Symposium

Journal of Cardiography 10: 629-647, 1980

Echocardiographic evaluation for right heart performance in infants and children

Hiroyuki NAKANO
Akihiro SAITO
Ken UEDA

Summary

There is an increasing need for the clinical evaluation of the cardiac function, but less is currently available for the noninvasive method for the right heart performance. In this report, we proposed a new method for the quantitative evaluation of the right atrial and right ventricular dimensions by M-mode echocardiography and showed the present method to be reliable and useful by comparison with the cineangiographic data.

The right atrial dimension was measured by precordial echocardiography. An excellent correlation ($r=0.92$) was found to exist between the echocardiographic measurement and the right atrial volume. The relationship of the right atrial dimension and body surface area in normal infants and children was best fit by an exponential equation: $RAD=3.25\ BSA^{0.54}$. The increased dimension of the right atrium was demonstrated in patients with atrial septal defect (ASD), ventricular septal defect (VSD) or patent ductus arteriosus (PDA) with pulmonary hypertension (PH), cyanotic heart diseases such as tetralogy of Fallot (TOF) and transposition of the great arteries (TGA), and aortic coarctation complex (CoA). Postoperative examinations revealed that the rapid reduction of the right atrial size was shown in ASD, whereas the right atrium remained dilated in the remaining heart diseases.

The right ventricular dimension was measured by the subxiphoid approach, and this measurement was well correlated with the right ventricular volume determined by cineangiograms both in end-diastole and end-systole ($r=0.94$ and $r=0.89$, respectively). An excellent exponential fit was also obtained with the echocardiographic right ventricular dimension as a function of body surface area: $RVD=4.4\ BSA^{0.74}$. The right ventricular size was increased in patients with ASD and the diseases associated with PH, but it was smaller in TOF compared to normal. The right ventricular dimension returned rapidly to normal after surgical correction in ASD and the other diseases with PH, and conversely this dimension increased rapidly to normal in tetralogy patients.

In addition, the pump function of the right ventricle could be noninvasively evaluated by the measurement of echocardiographic fractional shortening. Finally, it was shown to be possible to obtain the continuous measurement of the right ventricular dimension from subxiphoid echocardiography.

From these observations, it is concluded that the echocardiographic measurement for the right

静岡県立こども病院　循環器科
静岡市漆山 860 (〒420)

Division of Pediatric Cardiology, Shizuoka Children's Hospital, Urushiyama 860, Shizuoka 420

Presented at the 19th Meeting of the Japanese Society of Cardiovascular Sound held in Kyoto, October 20-21, 1979

Received for publication December 15, 1979

atrial and right ventricular dimensions provides reliable informations regarding hemodynamic alterations of the right heart in a variety of congenital cardiac defects in infants and children.

Key words
Echocardiography Right atrial dimension Right ventricular dimension Right heart performance Congenital heart disease Subxiphoid echocardiography

The left heart chambers have been quantitatively estimated by echocardiography, whereas there may be a paucity in reports on similar studies on the right heart chambers. In the field of pediatric cardiology, it is well known that primary or secondary hemodynamic alterations of the right heart are frequently encountered in congenital heart disease, and recent investigators[1] emphasize the clinical importance of the right ventricular function in adult patients with heart disease. Therefore, it is useful to perform the quantitative estimation of the right heart performance in a nonivasive manner.

In this report, we attempted to measure the right atrial and right ventricular dimensions by echocardiography. The technique herein provides new standard measurements of the right heart chamber sizes and serves as a useful means for the noninvasive evaluation of the right heart performance in a variety of heart diseases.

I. Echocardiographic estimation of right atrial dimension

Much attention has not been thus far paid to the right atrium with respect to hemodynamic studies, and no definitive method is available for the measurement of this chamber by echocardiography. We proposed a simple and reliable method for detecting the right atrium and the procedure[2,3] is as follows: The ultrasonic transducer is positioned in the fourth intercostal space of the left sternal border with the patient in the supine position. After detecting the anterior leaflet of the tricuspid valve, the interatrial septum and the left atrial posterior wall simultaneously, the continuous scanning toward the right is performed. Then the interatrial and left atrial posterior wall echoes are fused together into the right atrial posterior wall echo,

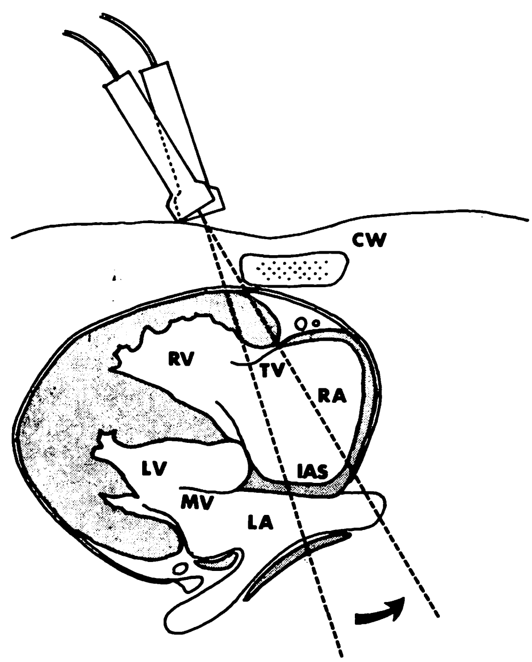


Fig. 1. Cross-sectional diagram demonstrating the relationship of the cardiac structures and the ultrasonic beam with the transducer in the 4th intercostal space of the left sternal border.
Arrow shows the direction of M-mode scanning.
CW=chest wall; RV=right ventricle; TV=tricuspid valve; RA=right atrium; IAS=interatrial septum; LV=left ventricle; MV=mitral valve; LA=left atrium.

while the anterior cusp echo of the tricuspid valve shifts to the tricuspid annular echo (**Fig. 1**). **Fig. 2** is a representative (A) and a diagrammatic (B) M-mode scan recording of the right atrial echocardiogram by this technique.

The echo from the anterior tricuspid valve annulus reveals a large excursion with anterior movement during ventricular systole, and the

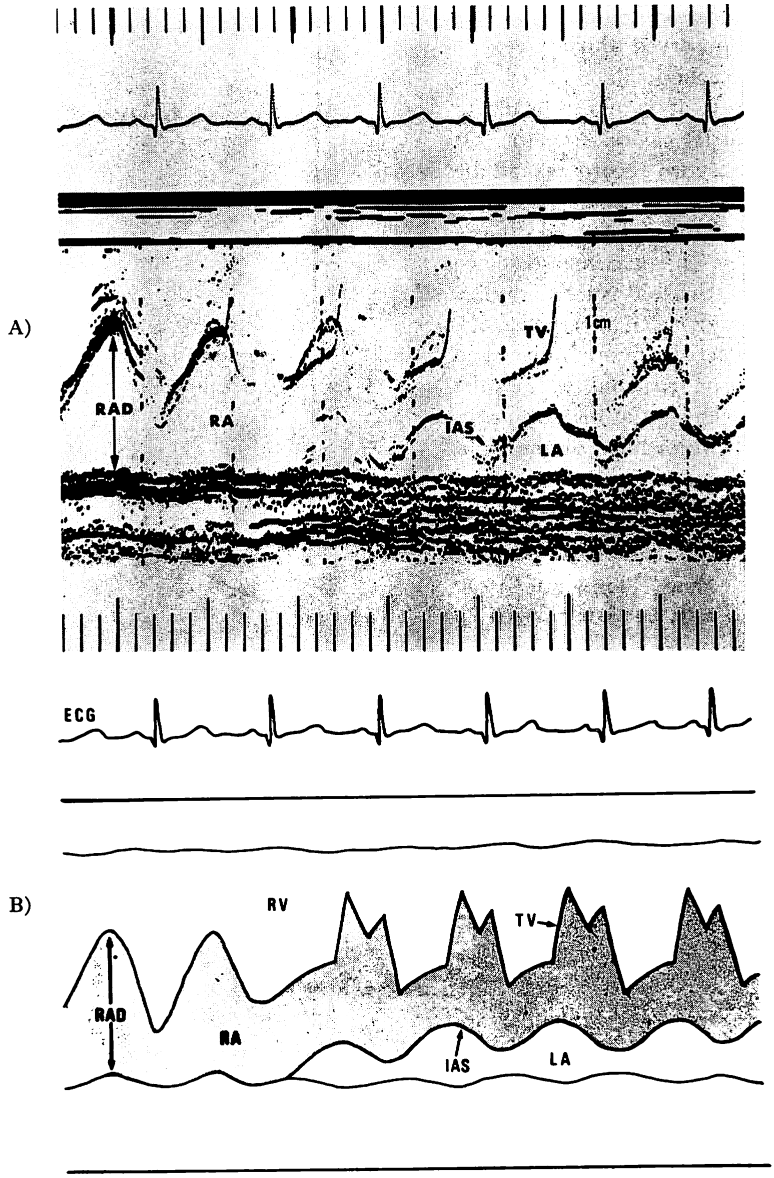


Fig. 2. Representative (A) **and diagrammatic** (B) **M-mode scan from the right atrium to the tricuspid valve in a normal child.**

The right atrial dimension is measured from the maximal distance between the tricuspid valve annulus and the right atrial posterior wall as indicated by a bidirectional arrow.

RV=right ventricle; RA=right atrium; TV=tricuspid valve; IAS=interatrial septum; LA=left atrium; RAD=right atrial dimension.

right atrial posterior wall also moves slightly in the same direction. Since a slight posterior movement is usually observed during ventricular systole in the echocardiogram of the left atrial posterior wall, it is not difficult to distinguish the right atrial cavity from the left one even in case of obscure recordings of the interatrial septal echo.

As indicated in **Fig. 2** the right atrial dimension can be defined as the maximal distance between the anterior tricuspid valve annulus and the right atrial posterior wall at end-diastole. In addition, we can select the first annular echo scanned from the anterior tricuspid valve as the reference point of the right atrial measurement. Clear and reproducible recordings of the right atrial echogram were obtained using this method in almost all patients who underwent echocardiographic examinations.

1. Comparison of echocardiographic right atrial dimension and angiographic right atrial volume

In order to examine the validity of the echocardiographic estimation of the right atrial dimension, the comparative study of the right atrial size by echocardiograms with that by angiocardiograms was performed in 58 infants and children with congenital cardiac defect. The maximal right atrial volume was calculated by biplane cineangiograms at end-diastole according to the method of Graham and associates[4]. As shown in **Fig. 3**, an excellent correlation (r= 0.92) was found between the two measurements with a curvilinear relationship. Although other regression equations or cubed echocardiographic measurements were not applied for the comparison of the right atrial dimensions and the corresponding volumes and it is not necessarily required to obtain a true volume of the right atrium by echocardiography, the echocardiographic measurement using a single dimension may presumably provide a useful and reliable estimation of the right atrial size. Additionally, we can speculate from these results that the direction of the ultrasonic beam for the right atrial measurement may be almost constant and that the right atrial geometry may not alter significantly with a volume overload.

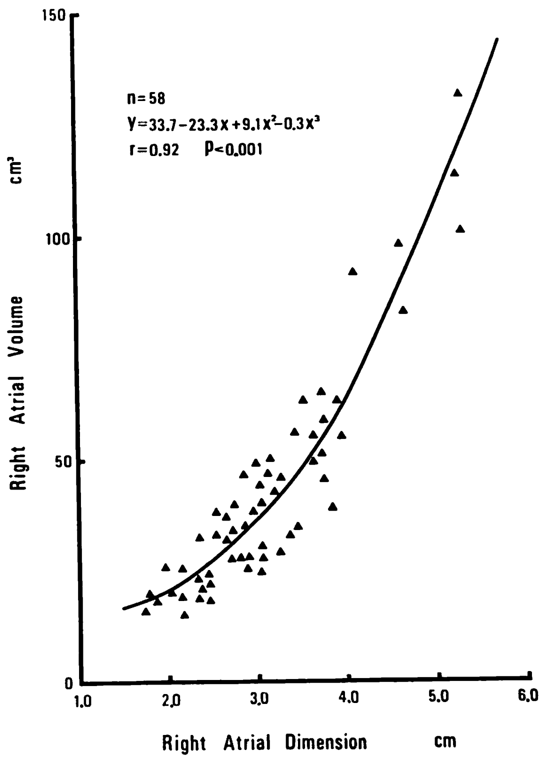


Fig. 3. Comparison between echocardiographic right atrial dimension and angiographic right atrial volume in infants and children with various cardiac defects.

2. Normal value for right atrial dimension in infants and children

Since pediatric patients show a wide scatter of body sizes, it is impossible to estimate accurately hemodynamic measurements such as cardiac chamber size without an appropriate correction for normalization[5]. The usual method of normalization for this purpose has been the division of the measurement by body surface area, however this is known to be not necessarily valid for the accurate assessment of the hemodynamic alterations[6].

We have investigated the correlation of the right atrial dimension and body surface area in 38 normal infants and children and found it to be best fit (r=0.93) with an exponential regression equation (**Fig. 4**). By making use of this exponential equation, normal range for predicted values can be estimated for each body surface area, and using a proportion of actual measurement to normal predicted value (% of normal), a more accurate assessment for the right atrial size can be made.

3. Right atrial dimension in congenital heart disease

In 117 infants and children who have undergone diagnostic cardiac catheterization, the right atrial dimension was measured by echocardiography. The patients were divided into six groups and each measurement was plotted against body surface area (**Fig. 5**).

All patients except for one case with secundum atrial septal defect had increased dimensions of the right atrium with an average value of 151% of normal. In patients with left ventricular volume overload with left to right shunt disorder, this chamber size was almost within normal range in the absence of pulmonary hypertension (105±8% of normal), whereas it was enlarged in the presence of pulmonary hypertension (140±20% of normal). Patients with cyanotic heart diseases such as tetralogy of Fallot and transposition of the great arteries showed the increased value for the right atrial cavity size (130±23% and 135±19% of normal, respectively), and the markedly dilated right atrium was also demonstrated in infants with aortic coarctation complex (167±30% of normal).

Based on these observations, it follows that the right atrial size in congenital heart disease is mostly increased except for ventricular septal defect or patent ductus arteriosus with a normal pulmonary arterial pressure. The dilated right atrium in atrial septal defect may be reflected by the increased flow volume in the right heart due to a left to right shunt at the atrial level. The larger extent of the increased right atrial chamber in this lesion suggests that the size of cardiac chamber is principally influenced by the flow volume.

On the other hand, the exact mechanism of the increased right atrial dimension in pulmonary hypertensive heart disease or cyanotic heart

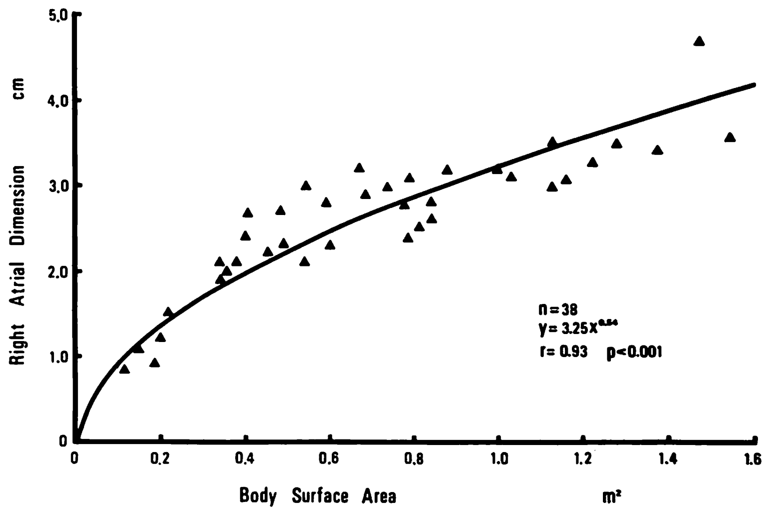


Fig. 4. Right atrial dimension as a function of body surface area in normal infants and children.

An excellent correlation is demonstrated between both measurements with an exponential relationship. With this regression equation, normal predicted value can be estimated in each body surface area.

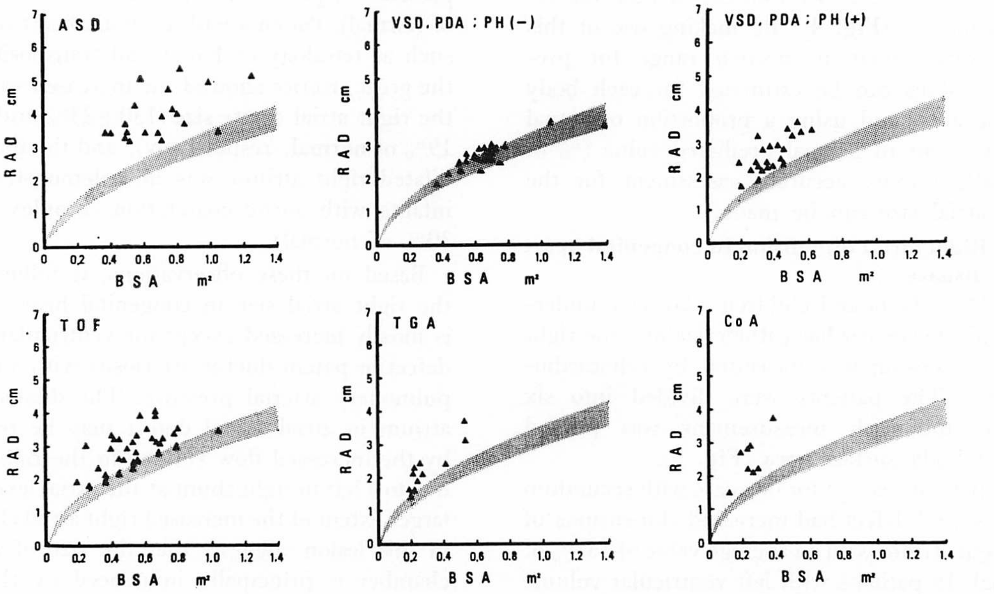


Fig. 5. Echocardiographic right atrial dimensions from patients with congenital heart disease.

Normal ranges are indicated by shaded area.

RAD=right atrial dimension; BSA=body surface area; ASD=atrial septal defect; VSD=ventricular septal defect; PDA=patent ductus arteriosus; PH=pulmonary hypertension; TOF=tetralogy of Fallot; TGA=transposition of the great arteries; CoA=aortic coarctation complex.

disease is not clear. The common hemodynamic alteration encountered in these disorders is a right ventricular pressure overload which is associated with myocardial hypertrophy of the right ventricle and reduced right ventricular compliance. Thus, we can speculate that the impaired right ventricular filling may be attributed to these observations. Finally, the marked enlargement of the right atrium in aortic coarctation complex is considered to be based on right heart failure commonly seen in this disease.

4. Right atrial dimension in atrial septal defect

In 20 patients with uncomplicated atrial septal defect, the relation between the right atrial dimension and the pulmonary to systemic flow ratio was examined. As indicated in **Fig. 6**, the echocardiographic right atrial cavity size represented as percent of normal was linearly correlated (r=0.65) with the flow ratio by the Fick method. It seems to be possible to estimate the atrial shunt ratio in this anomaly by the right atrial measurement in a similar manner as in ventricular septal defect in which the shunt estimation is feasible by the echocardiographic measurement of the left atrium or left ventricle[7]. It can be said that the ultrasonic determination of the right atrial size serves as a noninvasive means for evaluating the severity of atrial septal defect.

5. Postoperative evaluation of right atrial dimension

It is a matter of great concern to observe the postoperative changes of the hemodynamic abnormalities in patients following surgery. Repeated echocardiographic examinations make it possible to evaluate these changes without serial cardiac catheterizations.

Fig. 7 shows the pre- and postoperative changes of the echocardiographic right atrial

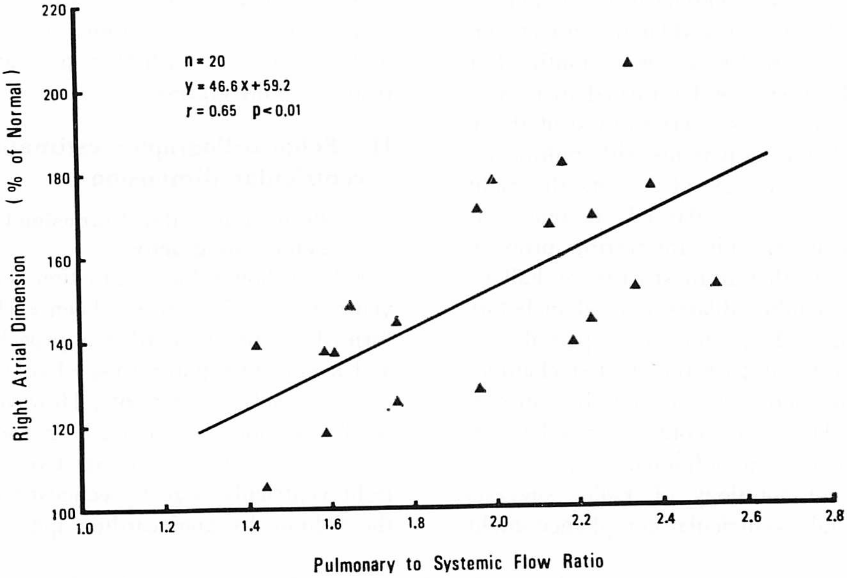


Fig. 6. Correlation between right atrial dimension and pulmonary to systemic flow ratio in patients with secundum atrial septal defect.

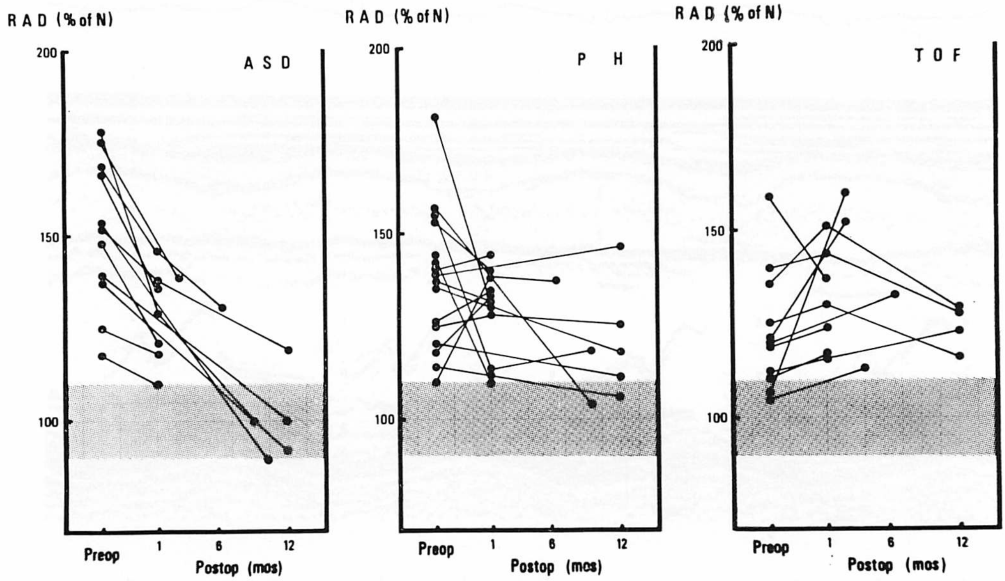


Fig. 7. Postoperative evaluation of echocardiographic right atrial dimension in patients with congenital heart disease.

Normal ranges are indicated by shaded area.

RAD=right atrial dimension; % of N=per cent of normal; ASD=atrial septal defect; PH=pulmonary hypertension; TOF=tetralogy of Fallot; Preop=preoperation; Postop (mos)=postoperative months.

size in patients with congenital cardiac anomalies. In atrial septal defect, the dilated right atrium became rapidly smaller at one month after surgery in all patients and returned to normal range at one year after surgery in most of them. On the other hand, in patients with pulmonary hypertension or tetralogy of Fallot, the right atrium yet remained enlarged at one year following operation. The interesting problem in particular was that in most cases of Fallot's tetralogy this chamber dilates more than before surgery during early postoperative periods.

We can point out that the dilated chamber caused by the increment of flow by surgical intervention. However, continuing dilatation of the right atrium in pulmonary hypertensive heart disease or tetralogy of Fallot suggests that reduced right ventricular compliance might be maintained for long terms despite corrective surgery. Further observations may be necessary to know when or whether myocardial hypertrophy would regress.

II. Echocardiographic estimation of right ventricular dimension

1. Right ventricular dimension by precordial echocardiography

Echocardiographic estimation of the right ventricular cavity size has been exclusively performed by the precordial approach[8] (**Fig. 8**), and it currently plays a useful role to a certain extent in selected patients. However, as far as we know, none is reported on the validity of this method by the comparative study of the right ventricular size by echocardiography and the volume by angiocardiography.

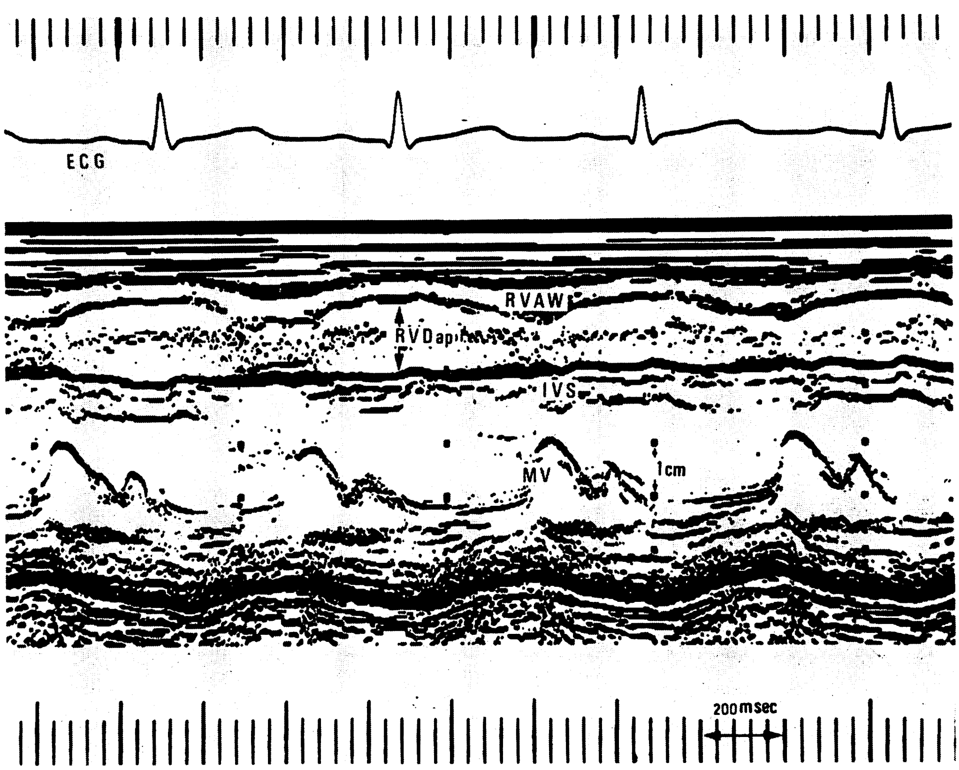


Fig. 8. Right ventricular echogram by precordial approach in a patient with mitral regurgitation.

RVDap=right ventricular dimension by anteroposterior approach; RVAW=right ventricular anterior wall; IVS=interventricular septum; MV=mitral valve.

In 55 infants and children with congenital heart disease, we compared the right ventricular dimension by precordial echocardiography with the right ventricular volume determined from biplane cineangiograms using the method of Graham and associates[9]. As indicated in **Fig. 9**, the correlation between both measurements was not so good (r=0.63) even with a curvilinear relationship. This finding is probably attributable to the fact that the measurement of the right ventricular dimension by the conventional method is frequently influenced by the changes in the position of patients, the direction of the ultrasonic beam and also the rotation of the heart[10]. Thus, the usual precordial approach is unsatisfactory for the quantitative estimation of the right ventricular size.

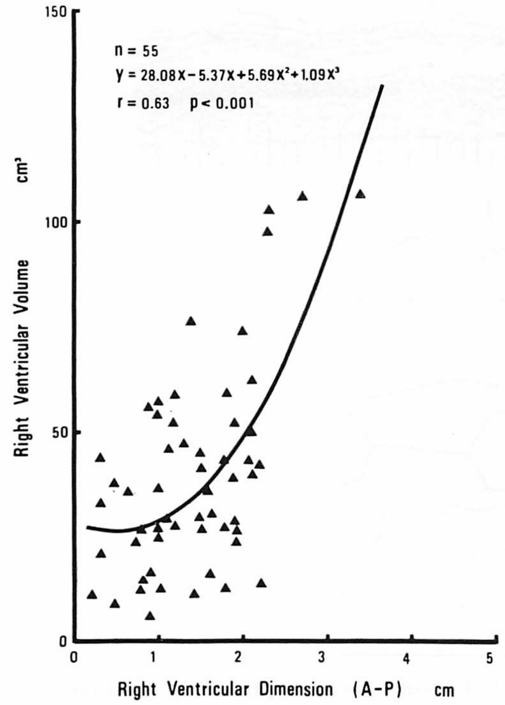


Fig. 9. Correlation between right ventricular dimension by precordial echocardiography and right ventricular volume by biplane cineangiocardiography.

A weak correlation is shown between both measurements with a curvilinear relation.

A-P=anteroposterior approach.

2. Right ventricular dimension by subxiphoid echocardiography

In order to standardize the measurement of the right ventricular dimension, we attempted a new method for quantifying this chamber size by the subxiphoid approach[11]. The procedure is as follows: the patient was examined in the supine position and the ultrasonic transducer was placed in the area just below the subxiphoidal process and was directed superiorly toward the throat. As indicated in **Fig. 10**, the ultrasonic beam passes through the right ventricle, tricuspid valve, aorta and aortic valve in order.

A representative subxiphoid echocardiogram and a diagrammatic subxiphoid echocardiogram are shown in **Fig. 11**. The right ventricular dimension was measured from the endocardial surface of the right ventricular anterior wall to the aortic anterior wall at end-diastole. Systolic right ventricular dimension was determined at the peak anterior movement of the aortic anterior wall. All subxiphoid echocardiograms were recorded in the transducer plane where the

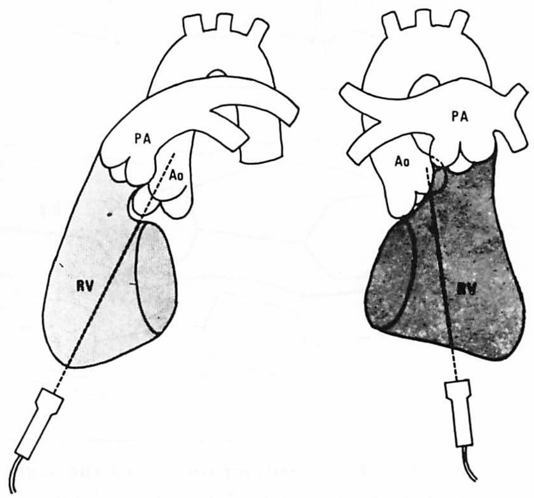
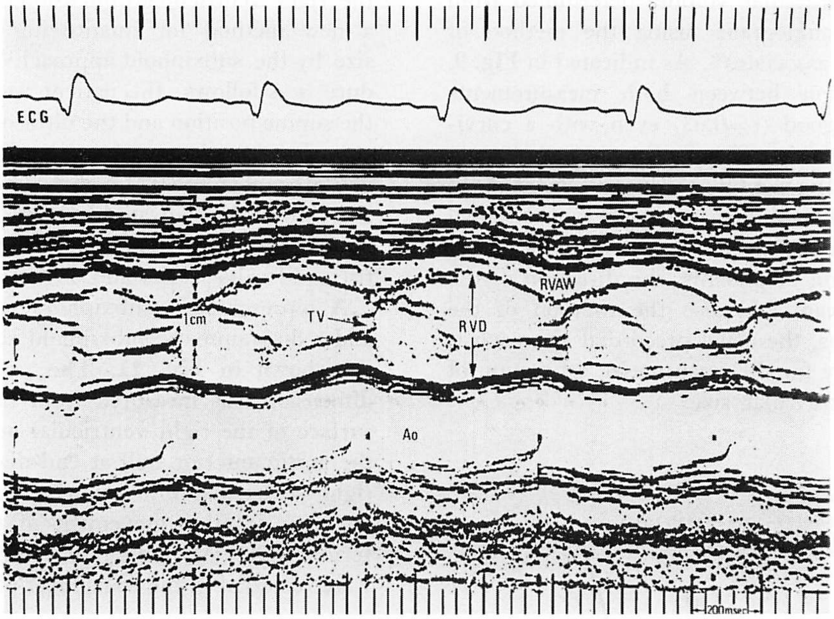


Fig. 10. Diagrammatic representation of subxiphoid examination.

The ultrasonic transducer is placed over the subxiphoid area and directed to the aortic valve.

Left: lateral view, right: frontal view. RV=right ventricle; PA=pulmonary artery; Ao=aorta.

A)



B)

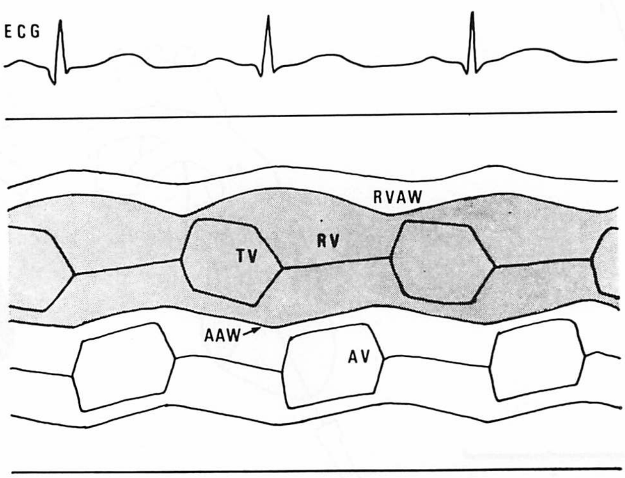


Fig. 11. Echocardiogram (A) **of the right ventricle by subxiphoid approach in a patient with tetralogy of Fallot and its diagram** (B).

RVD=right ventricular dimension; RVAW=right ventricular anterior wall; TV=tricuspid valve; Ao=aorta; RV=right ventricle; AAW=aortic anterior wall; AV=aortic valve.

tricuspid and aortic valves could be detected simultaneously.

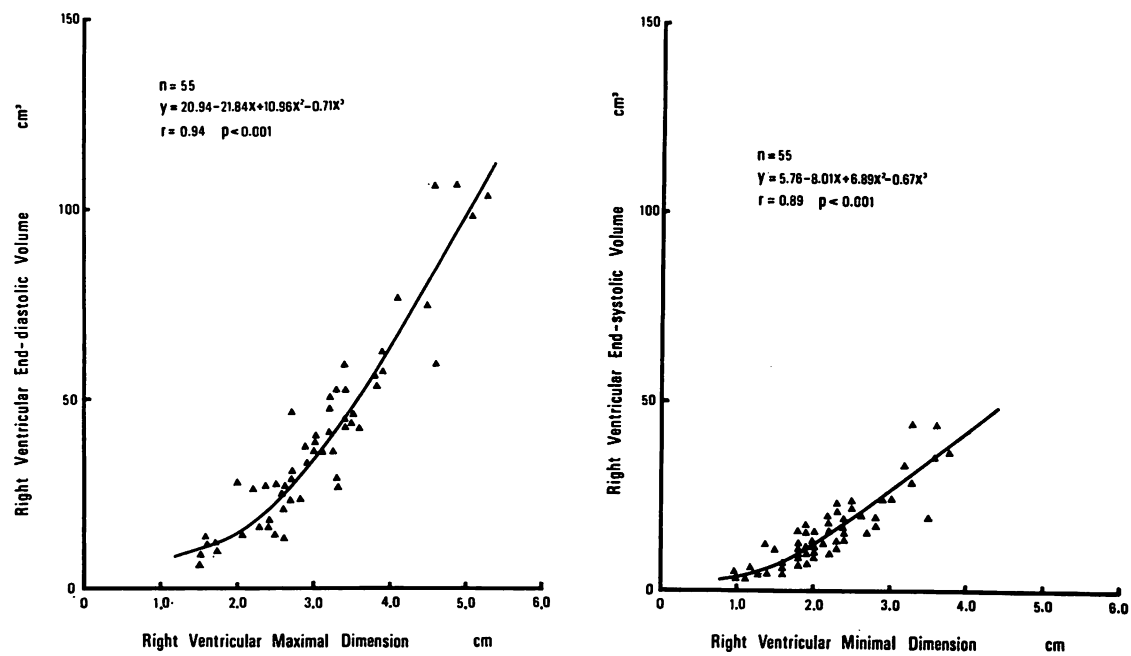
The right ventricular dimension by the subxiphoid approach is close to the oblique axis of the right ventricular inflow portion and the measurement seems to be less influenced by the direction of the ultrasonic beam and the rotation of the heart[12]. Clear and reproducible recordings with this technique were feasible in most of infants and children undergoing echocardiographic examinations.

3. Comparison of right ventricular dimension by subxiphoid echocardiograms and angiographic right ventricular volume

Since the right ventricle has an irregular shape, it is probably impossible to obtain a true volume of the chamber by a single dimension. However, it can be pointed out that a certain axis of the right ventricular dimension reflects the whole chamber size if the right ventricular geometry is not significantly affected by hemodynamic burdens.

Then, we compared the right ventricular dimension measured from the subxiphoid echochardiogram with the right ventricular volume by cineangiograms in 55 patients with various types of heart disease. As indicated in **Fig. 12**, fairly excellent correlations were found between these two variables with a cubic relationship both in end-diastole ($r = 0.94$) and in end-systole ($r = 0.89$). These results indicate that the present method is useful in estimating the right ventricular cavity size by echocardiography.

The following investigations were performed by making use of the right ventricular dimension by subxiphoid echocardiography.



(A) (B)

Fig. 12. Correlation between echocardiographic right ventricular dimensions by subxiphoid echocardiograms and cineangiocardiographic right ventricular volumes in end-diastole (A) and in end-systole (B).

Excellent correlations are demonstrated between the two measurements both in end-diastole and in end-systole.

4. Normal value for right ventricular dimension in infants and children

For the purpose of a more accurate assessment for the right ventricular size in a variety of heart diseases, a normal regression equation relating the right ventricular dimension by the subxiphoid approach and body surface area was obtained from the data on 48 normal infants and children. Both measurements were found to be best fit with an exponential relationship in the same manner as that in the right atrial dimension (**Fig. 13**). We can determine normal range for predicted values in each body surface area using this exponential equation.

5. Right ventricular dimension in congenital heart disease

Using subxiphoid echocardiography, the right ventricular size was evaluated in pediatric patients with congenital heart disease. Each measurement was plotted against body surface area (**Fig. 14**).

All patients with secundum atrial septal defect showed the increased dimensions of the right ventricle with an average of 130±9% of normal. The ventricular size was almost within normal range (103±10% of normal) in patients with ventricular septal defect or patent ductus arteriosus with normal pulmonary arterial pressure. On the other hand, in patients with pulmonary hypertensive heart diseases the right ventricular dimensions were significantly increased (130±14% of normal). The echocardiographic measurements were in normal range in patients with pulmonary stenosis (104±7% of normal), but the mean value for patients with tetralogy of Fallot was slightly decreased from normal (94±12% of normal).

The dilated right ventricular size in patients with secundum atrial septal defect may be attributed to the increased flow volume in the right heart due to the atrial left to right shunt. In contrast with the right atrial dimensional changes, the extent of the increased right ventricular dimension was somewhat mild and

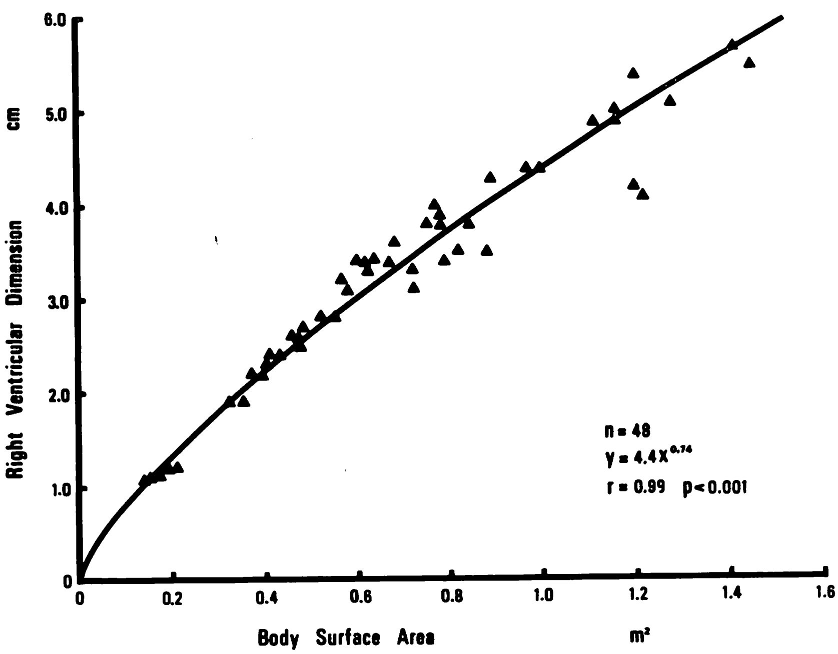


Fig. 13. Right ventricular dimension by subxiphoid echocardiograms as a function of body surface area in normal infants and children.

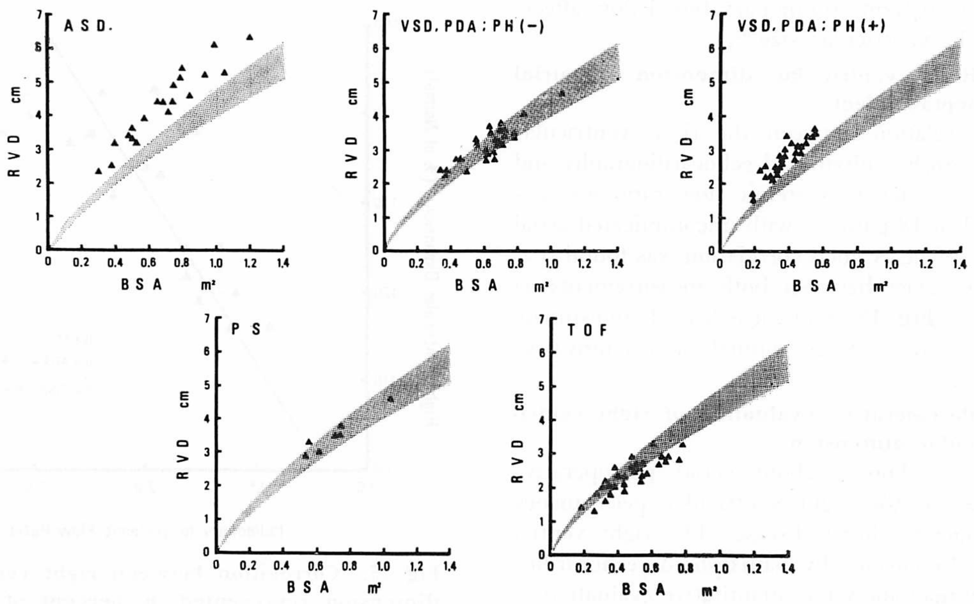


Fig. 14. Right ventricular dimensions by subxiphoid echocardiograms for patients with congenital heart disease.

Normal ranges are indicated by shaded area.

RVD=right ventricular dimension; BSA=body surface area; ASD=atrial septal defect; VSD=ventricular septal defect; PDA=patent ductus arteriosus; PH=pulmonary hypertension; PS=pulmonary stenosis; TOF=tetralogy of Fallot.

within narrow range in this condition. The similar finding that the atrial cavity size responded more sensitively to the increased flow than that of the ventricle was also observed in the left heart as shown in ventricular septal defect or patent ductus arteriosus[7].

The present study demonstrated that while in patients with left ventricular volume overload with a left to right shunt with normal pulmonary arterial pressure the right ventricular dimension was almost within normal range, the dimension was significantly increased in association with pulmonary hypertension. These results suggest that the right ventricular dimension probably might not depend on the shunt size but on right ventricular pressure afterload. Although recent investigators[13] pointed out that the size of the right ventricular volume was proportional to the degree of a left to right shunt in ventricular septal defect, the dilatation of the right ventricle in patent ductus arteriosus associated with pulmonary hypertension cannot be explained by their observations. In addition, since the left to right shunt in ventricular septal defect occurs predominantly during ventricular systole, the shunted flow is not thought to contribute to the right ventricular dilatation significantly. The exact mechanism of the right ventricular enlargement in the existence of pulmonary hypertension is not clear, but the increased ventricular afterload probably plays an important role in the determination of the chamber size[14].

In patients with pulmonary stenosis, the right ventricular dimension was within normal range. This observation is in agreement with that by cineangiography[6]. On the other hand, the right ventricular dimension was smaller than normal in patients with tetralogy of Fallot. This will be well explained by the fact that in tetralogy patients pulmonary blood flow affects the right ventricular size[15].

6. Right ventricular dimension in atrial septal defect

The relation between the right ventricular dimension by subxiphoid echocardiography and the pulmonary to systemic flow ratio was examined in 18 patients with uncomplicated atrial septal defect. A good correlation was found (r=0.69) to exist between both measurements as shown in **Fig. 15**. Thus, it is feasible to estimate the shunt ratio of this anomaly in a noninvasive manner.

7. Postoperative evaluation of right ventricular dimension

Less is known about serial postoperative changes of the right ventricular performance in congenital heart disease. The right ventricular dimension by subxiphoid echocardiography may allow the quantitative evaluation of such changes.

Fig. 16 shows the serial changes of the posto-

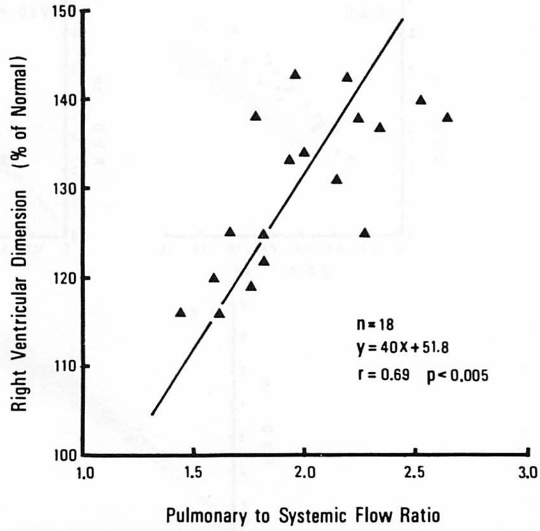


Fig. 15. Correlation between right ventricular dimension represented as percent of normal and pulmonary to systemic flow ratio in patients with atrial septal defect.

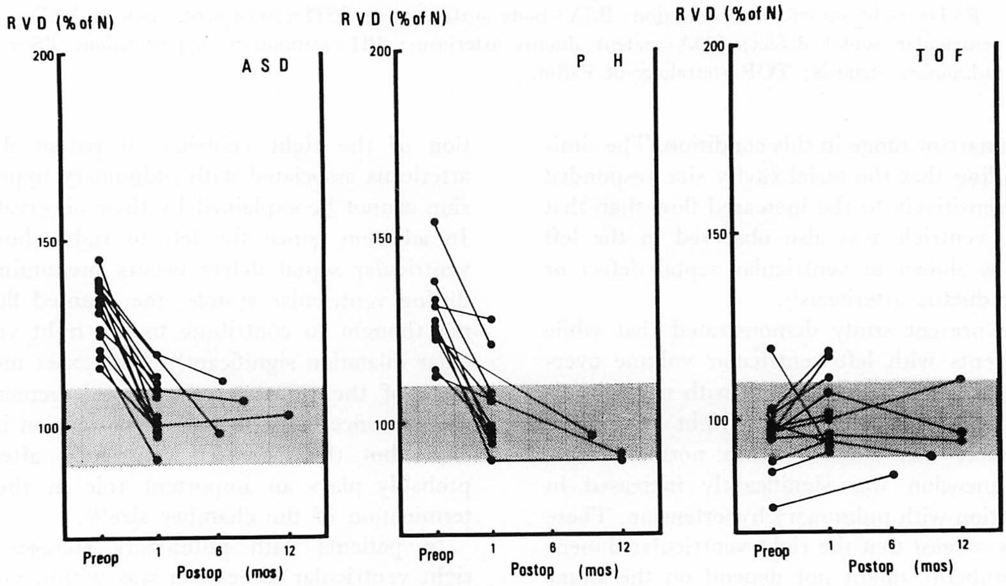


Fig. 16. Postoperative evaluation of right ventricular dimension in patients with congenital heart disease.

Normal ranges are indicated by shaded area.

RVD=right ventricular dimension; % of N=percent of normal; ASD=atrial septal defect; PH=pulmonary hypertension; TOF=tetralogy of Fallot; Preop=preoperation; Postop (mos)=postoperative months.

perative right ventricular size in patients with congenital cardiac anomalies. In atrial septal defect, the majority of them rapidly returned to normal range at one month after surgery. The extent of the right ventricular dilatation was generally lesser than that of the right atrium in postoperative patients with this lesion. The cause of the difference remains unkown, but longer time may be required to return to the normal size in the more dilated right atrial cavity compared with the right ventricle.

In most of patients with pulmonary hypertension, the right ventricular dimension also becomes normal size even at one month postoperatively. This finding is quite different from that seen in the right atrial dimension. If the dilatation of the right ventricular cavity is based on elevated right ventricular afterload as described earlier, rapid reduction of the ventricular size is considered to be associated with the decline of pulmonary arterial pressure following surgical correction. Accordingly, we can say that the postoperative right ventricular dimension may provide an indirect estimate for the right ventricular afterload.

On the other hand, in tetralogy patients the

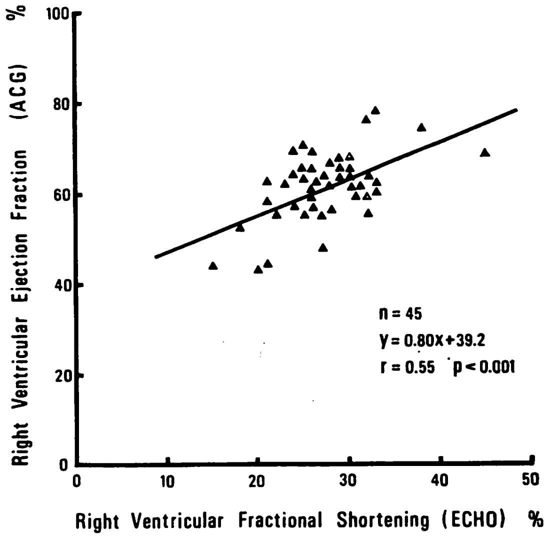


Fig. 17. Correlation between right ventricular fractional shortening by subxiphoid echocardiograms and right ventricular ejection fraction by cineangiocardiograms.

A weak linear correlation is demonstrated between both measurements. ECHO = measured by subxiphoid echocardiograms; ACG = measured by cineangiocardiograms.

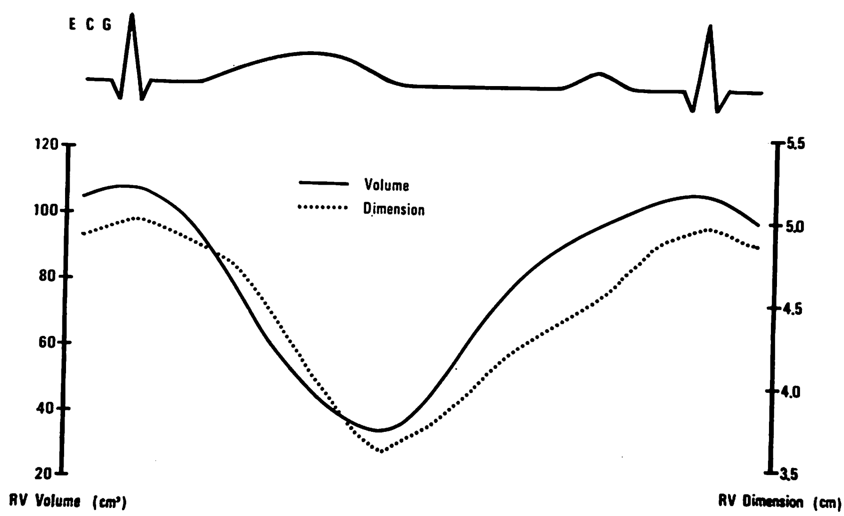
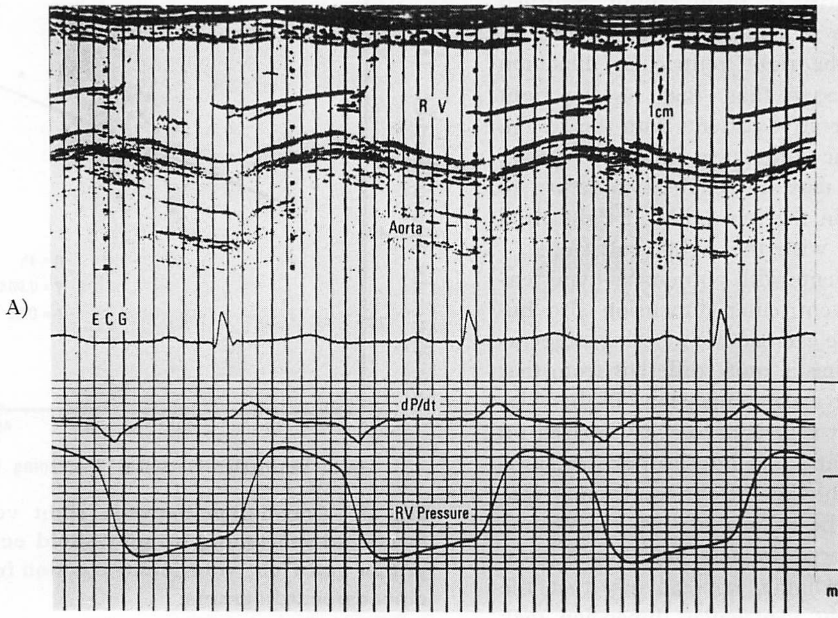


Fig. 18 Sequential changes in right ventricular dimension by subxiphoid echocardiograms and right ventricular volume in a patient with secundum atrial septal defect.

Both curves are proved to be rather similar. RV = right ventricular.

A)



B)

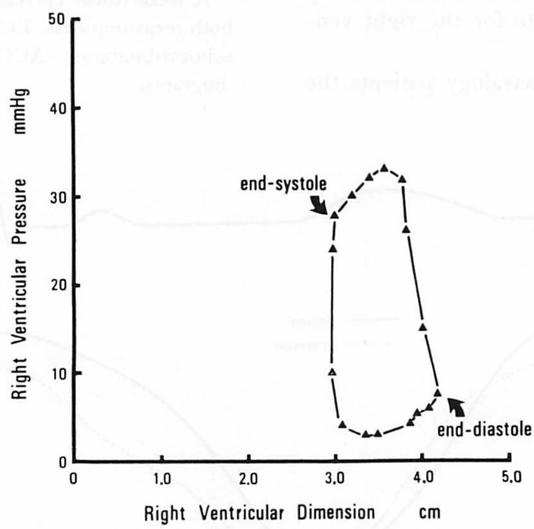


Fig. 19. (A) **Simultaneous recording of the subxiphoid echocardiogram and right ventricular pressure by a micromanometer in a patient with secundum atrial septal defect.** (B) **Right ventricular pressure-dimension loop in the same patient as in A.**
RV=right ventricle; dP/dt=the first time derivative of right ventricular pressure.

echocardiographic right ventricular dimension increased to normal range at one month following total correction. It will be due to the increased pulmonary blood flow in this defect.

8. Echocardiographic estimation of right ventricular pump function

We attempted a noninvasive evaluation of the right ventricular function on the basis of the close relationship between echocardiographic and cineangiocardiographic measurements both in end-diastole and in end-systole. As indicated in **Fig. 17**, the right ventricular fractional shortening (Dd-Ds/Dd) determined by subxiphoid echocardiography showed statistically significant relationship ($r=0.55$) with the angiographically determined ejection fraction. It might be clinically useful in assessing the pump function of the right ventricle by a noninvasive method.

9. Sequential changes of right ventricular dimension by subxiphoid echocardiography and its application

The composite ventricular volume curves throughout the cardiac cycle provide a useful measure for the assessment of the ventricular performance and function in detail. However, it is so tedious and time-consuming to obtain these volume curves from cineangiocardiograms that the aid of a computer is inevitable[16]. The continuous measurement of the chamber dimension determined from echocardiography is currently available in particular for the assessment of the left ventricular performance.

Fig. 18 indicates the comparison of the sequential changes in the right ventricular dimension by the subxiphoid echocardiogram and the cineangiographically determined right ventricular volume throughout one cardiac cycle in a patient with atrial septal defect. Both curves are not quite identical, but it appears that a relatively close relationship exists between them. Accordingly, it is possible to obtain the continuous measurement of the right ventricular size from the subxiphoid echocardiogram in a similar manner as in the left ventricle.

Simultaneous recording of the subxiphoid echocardiogram and right ventricular pressure measured by a micromanometer is demonstrated in **Fig. 19**A. The measurement of the right ventricular dimension and right ventricular pressure was obtained every 20 msec and a right ventricular pressure-dimension loop was constructed (**Fig. 19**B). By using this manner, right ventricular pressure-dimension loops are easily drawn in patients with various types of congenital cardiac defects (**Fig. 20**).

In a patient with atrial septal defect, the increased end-diastolic dimension and a large change of dimension during the cardiac cycle were apparent. On the other hand, abnormally increased right ventricular pressure was evident in a patient with pulmonary stenosis. Analysis of pressure-dimension relationship will permit to obtain some useful informations regarding right ventricular systolic and diastolic characteristics.

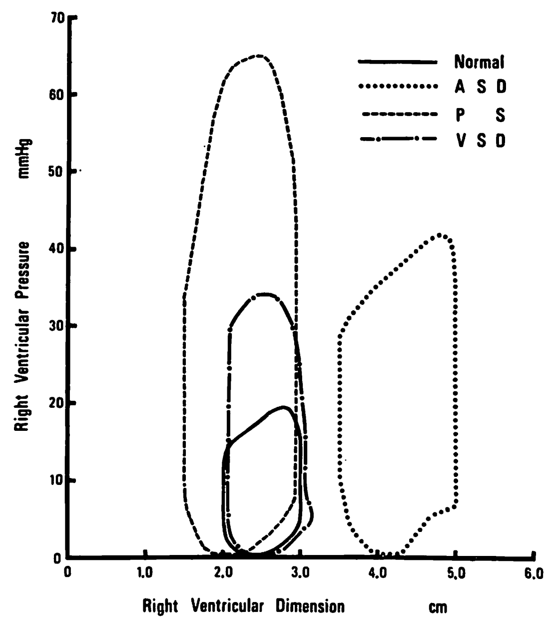


Fig. 20. Right ventricular pressure-dimension loops in a normal child and patients with congenital heart disease.

ASD = atrial septal defect; PS = pulmonary stenosis; VSD = ventricular septal defect.

要　　約

心エコー図による小児期心疾患の右心系特性の評価

中野博行，斎藤彰博，上田　憲

心機能の評価は臨床的にますます重要となりつつあるが，右心系特性の非観血的評価法についての報告は少ない．本研究では，Mモード心エコー法を用いた右房および右室径の定量的評価の新しい方法論を提示し，シネアンジオより得られたデータと比較して，これが信頼性のある有用な方法であることを明らかにした．

右房径は前胸部からアプローチして計測した．心エコー図による右房径はシネアンジオより計測した右房容積と良い相関を示し (r=0.92)，また正常値は体表面積とのあいだに右房径=3.2(体表面積)$^{0.54}$ の指数函数で最良の相関を示した．各疾患別の右房径は，心房中隔欠損，肺高血圧を伴う心室中隔欠損あるいは動脈管開存，チアノーゼ群心疾患および大動脈縮窄で増大を示した．術後の右房径は心房中隔欠損で急速に正常化したが，他の疾患群では拡大が持続した．

右室径は剣状突起下心エコー法より計測した．その計測値は，シネアンジオより計測した右室容積とのあいだに，拡張末期で r=0.94，収縮末期で r=0.89 と，ともに良い相関が認められた．さらに，右室径の正常値は体表面積とのあいだに，右室径=4.4(体表面積)$^{0.74}$ の関係がみられた．右室径は，心房中隔欠損，肺高血圧を伴う心疾患で増大し，逆にファロー四徴では正常より小さかった．術後の右室径は心房中隔欠損および肺高血圧を伴う心疾患において急速に縮小して正常化し，また，ファロー四徴においては縮小していた右室は急速に正常化した．

このほか，心エコー図による右室径の計測から右室ポンプ機能の非観血的評価が可能であり，さらに剣状突起下心エコー図を用いて心周期の連続的な右室径の計測が可能であった．

これらの所見より，心エコー図による右房径および右室径の計測は，小児期心疾患の右心系血行動態の変化に関する有用な情報を提供するといえよう．

References

1) Stein PD, Sabbah HN, Anbe DT, Marzilli M: Performance of the failing and nonfailing right ventricle of patients with pulmonary hypertension. Amer J Cardiol **44**: 1050, 1979
2) Saito A, Ueda K, Nakano H: Echocardiographic determination of right atrial dimension. J Cardiography **8**: 37, 1978 (in Japanese)
3) Saito A, Ueda K, Nakano H: Echocardiographic determination of right atrial dimension (II). J Cardiography **8**: 425, 1978 (in Japanese)
4) Graham TP Jr, Atwood GF, Faulkner SL, Nelson JH: Right atrial volume measurements from biplane cineangiocardiography: Methodology, normal values, and alterations with pressure or volume overload. Circulation **49**: 709, 1974
5) Nakano H: Left ventricular volume estimation in normal infants and children. Ann Paediat Jpn **23**: 39, 1977
6) Nakazawa M, Marks RA, Isabel-Jones J, Jarmakani JM: Right and left ventricular volume characteristics in children with pulmonary stenosis and intact ventricular septum. Circulation **53**: 884, 1976
7) Ueda K, Saito A, Nakano H: Quantitative echocardiography in left ventricular volume overload with left to right shunt disease. Heart **11**: 915, 1979 (in Japanese)
8) Lundstroem NR, Mortensson W: Clinical application of echocardiography in infants and children. III. Estimation of left and right ventricular size: A comparison between echocardiography and angiocardiography. Acta Pediat Scand **63**: 257, 1974
9) 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
10) Feigenbaum H: Echocardiography. Lea & Febiger, Philadelphia, 1976, p 261
11) Saito A, Ueda K, Nakano H: Quantitative evaluation of the right ventricular performance with echocardiography. I: Estimation of the right ventricular size with subxiphoid approach. J Cardiography **9**: 75, 1979

12) Saito A, Ueda K, Nakano H: Quantitative evaluation of the right ventricular performance with echocardiography: II. A study of reliability of right ventricular dimension by subxiphoid echocardiography. J Cardiography **9**: 447, 1979

13) Graham TP Jr, Atwood GF, Boucek RJ Jr, Cordell D, Boerth RC: Right ventricular volume characteristics in ventricular septal defect. Circulation **54**: 800, 1976

14) Saito A, Ueda K, Nakano H: Quantitative evaluation of right ventricular performance with echocardiography: III. Clinical evaluation of right ventricular dimension in infants and children with congenital heart disease. J Cardiography **10**: 433, 1980

15) Jarmakani JM, Nakazawa M, Isabel-Jones J, Marks RA: Right ventricular function in children with tetralogy of Fallot before and after aortic-to-pulmonary shunt. Circulation **53**: 555, 1976

16) Nakano H, Kamiya T, Mori C: Studies on left ventricular function in children utilizing computerized angio-analyzer system. Ann Paediat Jpn **22**: 53, 1976