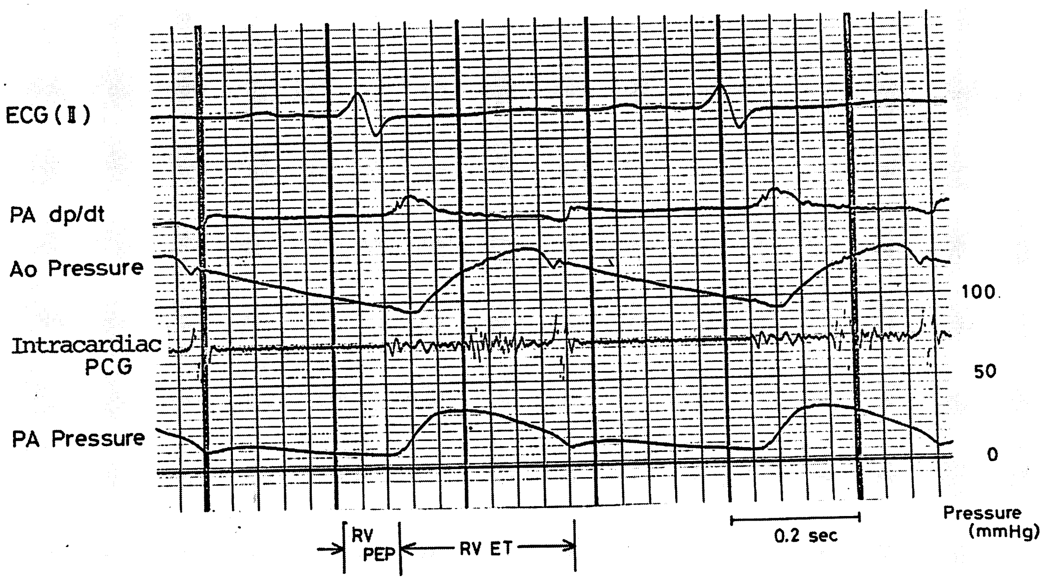


Fig. 1. An example of catheterization record.

Displayed from the top downward: electrocardiogram (second lead), first time derivative of pulmonary artery pressure, aortic pressure, intracardiac phonocardiogram and pulmonary artery pressure. As displayed at the bottom, right ventricular preejection period (R PEP) and right ventricular ejection time (RV ET) are measured.

during the period from October, 1977 to March, 1979.

They were divided into groups according to diseases, the numbers of which are listed on **Table 1**. The miscellaneous disease group contains complicated heart disease of the right heart, and the group of no organic heart disease (NOHD) contains patients with non-regurgitant, prolapsing mitral valve or cardiac arrhythmias or hemodynamically non-significant extracardiac arteriovenous shunts. The patients with history of Kawasaki's disease (MCLS) who were given cardiac catheterization seeking for coronary artery involvement, make up the group of history of MCLS. The last two groups, namely those of history of MCLS and NOHD, were considered " hemodynamically normal ".

Patients with WPW syndrome, complete right bundle branch block and transposition of great arteries were excluded from the study; postoperative patients with the open heart procedure was also excluded.

Methods

During one series of cardiac catheterization procedure, pulmonary artery and right ventricular pressures were measured and recorded by means of the catheter tip micromanometer (Miller Co) and Hewlett-Packard 4558 recorder. Pressures were also measured by fluid-filled catheter and pressure transducer (Hewlett-Packard Co) at the same time, so that pressure drift of catheter tip manometer was warranted to be negligible.

Pressures were analyzed in use of Hewlett-Packard 5600M pressure analysis system. Just after the pressure measurement, the biplane cineangiography of the right atrium or right ventricle was performed, yielding right ventricular

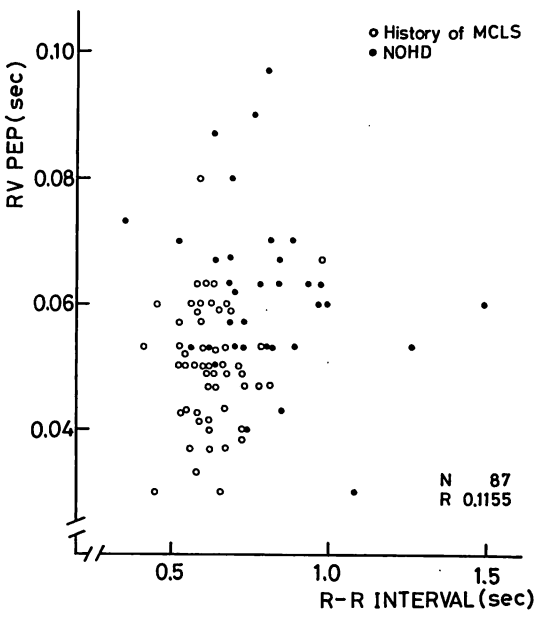


Fig. 2. Plotting of right ventricular preejection period (RV PEP) **against R-R interval in cases with history of Kawasaki's disease** (MCLS) **or no organic heart disease** (NOHD).

No correlation is recognizable.

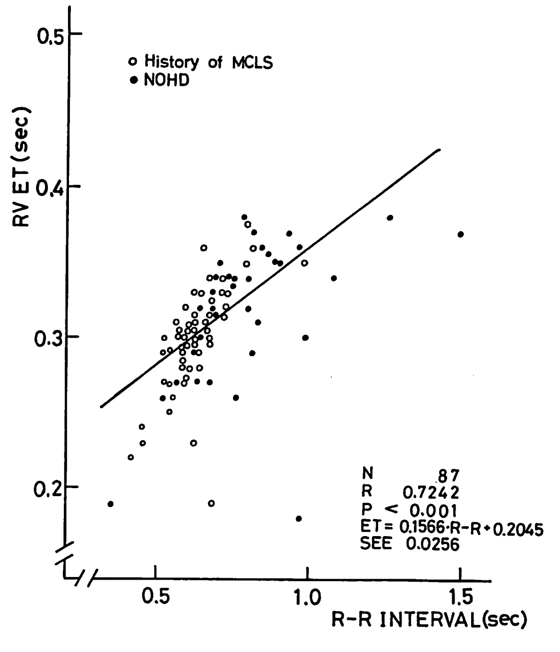


Fig. 3. Plotting of right ventricular ejection time (RV ET) **against R-R interval in the same cases as in Fig. 2.**

Close positive correlation is observed, implying inverse relation of RV ET with heart rate.

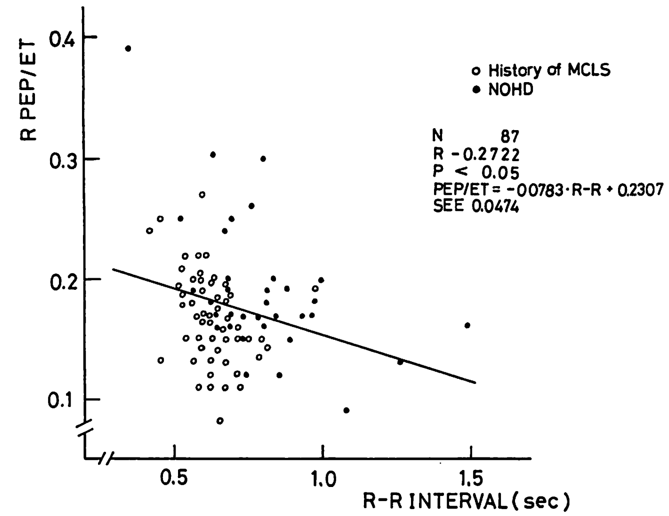


Fig. 4. Plotting of the ratio of pre-ejection period to ejection time of the right ventricle (R PEP/ET) against R-R interval in the same cases as in Fig. 2.

Statistically significant inverse relation is observed. But it is less intense and the slope of the regression line is not steep.

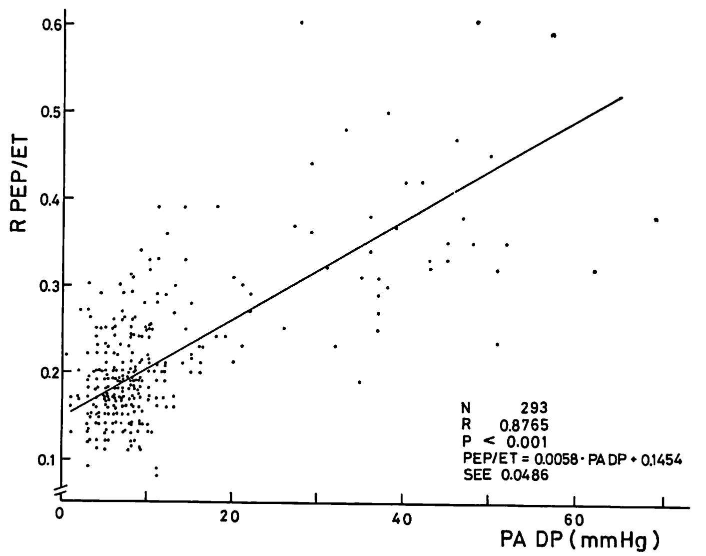


Fig. 5. Plotting of the ratio of pre-ejection period to ejection time of the right ventricle (R PEP/ET) against pulmonary artery diastolic pressure (PA DP).

Close direct relation exists. No case whose PEP/ET is greater than 0.4 exists at the range of PA DP below 15 mmHg.

volume data through the biplane integration method of Graham et al[7] with Hewlett-Packard 5600M voulme analysis system.

As shown in **Fig. 1**, right ventricular pre-ejection period (RV PEP) and right ventricular ejection time (RV ET) were measured from pulmonary artery pressure recording; the former from the onset of the Q wave of simultaneous electrocardiogram to the upstroke of pulmonary artery pressure, and the latter then to the dicrotic notch of it. Paper speed for recording was 200 mm per second; measurements were performed on at least three successive beats with few exceptions in cases with extrasystole.

Results

In " hemodynamically normal " cases, we analyzed the relationship between R STIs and heart rate. **Figs. 2~4** are plottings of RV PEP, RV ET, and R PEP/ET against R-R intervals of simultaneous electrocardiogram. RV PEP scattered at wide range, independently of R-R interval. RV ET closely correlated with R-R interval, and R PEP/ET was somewhat inversely related with it, accordingly. Dependence of R PEP/ET on R-R interval, and, therefore, on heart rate was not negligible, but the correlation was not so intense, and in the range of R-R interval, 0.5-1.0 second, where a large number of cases were included, the difference of R PEP/ET due to heart rate was accounted to be 0.04, estimated from linear regression equation.

R PEP/ET was plotted against pulmonary artery diastolic pressure (PA DP) in all cases (**Fig. 5**). Intense direct relation was recognizable. Cases with PA DP below 15 mmHg who are thought not involved with pulmonary hypertention decrease dramaticaly at the range of R PEP/ET above 0.3, and do not exist above 0.4.

R PEP/ET was then plotted against right ventricular end diastolic pressure (RV EDP) (**Fig. 6**). Apparently, no correlation was recognized. In our cases, a few had PA DP over 10 mmHg, because the cardiac catheterization

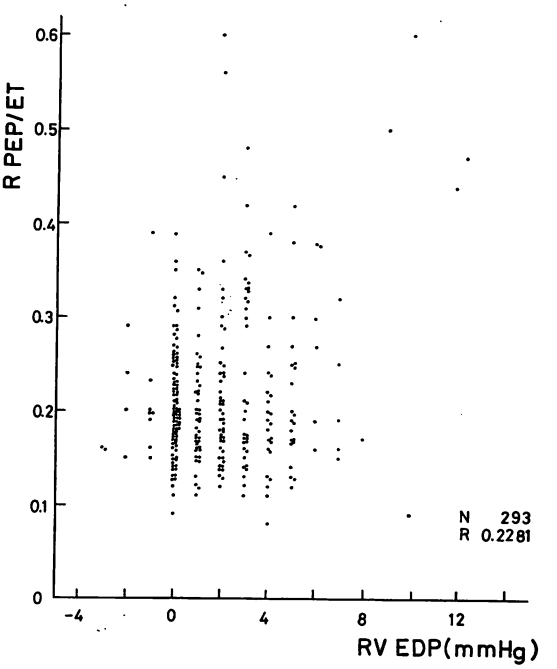


Fig. 6. Plotting of the ratio of pre-ejection period to ejection time of the right ventricle (R PEP/ET) **against right ventricular end diastolic pressure** (RV EDP).

Apparently, no correlation is recognizable.

was undergone only when heart failure was under the control except certain situations, when RV EDP was not seriously elevated.

It is of much interest to know the relation between R STIs and volume indices. R PEP/ET was plotted against right ventricular end-diastolic volume index (RV EDVI) and right ventricular ejection fraction (RV EF) (**Figs. 7** and **8**). Since volume data were not obtainable from all cases, these plottings were possible in 90 cases (about one third of all). Cases with various diseases were included. In the former plotting, no correlation existed, and in the latter, statistically significant inverse relation existed. This relation, though not definitely, suggests the tendency that R PEP/ET increases with lowered pump function of right ventricle.

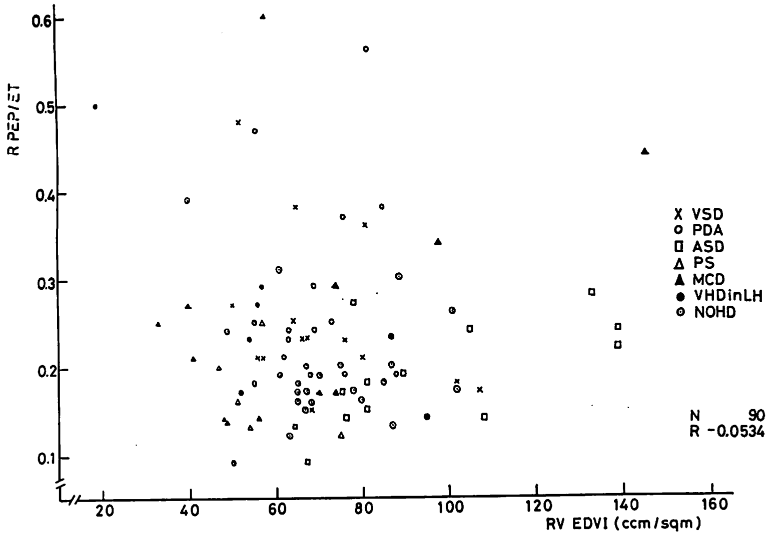
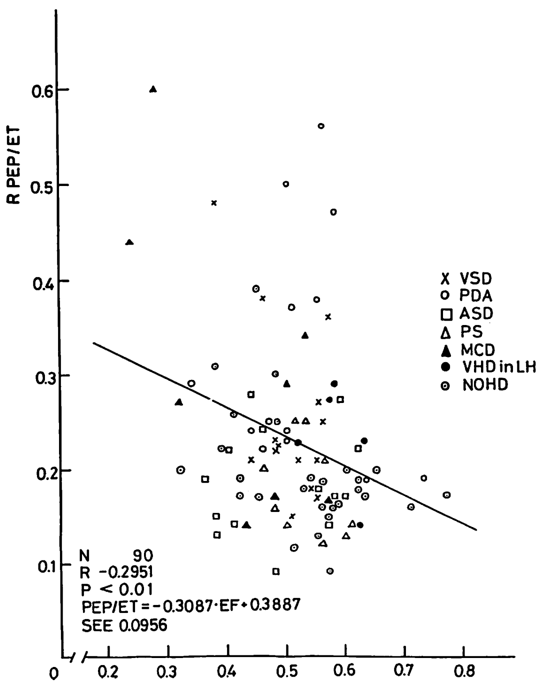


Fig. 7. Plotting of the ratio of pre-ejection period to ejection time of the right ventricle (R PEP/ET) against right ventricular end diastolic volume index (RV EDVI).
No significant correlation exists.



←**Fig. 8. Plotting of the ratio of pre-ejection period to ejection time of the right ventricle** (R PEP/ET) **against right ventricular ejection fraction** (RV EF).
Though correlation coefficient is not large, statistically significant inverse relation is observed, implying that PEP/ET may be increased with depressed pump function.

Relations of R PEP/ET with various functional parameters of right side of the heart are listed on **Table 2**. In addition to four parameters mentioned previously, maximal first time derivative of right ventricular pressure (RV P-dP/dt) and right ventricular systolic pressure (RV SP) are listed. In any way, no index which correlated with R PEP/ET more intensively than PA DP existed.

The relationships between R PEP/ET and PA DP in various diseases are displayed in **Figs. 9~14**. In groups with ventricular septal defect and patent ductus arteriosus, where pulmonary hypertension is common, close correlation was observed. On the other hand, in

Table 2. Correlation of R PEP/ET with various functional indices of the right heart

		N	R	Regression Formula	(R PEP/ET)	SEE
RV EDP	(mmHg)	293	0.2281	0.0082 RV EDP	+0.2020	0.0821
RV SP	(mmHg)	293	0.5091	0.0019 RV SP	+0.1540	0.0726
PA DP	(mmHg)	293	0.8765	0.0058 PA DP	+0.1454	0.0406
RV P-dP/dt	(mmHg/sec)	274	0.4592	0.0001 RV P-dP/dt	+0.1556	0.0741
RV EDVI	(ccm/sqm)	90	−0.0534	−0.0002 RV EDVI	+0.2466	0.0999
RV EF		90	−0.2951	−0.3078 RV EF	+0.3887	0.0956

R PEP/ET=the ratio of pre-ejection period to ejection time of the right ventricle; N=number; R=correlation coefficient; SEE=standard error of the estimates; RV EDP=right ventricular enddiastolic pressure; RV SP=right ventricular systolic pressure; PA DP=pulmonary artery diastolic pressure; RV P-dP/dt=maximal first time derivative of right ventricular pressure; RV EDVI=right ventricular end-diastolicvolume index; RV EF=right ventricular ejection fraction.

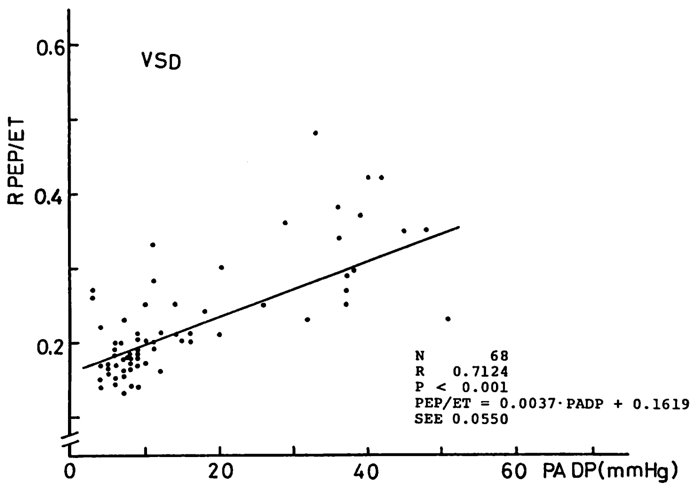


Fig. 9. The relation between the ratio of pre-ejection period to ejection time of right ventricle (R PEP/ET) **and pulmonary artery diastolic pressure** (PA DP) **in cases with ventricular septal defect** (VSD).

Close correlation is apparent.

atrial septal defect and " hemodynamically normal " group, in which all were with PA DP below 20 mmHg, no significant correlation existed. In cases with cardiomyopathy included in myocardial disease and with pulmonary stenosis included in miscellaneous RV abnormalities, no extraordinary value of R PEP/ET was recognized in its relation to PA DP.

Discussion and Conclusion

This study was aimed to know what kind of index of cardiac performance changes with the STIs of right side of the heart, and not attempted to estimate these variables from STIs.

While PEP/ET is said to be relatively uninfluenced by heart rate in comparison to PEP or ET alone[1,5], our data implied that PEP/ET is also dependent on heart rate. The resultant error in the values of PEP/ET is, however, not so serious at the range of heart rate in cases of this study, so that we did not correct STIs by heart rate to obtain "STI indices".

Correlation of R PEP/ET with other cardiac indices were analyzed. Among these, the closest correlation was observed with PA DP; correlations with the other indices were unremark-

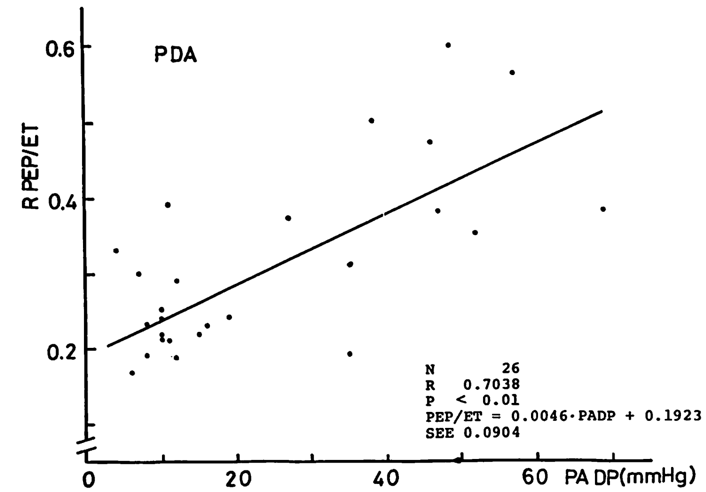


Fig. 10. The same relation as in Fig. 9 in cases with patent ductus arteriosus (PDA). Close correlation is apparent.

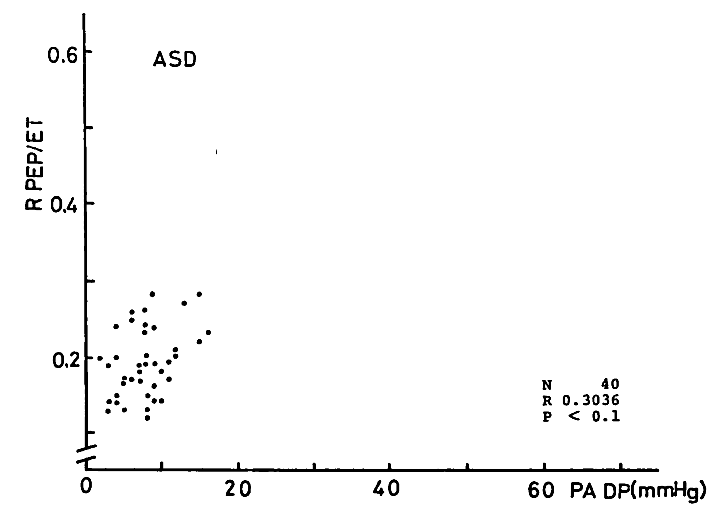


Fig. 11. The same relation as in Fig. 9 in cases with atrial septal defect (ASD). Correlation is not recognizable.

able. RV SP, which is thought to make theoretically similar influence on R STIs, does not correlate with R PEP/ET so intensely. With volume indices, namely RV EDVI and RV EF, correlations were still poor, although a tendency of inverse relationship with RV EF was recognized. These observations were almost in consistence with the observations on PEP/ET by other authors who appreciate it by means of echocardiography[8,9].

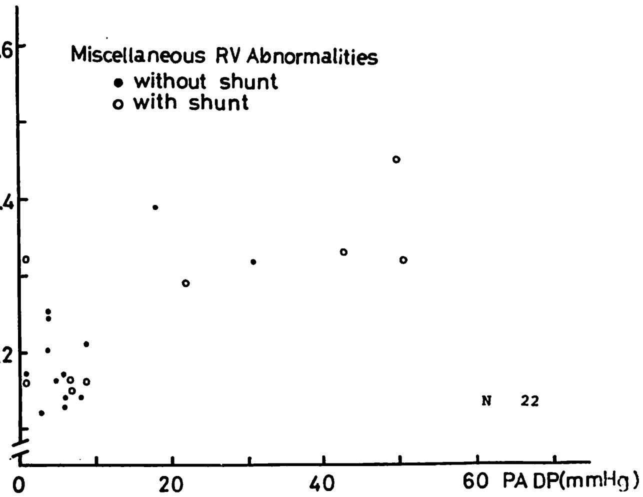


Fig. 12. The same relation as in Fig. 9 in cases with miscellaneous abnormalities mainly in right side of the heart.

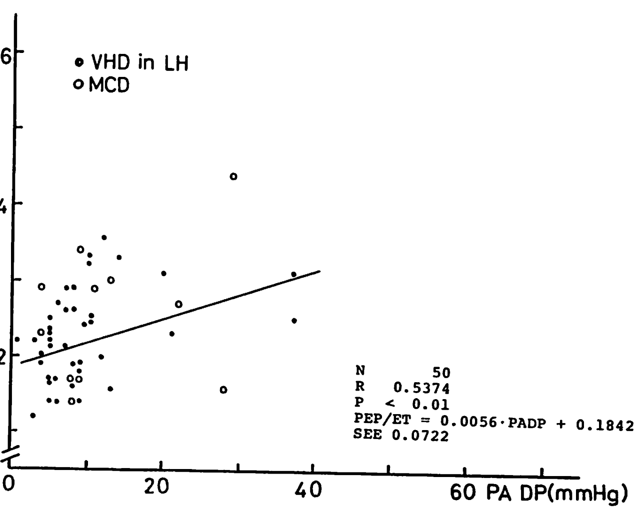


Fig. 13. The same relation as in Fig. 9 in cases with valvular heart disease in left side of the heart (VHD in LH) **or myocardial disease** (MCD).

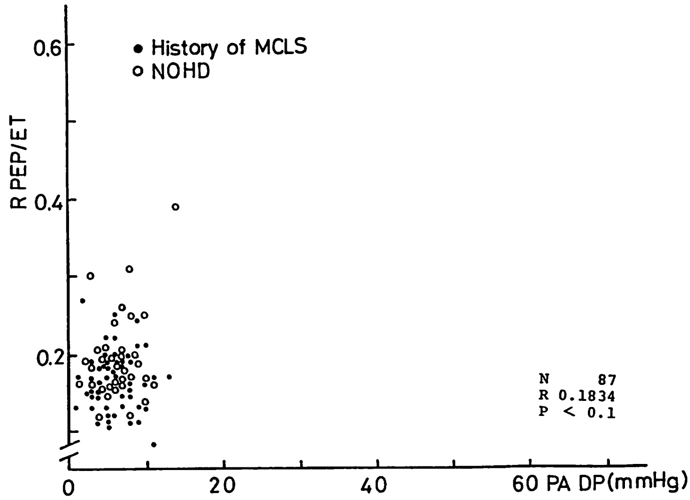


Fig. 14. The same relation as in Fig. 9 in cases with history of Kawasaki's disease (MCLS) **or no organic heart disease** (NOHD).

In every case, pulmonary artery diastolic pressure (PA DP) is not severely elevated, and significant correlation does not exist, accordingly.

Difference in the relation between R PEP/ET and PA DP in various disease states including cardiomyopathy and pulmonary stenosis does not essentially exist in the cases investigated. Greater PEP/ET is without exception accompanied by high pulmonary artery diastolic pressure (not vice versa) in any disease. Upper limit of R PEP/ET in its relation to PA DP may be said to be about 0.35.

References

1) Weissler AM, Harris WS, Schoenfeld CD: Bedside technics for the evaluation of ventricular function in man. Amer J Cardiol **23**: 577, 1969
2) Leighton RF, Weissler AM, Weinstein PB, Wooley CF: Right and left ventricular systolic time intervals. Effects of heart rate, respiration and atrial pacing. Amer J Cardiol **27**: 66, 1971
3) Hirschfeld S, Meyer R, Schwartz DC, Korfhagen J, Kaplan S: Measurement of right and left ventricular systolic time intervals by echocardiography. Circulation **51**: 304, 1975
4) Nanda NC, Gramiak R, Robinson TI, Shah PM: Echocardiographic evaluation of pulmonary hypertension. Circulation **50**: 575, 1974
5) Hirschfeld S, Meyer R, Schwartz DC, Korfhagen J, Kaplan S: The echocardiographic assessment of pulmonary artery pressure and pulmonary vascular resistance. Circulation **52**: 642, 1975
6) Tsuda S: Studies on right ventricular performance by noninvasive measurement of systolic time intervals in patients with chronic right ventricular overlaoding. (in Japanese) Jap Circulat J **42**: 1373, 1978
7) Graham TP Jr, Jarmakani JM, Atwood GF, Canent RV Jr: Right ventricular volume determinations in children. Normal values and observations with volume or pressure overload. Circulation **47**: 144, 1973
8) Garrard CL Jr, Weissler AM, Dodge HT: The relationship of alterations in systolic time intervals to ejection fraction in patients with cardiac disease. Circulation **42**: 455, 1970
9) Riggs T, Hirschfeld S, Borkat G, Knoke J, Liebman J: Assessment of the pulmonary vascular bed by echocardiographic right ventricular systolic time intervals. Circulation **57**: 939, 1978