

# Quantitative evaluation of right ventricular performance with echocardiography: III. Clinical evaluation of right ventricular dimension in infants and children with congenital heart disease

Akihiro SAITO  
Ken UEDA  
Hiroyuki NAKANO

## Summary

Right ventricular dimensions (RVDsx) were measured from subxiphoid echocardiograms in 111 infants and children with congenital heart disease as well as in 48 normal children. In patients with atrial septal defect, a significant correlation ( $r=0.69$ ) was found between Qp/Qs and RVDsx % of normal. RVDsx in patients with ventricular septal defect was found to be reflected not by the magnitude of left-to-right shunt but mainly by mean pulmonary arterial pressure. RVDsx in patients with pulmonary stenosis was within normal range and no correlation was found with right ventriculo-pulmonary arterial pressure gradient. In patients with tetralogy of Fallot, RVDsx was in inverse relationship ( $r=-0.80$ ) with hematocrit value which was considered to indicate the severity of this anomaly.

It is suggested that the echocardiographic determination of the right ventricular dimension reflects sensitively the hemodynamic alteration of the right ventricle and provides useful informations for the management of the patients with congenital heart disease.

## Key words

Subxiphoid echocardiogram      Right ventricular dimension      Right ventricular performance  
Congenital heart disease

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Echocardiography provides a noninvasive method to measure the size of cardiac chambers and great vessels, and it also serves as a convenient means of the estimation for the

volume of the left ventricle<sup>1)</sup> to assess its performance in man.<sup>2,3)</sup>

Recently, we have reported the feasibility and utility of determining right ventricular

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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

dimension using subxiphoid echocardiography (RVDsx)<sup>4)</sup>, and this was proven to be a reliable measurement for the right ventricular (RV) cavity size<sup>5)</sup>.

The purpose of the present investigation was to assess the effect of the alterations of the RV hemodynamics on RVDsx in infants and children with congenital heart disease and to examine whether it is possible to evaluate RV performance noninvasively.

### Materials and Methods

The materials consisted of 111 children with congenital heart disease in all of whom diagnostic cardiac catheterization was performed within 24 hours from the recordings of echocardiograms. There were 60 boys and 51 girls, ranging in age from one month to 10 years and two months. They included 18 with secundum atrial septal defect (ASD), 27 with ventricular septal defect (VSD), 31 with VSD with pulmonary hypertension (PH), 7 with pulmonary stenosis (PS) and 28 with tetralogy of Fallot (TOF).

Forty-eight normal children, 26 boys and 22 girls, were also examined. The age of the subjects ranged from one day to 15 years and none had heart disease as judged by physical examination or cardiac catheterization.

Subxiphoid echocardiograms were obtained in the previously described manner<sup>4,5)</sup> using a commercially available ultrasonic sonoscope (Ekoline 20 A, Smith-Klein instruments) interfaced with an optical recorder (Electronics for Medicine VR-12) and a 3.5 or 5 MHz non-focused transducer.

**Fig. 1** shows a representative subxiphoid echocardiogram. RVDsx was defined as the distance from the endocardial surface of the RV to the anterior aortic wall at the peak of the R wave on the electrocardiogram.

In 48 normal children, RVDsx was correlated to body surface area (BSA) by exponential regression analysis. In 111 patients with congenital heart disease, RVDsx was compared with hemodynamic data obtained from cardiac catheterizations. All pressure recordings were

obtained with a Millar micromanometer and shunt determinations were made using the Fick principle.

### Results

#### 1) Normal data for RVDsx

In 48 normal infants and children, RVDsx was compared with BSA (**Fig. 2**). There was an excellent correlation ( $r=0.99$ ) between these two variables with an exponential regression equation;  $RVDsx \text{ (cm)} = 4.4 \text{ (BSA in m}^2\text{)}^{0.74}$ . Using this regression equation, predicted normal values were determined from each BSA, and RVDsx in each patient could then be expressed as percent of predicted normal value (% of normal). In 48 normal children, mean value for RVDsx % of normal was  $100.8 \pm 6.8\%$ .

#### 2) Patients with ASD

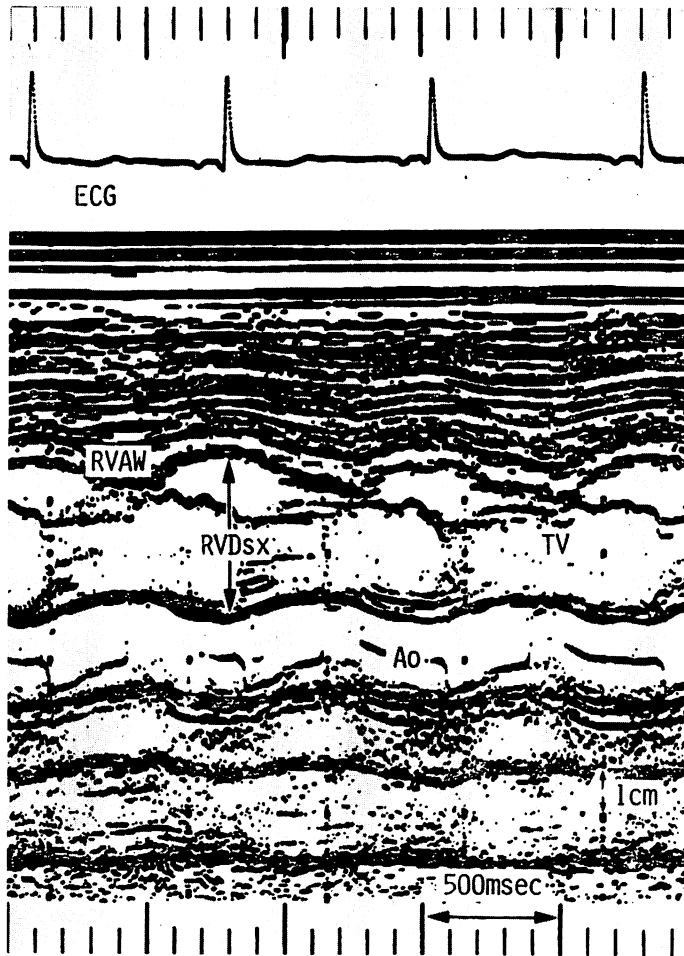
RVDsx was larger than normal in all patients. RVDsx expressed as percent of normal was compared with Qp/Qs and a statistically significant relationship ( $r=0.69$ ,  $p<0.005$ ) was obtained (**Fig. 3**).

#### 3) Patients with VSD

Patients with VSD were divided into three groups according to the degree of left to right shunt, that is, small, moderate and large shunt. And in each group, patients were divided again into two subgroups, those with PH and without PH. In each group, RVDsx expressed as percent of normal was compared between both subgroups. Then, RVDsx in patients without PH was compared between small, moderate and large shunt groups, and similar comparison was made for those with PH (**Fig. 4**).

In each group, mean value for RVDsx % of normal for those with PH was significantly increased from that for those without PH. On the other hand, mean value for RVDsx % of normal for those without PH was not different between small, moderate and large left to right shunt group, and was within normal range. Similarly, mean value for RVDsx for those with PH was not different between three groups, but was larger than normal ( $p<0.001$ ).

**Fig. 5** shows the comparison between RVDsx % of normal and mean pulmonary arterial



**Fig. 1. Representative subxiphoid echocardiogram.**

ECG=electrocardiogram; RVAW=right ventricular anterior wall; RVDsx=right ventricular dimension by subxiphoid echocardiogram; TV=tricuspid valve; Ao=aorta.

pressure in all patients with VSD. There was a significantly positive correlation ( $r=0.57$ ,  $p<0.001$ ).

4) *Patients with PS*

In 6 of 7 patients with PS, RVDsx was within normal range and mean value of that was also normal. The comparison between RVDsx % of normal and right ventriculo-pulmonary arterial pressure gradient was demonstrated in **Fig. 6**, and no significant correlation was found ( $r=-0.20$ ).

5) *Patients with TOF*

RVDsx was larger than normal in two patients and smaller than normal in 11 patients. Mean value for RVDsx % of normal was slightly smaller than normal ( $p<0.01$ ). RVDsx % of normal was compared with hematocrit value and fairly good negative correlation ( $r=-0.80$ ,  $p<0.001$ ) was found between these two variables (**Fig. 7**). There was no significant correlation between RVDsx % of normal and RV peak pressure.

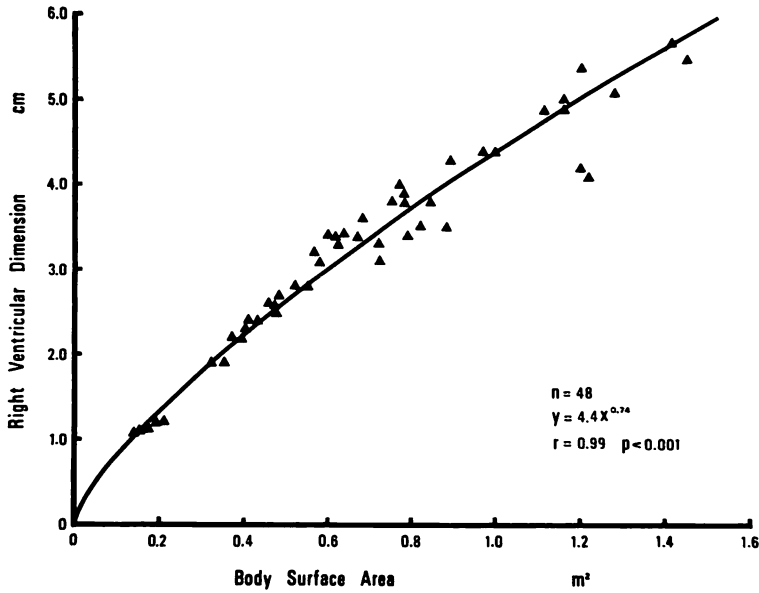


Fig. 2. Correlation between right ventricular dimension by subxiphoid echocardiograms and body surface area in normal infants and children.

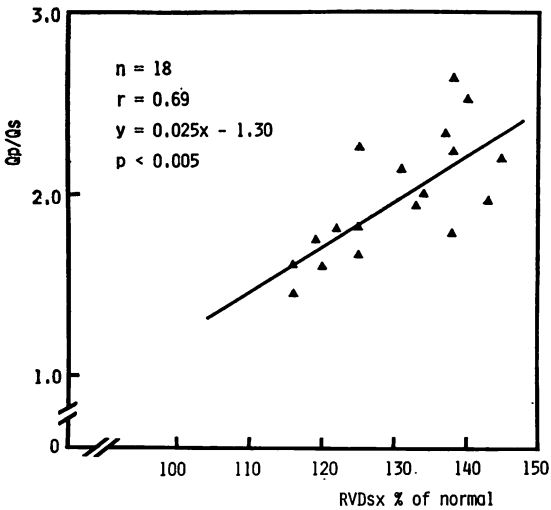


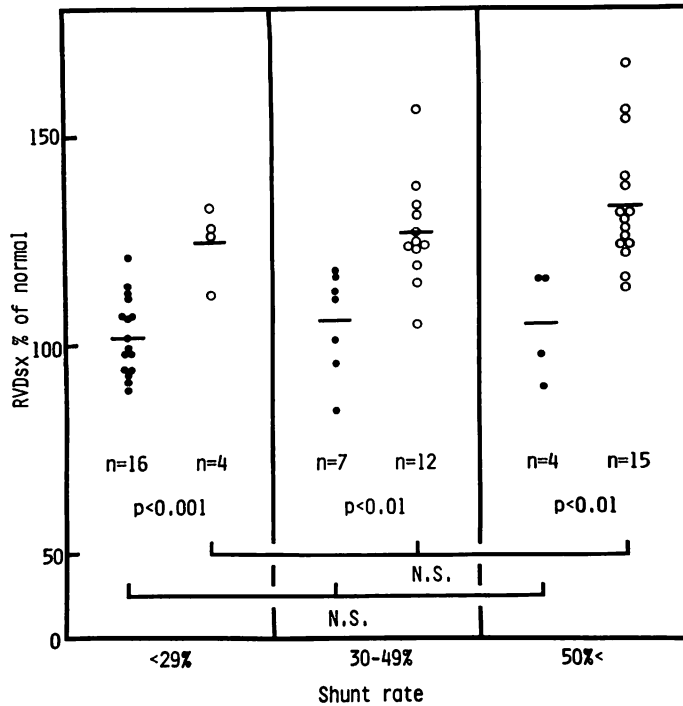
Fig. 3. Correlation between right ventricular dimension expressed as percent of normal (RVDsx % of normal) and pulmonary to systemic flow ratio (Qp/Qs) in patients with atrial septal defect.

### Discussion

For many pediatric cardiologists, non-invasive evaluation of the RV size is an important clinical determination in the management of patients with congenital heart disease. Echocardiography is a noninvasive technique to evaluate the size of cardiac chambers and great vessels, and since a study of Popp and co-workers<sup>6)</sup>, it provides a convenient method to estimate the RV size. But, the dimension determined by this technique was not satisfactory for the estimation of the RV volume<sup>4,5,7)</sup>.

Recently, we have reported<sup>4,5)</sup> that the RV dimension obtained from subxiphoid echocardiograms (RVDsx) was a reliable and clinically useful measurement for the RV volume. In this investigation, we measured RVDsx in patients with various types of congenital cardiac defects and examined whether RVDsx reflected the alterations of RV hemodynamics in comparison with the hemodynamic data obtained from cardiac catheterizations.

RVDsx in patients with ASD expressed as



**Fig. 4. Right ventricular dimension in patients with ventricular septal defect.**

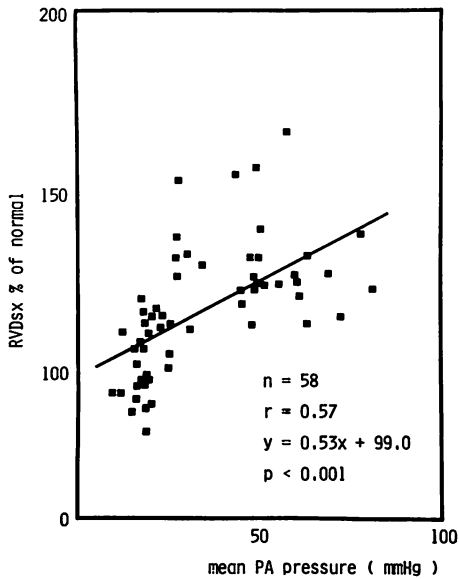
Closed circle indicates patients with normal pulmonary arterial pressure and open circle indicates patients with elevated pulmonary arterial pressure.

percent of normal correlated well with Qp/Qs. So far as we know, there is no simple, safe and noninvasive technique for estimating Qp/Qs in patients with ASD except for radionuclide angiocardiology<sup>8)</sup>. RVDsx is suggested to be a new index to evaluate the severity of this disorder.

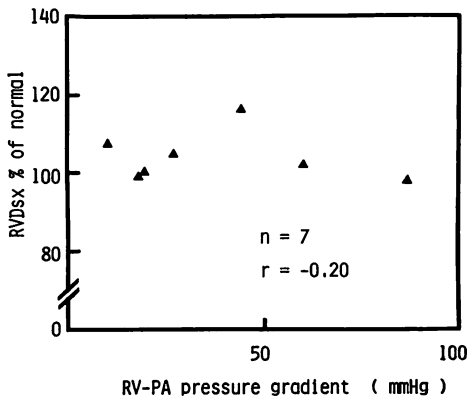
It is interesting that RVDsx in patients with VSD expressed as percent of normal was not different from normal even if the degree of left to right shunt varied when PH was not associated but was significantly increased when PH was associated. Furthermore, RVDsx % of normal showed a significant positive correlation with mean pulmonary arterial (PA) pressure. These findings suggest that RV dimension is influenced not by the magnitude of left to right shunt but by PA pressure. This result is somewhat different from the angiographic findings of Graham and co-workers<sup>9)</sup>. These

authors demonstrated that RV end-diastolic volume (RVEDV) was normal in patients with VSD with small left to right shunt but was increased in patients with large shunt, and they explained that the major factor in producing RV enlargement with a VSD is the significant degree of intracardiac shunting during diastole and "isovolumic" contraction. However, their patients with small shunt showed normal PA pressure and the majority of large shunt group showed elevated PA pressure. Thus, it is possible to interpret that RV size is mainly influenced by PA pressure rather than the magnitude of left to right shunt.

In the recent studies about cardiac function, there are several interesting investigations which are helpful to explain our findings in patients with VSD. Ross<sup>10)</sup> reported that when afterload was increased, preload had to be also increased to maintain an adequate stroke volume

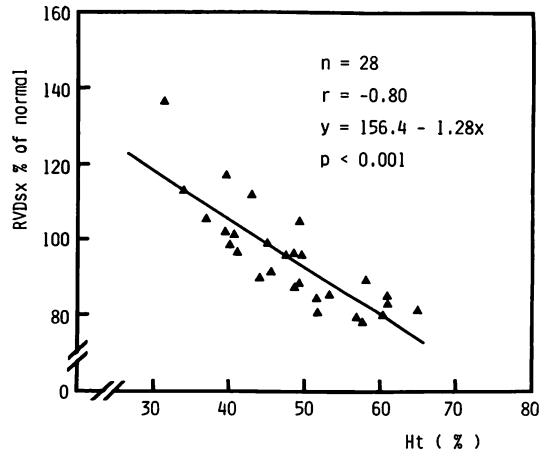


**Fig. 5. Correlation between right ventricular dimension and mean pulmonary arterial pressure in patients with ventricular septal defect.** PA=pulmonary arterial.



**Fig. 6. Correlation between right ventricular dimension and right ventriculo-pulmonary arterial pressure gradient in patients with pulmonary stenosis.** RV=right ventricle; PA=pulmonary artery.

if provided venous return was allowed to vary and the contractility was fixed. If this theory can be applied to the RV in patients with congenital heart disease, it gives a clear expla-



**Fig. 7. Correlation between right ventricular dimension and hematocrit value in patients with tetralogy of Fallot.** Ht=hematocrit.

nation of the enlargement of RV in patients with PH (increased afterload). Maughan and his associates<sup>11)</sup> investigated the canine right ventricle and showed that end-systolic pressure-volume relationship of RV could be regarded as linear. According to this theory, RVEDV and RV size must be increased to maintain an adequate RV stroke volume, because RV end-systolic volume is increased with the elevation of afterload if the contractility is not increased. This theory is an additional support of our findings.

RVDsx was normal in patients with PS and showed no apparent relation with RV-PA pressure gradient. These findings coincide with the previous studies<sup>12,13)</sup> examined with angiocardigraphy. However, according to the form-mentioned theories<sup>10,11)</sup>, RVEDV and RV size in patients with PS must be increased under fixed contractility because afterload is increased. But, in the present study, no enlargement of RV was observed in spite of the elevation of afterload. Thus it is suggested that the contractility of RV in patients with PS is elevated. Additional support to this presumption is the study of Nakazawa and co-workers<sup>14)</sup> who showed that right ventricular ejection fraction was increased

in patients with PS.

RVDsx % of normal in patients with TOF was found to be in inverse relationship with hematocrit value. It is generally accepted that the degree of elevation of hematocrit in patients with TOF is well correlated with the severity of hypoxia and thus with the degree of pulmonary flow in the absence of anemia<sup>15,16)</sup>. Therefore, RVDsx in patients with TOF was thought to be dependent on pulmonary flow. Patients with relatively low hematocrit and relatively mild hypoxemia showed normal or slightly increased RVDsx, and patients with high hematocrit value and severe hypoxemia showed slightly decreased RVDsx. RVDsx was found to have no significant correlation with RV peak pressure. These findings correspond with the previous investigations in tetralogy patients<sup>17,18)</sup>.

The result of the present investigation suggests that RVDsx reflects well the alteration of RV performance, that is, the alteration of preload, afterload and contractility, and the determination of RVDsx gives important informations in the management of patients with congenital cardiac defect.

## 要 約

心エコー図による右室パフォーマンスの定量的検討。

III. 先天性心疾患における右室径の臨床的評価  
斎藤彰博, 上田 憲, 中野博行

剣状突起下心エコー図法を用いて、48例の正常児および111例の先天性心疾患児の右室径を計測した。心房中隔欠損では、正常予測値で表わした右室径の大きさと肺体血流比とのあいだに有意の相関( $r=0.69$ )がみられた。心室中隔欠損では、右室径の大きさは左右短絡の程度とは関係なく、平均肺動脈圧によって影響を受けた。肺動脈狭窄では右室径は正常範囲内にあり、また、右室径の大きさと右室肺動脈圧較差とは相関がみられなかった。フォロー四徴では、右室径は重症度を示すと考えられるヘマトクリット値と逆相関( $r=$

$-0.80$ )の関係にあった。

以上より、心エコー図法による右室径計測は右室の血行動態の変化を敏感に反映すると同時に、先天性心疾患児の管理上有用な情報を提供するものと思われる。

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