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心エコー図による右室パフォーマンスの定量的観察(第一報): 剣状突起下心エコー図法による右室径の評価

Quantitative evaluation of the right ventricular performance with echocardiography. I: Estimation of the right ventricular size with subxiphoid approach

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Summary

There are many problems in measuring right ventricular dimension by echocardiograms using usual precordial approach. Because the right ventricle lies directly beneath the sternum, echocardiographic measurement of right ventricular dimension is easily affected by the position of the patient, the direction of the ultrasonic beam and the rotation of the heart.

In the present investigation, an attempt was made to evaluate subxiphoid echocardiography for the estimation of right ventricular size by comparison with the results obtained from cineangiograms.

The subjects were 77 patients (37 females and 40 males) with congenital heart disease. Right ventricular volumes were calculated from right ventricular biplane cineangiograms with a Simpson's rule in all patients. Right ventricular dimensions were measured from echocardiograms in 76 patients using precordial approach (RVDap) and in 52 patients and 23 normal subjects using the subxiphoid approach (RVDsx). RVDap was measured by usual method, and RVDsx was measured from the endocardial surface of the anterior right ventricular wall to the anterior aortic wall of the subxiphoid echocardiograms in the transducer plane where the tricuspid and aortic valves could be recorded simultaneously at the R wave of ECG.

There was no statistically significant relationship between RVDap and RV volume, but fairly significant correlation was found between RVDsx and RV volume ($r=0.84$, $p<0.001$). The relationship between RVDsx and BSA in normals was significant ($r=0.98$, $p<0.001$) with excellent fit by exponential equation, RVDsx (cm)$=4.64$ (BSA in $m^2)^{0.78}$. The right ventricular ejection fraction by subxiphoid echocardiography showed a weak correlation with that by angiocardiography.

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The conclusion is that RVDsx is a useful and reliable index estimating right ventricular cavity size, and right ventricular ejection fraction determined by echocardiography can serve as a noninvasive means for the evaluation of pump function of the right ventricle.

Key words
Right ventricular dimension RVDsx　Subxiphoid echocardiogram　Right ventricular performance

In the routine echocardiographic examination, estimation of right ventricular size has many limitations. Because the right ventricle lies directly beneath the sternum, echocardiographic measurement of the right ventricular dimension by anteroposterior approach (RVDap) is often affected by the rotation of the heart, the transducer angulation and the position of patients. Although RVDap is useful in selected patients, it is not always a sensitive and reliable index in most of patients with cardiac disorders.

In the present study, we attempted a new method for quantifying the right ventricular size by echocardiography using the subxiphoid approach, and aimed to standardize the measurement of the right ventricle.

Materials and methods

The subjects studied were 77 patients (37 females and 40 males) with congenital heart diseases with the age ranging from one month to 15 years (Table 1). All patients underwent cardiac catheterization and right ventricular biplane cineangiography.

Right ventricular dimensions were measured from echocardiograms in 76 patients using the precordial approach (RVDap) and in 52 patients and 23 normal subjects using the subxiphoid approach (RVDsx).

Table 1. Materials

Cineangiogram	
RV volume study	77 cases
Echocardiogram	
RV dimension (ap)	76 cases
RV dimension (sx)	52 cases
Control	
RV dimension (sx)	23 cases

All echocardiograms were taken using a Smith-Kline Ekoline 20-A ultrasonoscope interfaced with an Electronics for Medicine VR-12 optical recorder and a nonfocused 0.25 inches transducer with a frequency of 3.5 or 5 MHz.

RVDap was measured in the transducer plane where the anterior and posterior mitral valves were recorded simultaneously (**Fig. 1**).

Subxiphoid examination: The patients were examined in the supine position. The transducer was placed over the subxiphoid area and was directed superiorly. As indicated in **Fig. 2**, the ultrasonic beam passes through the right ventricle, tricuspid valves, aorta and aortic valves.

A subxiphoid echocardiogram is shown in **Fig. 3**. Right ventricular dimension (RVDsx)

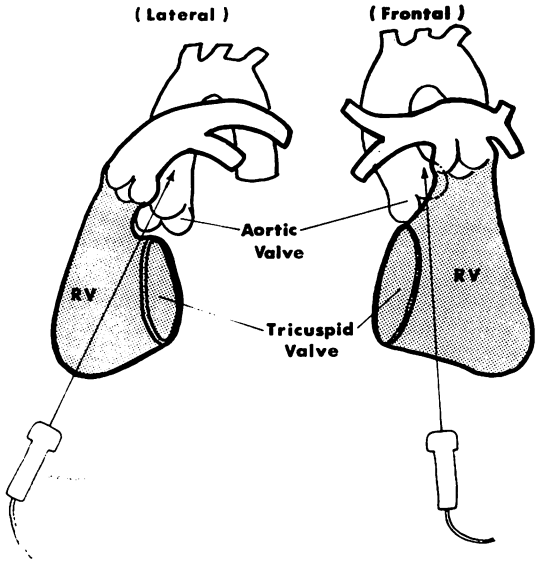

Fig. 2. Diagram of subxiphoid examination.
The transducer is placed over the subxiphoid area and directed to the aortic valves.

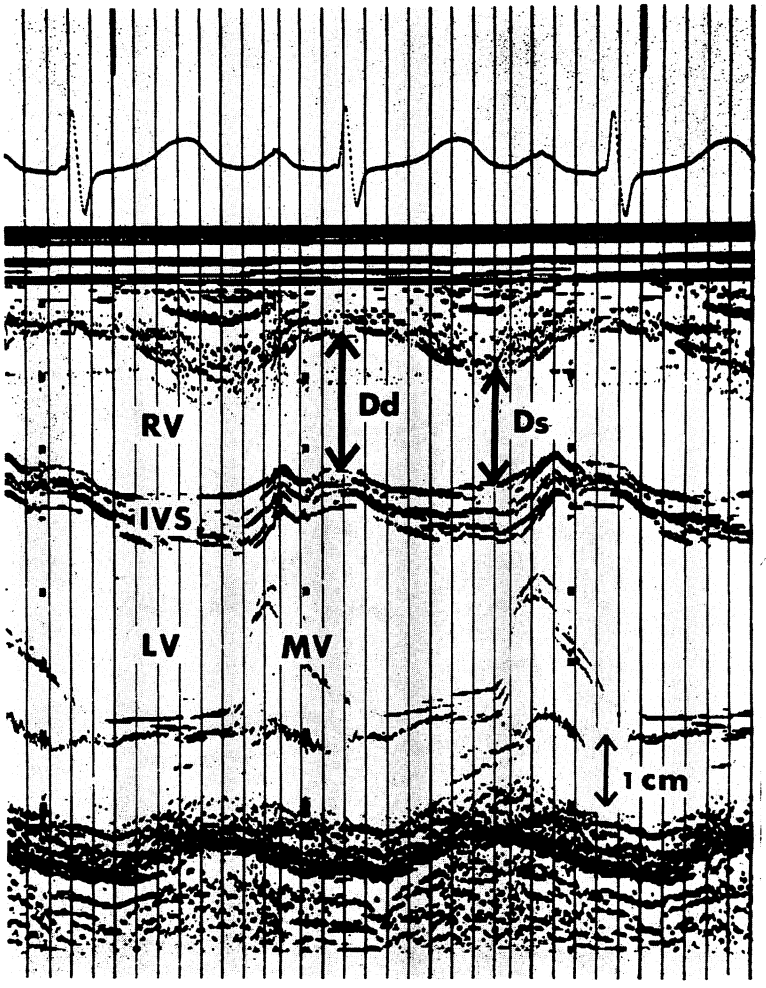

Fig. 1. Echocardiogram using precordial approach.

RV=right ventricle ; IVS=interventricular septum ; LV=left ventricle ; MV=mitral valve, Dd=end-diastolic dimension ; Ds=end-systolic dimension.

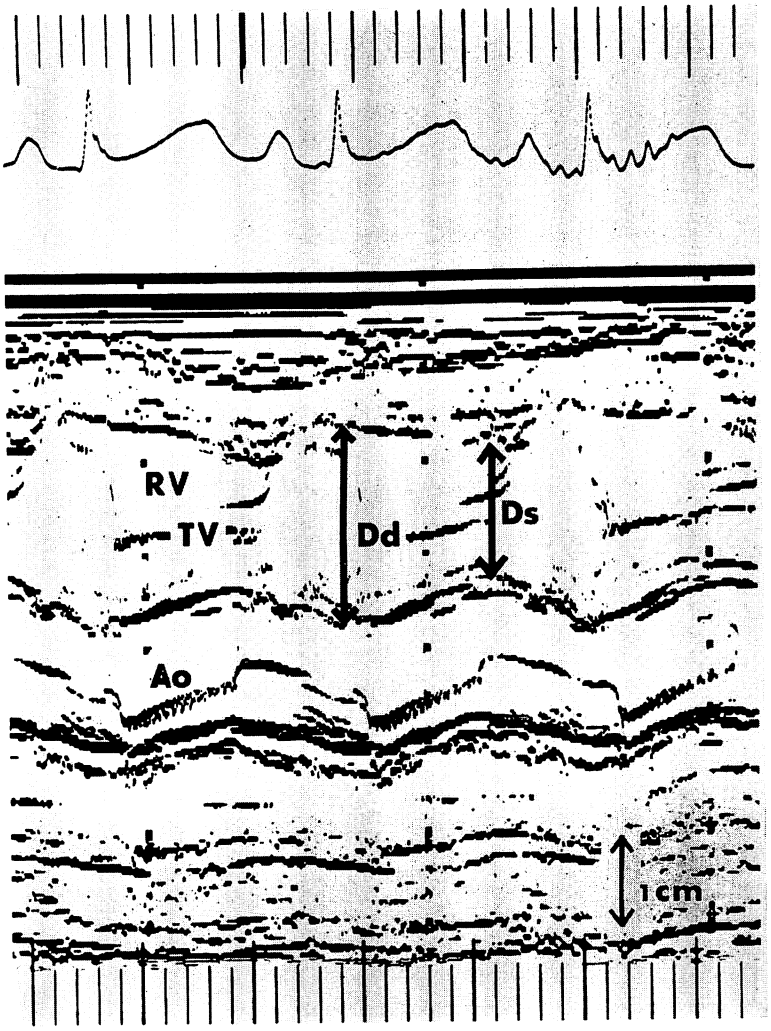

Fig. 3. Echocardiogram using subxiphoid approach.
RV=right ventricle; LV=left ventricle; Ao=aorta; Dd=end-diastolic dimension; Ds=end-systolic dimension.

was measured from the endocardial surface of the anterior right ventricular wall to the anterior aortic wall at end-diastole (at the R wave of ECG). Systolic right ventricular dimension was measured at the peak anterior motion of the anterior aortic wall. All subxiphoid echocardiograms were recorded in the transducer plane where the tricuspid and aortic valves could be recorded simultaneously.

Right ventricular volume analysis: Biplane cineangiograms of the right ventricle were obtained at 60 frames/sec. Right ventricular volumes were calculated from cineangiograms according to the method of Graham et al.[8], based on a Simpson's rule. These right ventricular end-diastolic volumes and ejection fractions were used for a comparison with the echocardiographic data.

Results

The correlation between RVDap and RV volume is shown in **Fig. 4**. There was no statistically significant relationship between both measurements. On the other hand, there was

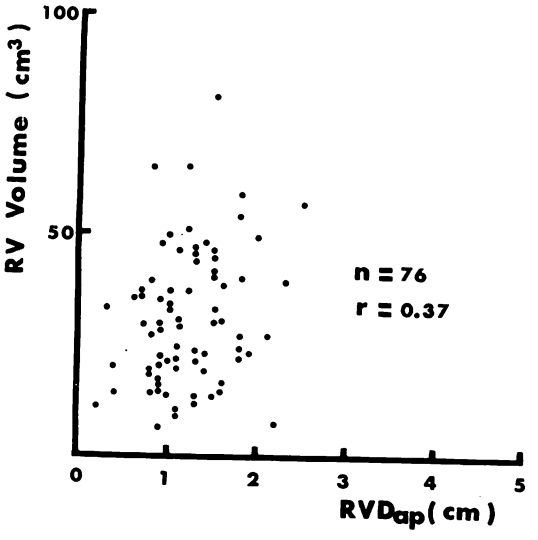

Fig. 4. Correlation between RVDap and RV volume.

RVDap=right ventricular dimension using anteroposterior approach.

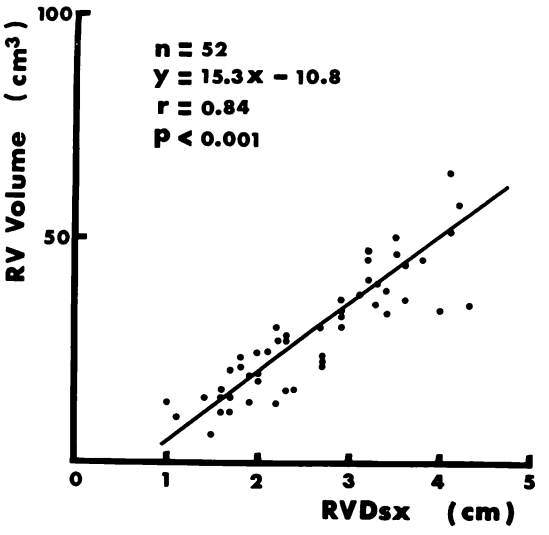

Fig. 5. Correlation between RVDsx and RV volume.

RVDsx=right ventricular dimension using subxiphoid approach.

a significant relationship between RVDsx and RV volume ($r=0.84$, $p<0.001$) (**Fig. 5**).

RVDsx in the normal subjects is shown as a function of body surface area (BSA) in **Fig. 6**. The relationship was significant and was fit best by the exponential equation;

$$RVDsx\ (cm)=4.64\ (BSA\ in\ m^2)^{0.78}$$

($r=0.98$, $p<0.001$).

Echocardiographic right ventricular ejection fraction (RV-EF) was calculated from the equation; $RV\text{-}EF=(Dd^3-Ds^3)/Dd^3$, where Dd and Ds are end-diastolic and end-systolic right ventricular dimensions, respectively, measured from subxiphoid echocardiograms. Comparison between right ventricular ejection fraction determined by angiocardiography and that by echocardiography is demonstrated in **Fig. 7**. There was a slightly positive correlation between both measurements ($r=0.43$, $p<0.01$).

Echocardiographically determined ejection fraction was divided into two groups according to the value below or above the level of 50% and compared with that by angiography (**Fig. 8**). Although the overlapping exists, there was a

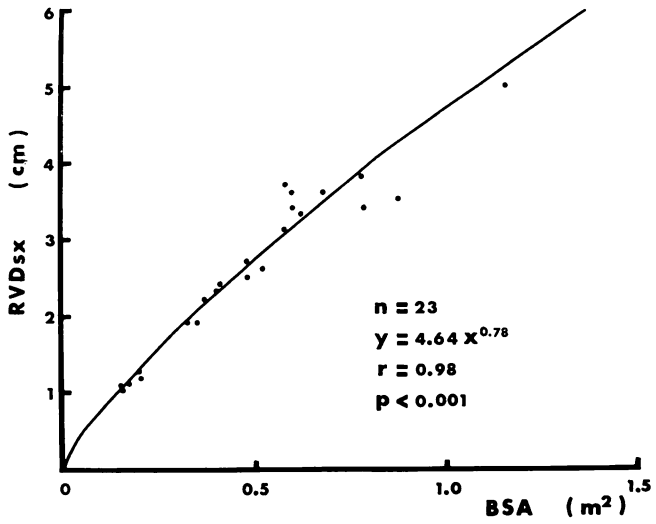

Fig. 6. RVDsx in the normal subject shown as a function of BSA.
RVDsx=right ventricular dimension using subxiphoid approach; BSA=body surface area.

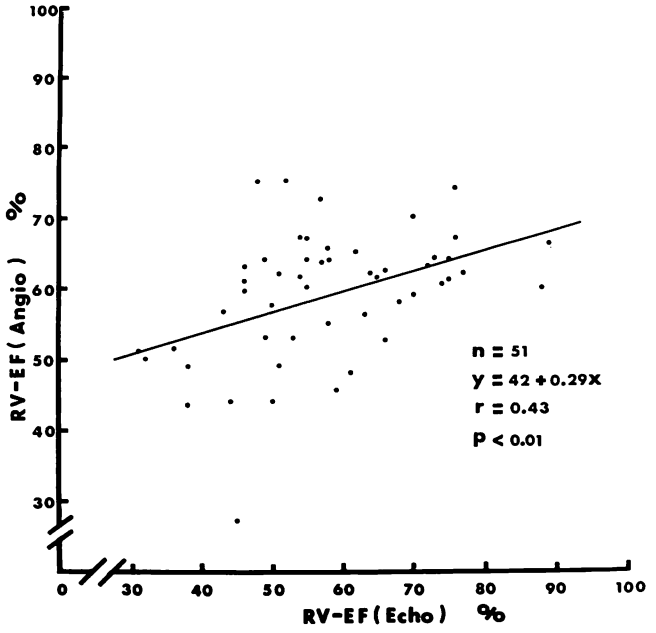

Fig. 7. Comparison between RV-EF by angiocardiography and RV-EF by echocardiography.
RV-EF=right ventricular ejection fraction.

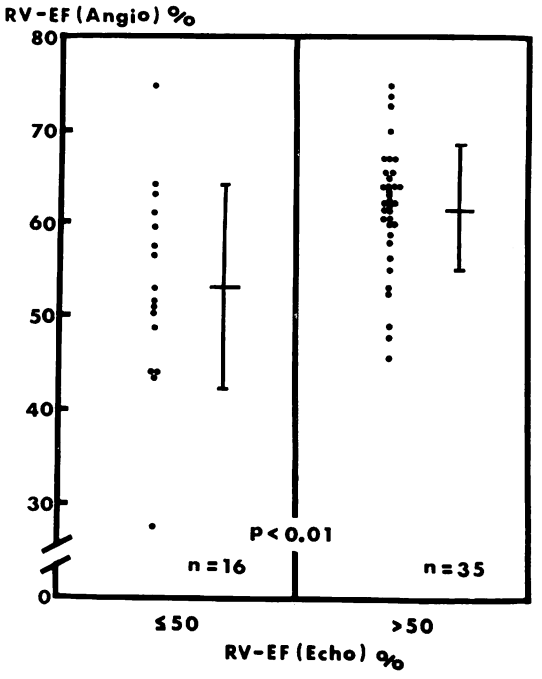

Fig. 8. Comparison of ejection fraction by angiocardiography with that of echocardiography.

RV-EF=right ventricular ejection fraction.

statistically significant difference between both groups ($p<0.01$).

Discussion

Echocardiography is a safe and useful technique for anatomical diagnosis of many types of cardiac lesion, and it also gives many informations concerning the size of cardiac cavity, which provide the diagnostic implications.

However, there are many limitations in echocardiographic estimation of right ventricular size. It is sometimes difficult to clearly define the anterior border of the right ventricle[1,2].

By usual precordial approach, only a small portion of the right ventricle is observed within the way of path of the ultrasonic beam. Thus, the measurement of the right ventricular dimension by conventional method often has a pitfall due to the changes in the position of patients and the direction of the ultrasonic beam, and also due to the rotation of the heart.[2~4] Right ventricular dimension seems to be underestimated in patients with dilated left ventricle.

Although there is a report which compared the RV dimension measured from echocardiograms with the size of the right ventricle measured from angiocardiograms[2], the comparative study of echocardiographic RV dimension by subxiphoid approach with that by angiocardiograms as in the present study has not been reported so far.

The present study demonstrated that there was no relationship between right ventricular volume and RVDap, but a fairly good correlation was found between right ventricular volume and RVDsx. Therefore, RVDsx seems to be a useful and reliable index for the estimation of right ventricular cavity size.

Using subxiphoid approach, many structures could be examined, and dimensions were measured by this technique[5,6]. But the only dimension that could not be measured was the right ventricle[7].

In the present study, RVDsx was measured in the same transducer plane in which the tricuspid and aortic valves could be recorded simultaneously. RVDsx is defined to be the vertical distance between the endocardial surface of the anterior right ventricular wall and the anterior aortic wall at end-diastole. This dimension is thought to be nearly equal to the long axis of the inflow portion of the right ventricle. Thus, RVDsx provides a standard measurement for right ventricular dimension.

In normal subjects, an excellent exponential relationship was seen between RVDsx and BSA. By making use of this exponential equation, normal range for predicted values can be estimated in each BSA, and using a proportion of actual measurement to normal predicted value, a more accurate assessment for right ventricular size can be made.

Finally, this study suggested that echocardiography seems to offer a noninvasive means for evaluation of pump function of the right ventricle.

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