Echocardiogram of the Pulmonary Valve

Variability of the Pattern and the Related Technical Problems

Yoshiyuki HADA, M.D., Tsuguya SAKAMOTO, M.D., F.A.C.C.,
Terumi HAYASHI, M.D., Hirofumi ICHIYASU, M.D.,
Keiko AMANO, M.D., Chuwa TEI, M.D.,
and Kazuaki KATO, M.D.

SUMMARY

In order to examine the variability of the pattern due to the location and direction of the ultrasonic transducer, echocardiograms of the pulmonary valve were obtained from different precordial areas in 28 patients with various diseases and in 3 normal subjects.

By higher positioning of the transducer, the diastolic slope became slower or upward and the 'a' wave became indiscernible, giving the pattern of pulmonary hypertension even in the normotensives. The anterior cusp was also detected by tilting of the transducer in some cases.

Systolic time intervals (STI) of the right ventricle, however, were not influenced by the beam angle.

The present data strongly suggests that the echocardiogram of the pulmonary valve should be carefully evaluated in the light of the spatial relationship of the echo beam and the valve in order to give the diagnostic importance.

Additional Indexing Words:
Pulmonary hypertension (PH) False PH pattern

SINCE the pulmonary valve echo was firstly attempted by Nimura et al1) in 1968 and detected by Gramiak et al2) in 1972, the valve echo has been proved useful in the clinical evaluation of various diseases, such as pulmonary hypertension,3)-6) pulmonary stenosis,7),8) pulmonary regurgitation,9) and others.10),11)

Pulmonary hypertension is echocardiographically diagnosed by the evidence of diastolic plateau pattern (flattening of e-f slope and the absence of
the 'a' dip), rapid opening slope, mid-systolic closure, and systolic fluttering. On the other hand, echocardiographic diagnosis of pulmonary stenosis is based on large 'a' dip of the valve and valvular fluttering especially in case of infundibular stenosis. Recent reports dealing with the pulmonary valve echo mentioned that the valve echo is obtained by tilting the transducer laterally and superiorly from the site of the aortic valve echo usually at the third or fourth left intercostal space parasternally. Otherwise, the transducer is directed cephalad from the mitral valve position, or the transducer is directly placed over the precordial pulmonary artery pulse. Usually only the left cusp, opening posteriorly in systole, is recorded and it has been attributed to the beam traversing through the cusp owing to the plane of the valve motion and the angle of the ultrasonic beam.

However, the influence of the transducer's location and angle of echo beam on the pulmonary valve echo pattern has been little mentioned in these reports. The purpose of this study is, therefore, to demonstrate the variability of the echo pattern of the pulmonary valve and to investigate the technical problems related to the various transducer's locations and angles.

**Materials and Methods**

Echocardiograms of pulmonary valve were examined in 28 patients and 3 normal subjects (Table I), in whom 2 or more echo patterns of the valve were detected from different intercostal spaces. These materials include 8 cases complicated with atrial fibrillation and 2 cases with complete right bundle branch block (CRBBB). They are 20 males and 11 females, aged from 14 to 75 years old (average 41.7).

<table>
<thead>
<tr>
<th>Table I. Classification of 31 Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valvular heart disease...............</td>
</tr>
<tr>
<td>mitral ................................</td>
</tr>
<tr>
<td>aortic ................................</td>
</tr>
<tr>
<td>combined .............................</td>
</tr>
<tr>
<td>Pulmonary stenosis ..................</td>
</tr>
<tr>
<td>Atrial septal defect ...............</td>
</tr>
<tr>
<td>Endocardial cushion defect ........</td>
</tr>
</tbody>
</table>

Following the observation of the respiratory change of the valve motion, all tracings were recorded in the supine position during expiratory apnea with a glottis open. Strip-chart recordings were made using Aloka SSD-100 Polygraph with a 2.25 MHz, 10 mm diameter unfocused transducer, simultaneously with electrocardiogram and phonocardiogram. Paper speed was 50 mm/sec for the observation and 100 mm/sec for the measurement.

Diastolic slope and opening slope were defined as shown in Fig. 1. Downward movement in diastole was designated as positive, and upward movement,
Fig. 1. Measurement technique of right-sided systolic time intervals (STI), diastolic slope, and opening slope. PV: pulmonary valve, MV: mitral valve, PEP: pre-ejection period, ET: ejection time, 2L: 2nd intercostal space at the left sternal margin.

as negative. An e–e' portion (cf. Fig. 3) was not measured, because it was scarcely detected in most cases except the cases with pulmonary hypertension, in which echocardiogram of the pulmonary valve is easily recorded throughout whole cardiac cycle. Distance from the chest wall to the valve was determined at the time of the onset of the QRS complex of the electrocardiogram.

Right-sided pre-ejection period (RPEP) was measured from the beginning of the QRS complex to the onset of the valve opening determined by a tangent line as shown in Fig. 1. Right-sided ejection time (RET) was obtained in some cases, in which complete valve echo was recorded.

The method to obtain the valve echo was as follows:

1) Recording with the beam directed laterally and superiorly toward to the left shoulder from the position detecting the aortic valve, usually at 3L.* A dense band of echo below the pulmonary valve is the atriopulmonary sulcus and echo-free space under the sulcus is the left atrium.

2) Recording from one intercostal space above, angulating the echo beam to the valve position. By this technique, the mitral valve echo may be found behind the pulmonary valve.

3) Recording from one intercostal space below (i.e., 4L or 5L).

* Abbreviations of precordial areas: 1L–5L indicate the first, second, ... and fifth intercostal spaces at the left sternal margin.
(4) Recording placing the transducer directly over a pulmonary artery impulse, whenever it is palpable, or at the point of the grossly accentuated pulmonary component of the second heart sound.

The posteriorly opening valve was regarded as the left cusp and the anteriorly opening valve as the anterior or right cusp.

Right heart catheterization was performed in 12 out of 31 cases within a week or 2 prior to or following echocardiographic examination.

The measurements were made on diastolic slope, opening slope, the 'a' wave pattern and distance from the chest wall to the valve in all 31 cases based on the echograms from various areas.

Results

Intercostal spaces recorded were 5L and 4L in 1 out of 31 cases, 4L and 3L in 18, 3L and 2L in 11, and 2L and 1L in 1. No pulmonary valve echo was obtained from 3 intercostal spaces. The results are shown in Fig. 2 and are illustrated in Fig. 3 to Fig. 9.

I. Diastolic slope of the valve echo (Fig. 2)

The precise measurement of diastolic slope was possible in 22 cases. With higher positioning of the transducer and vertical or inferior direction of the echo beam, the slope tended to be more flat in 8 cases (Figs. 3, 5), or negative (upward) in 6 (Figs. 8, 9), or little changed in 8 (Figs. 6, 7). These changes had no correlation with the pulmonary artery pressure level. An e-e' part of the slope became more evident and flat in pulmonary hypertension, and also in some normals. Usually, the positioning of the transducer in higher intercostal spaces gave the record of mitral valve behind the pulmonary valve echo (Fig. 1).

II. Opening slope (Fig. 2)

The positioning and angle of the transducer made the opening slope variable, and no uniform tendency was demonstrated, though the slope in pulmonary hypertension tended to be rapid (Figs. 3, 5).

III. The 'a' wave

Either with higher positioning of the transducer (Fig. 9), or by tilting medially (Figs. 3, 4), the 'a' wave of the valve echo became indiscernible or eliminated in 4 cases. However, it was not changed in 19 cases, regardless of the positioning of transducer (Figs. 6, 7). There was no case in whom the 'a' wave became more evident by higher positioning of the transducer.
Fig. 2. Comparison of various measurement values due to the different positioning of the transducer.

Low and High indicate the lower and higher intercostal spaces (ics) of the positioning of transducer in the same subject.

Fig. 3 (opposite page). Illustrative case with different echo pattern by various positioning of the transducer. Eisenmenger complex, 23-year-old female.

Three patterns of pulmonary valve echo are successively depicted from 3 different areas. Upper panel is obtained vertically at 3L, lower left at 3L laterally (3L lat.), where the point of a pulmonary artery impulse is located, and lower right is inferiorly from 2L lat. The downwardly angulated beam
made the valve closer to the chest wall, and diastolic slope negative. Systolic
e valve motions are variable in each figure, though the W-shaped pattern is
depicted in each.

PV: pulmonary valve, Ant. C: anterior cusp, Left C: left cusp, PA
Pulse: indirect pulmonary artery pulse.
IV. Systolic pattern of the valve echo

Contrary to the normals, later half of systole and early diastole were easily detected in pulmonary hypertension and W-shaped pattern (mid-systolic semi-closure)\(^3,6\) if existed, was evident irrespective of the beam angle, although the pattern was variable (Fig. 3). Systolic fluttering was observed in some pulmonary hypertensive cases (Fig. 3).

V. Distance between the chest wall and the valve (Fig. 2)

From higher positioning, distance to the valve was shortened (Figs. 3, 5~9) except 2 cases (Fig. 4).

VI. Right-sided STI (Fig. 2, Table II)

RPEP were not influenced by the positioning of the transducer and the beam direction. The right-sided PEP/ET was calculated in 5 out of 12 cases,
Fig. 5. Illustrative case of different pulmonary valve echogram. Combined mitral and tricuspid valvular disease, 47-year-old female.

Diastolic slope, especially e-e' portion, is slower and the valve closer to the chest wall at 2L than 3L. Right ventricular pressure is 76/11 mmHg (pulmonary artery pressure not determined).

Fig. 6. Illustrative case of different pulmonary valve echogram. Atrial septal defect, 61-year-old male.

In both situations, the valve echoes did not have any changes irrespective of the transducer's location, although the valve comes closer to the chest wall when recorded from higher position (3L lat.).
Vol. 18  
No. 3  
ECHOCARDIOGRAM OF PULMONARY VALVE  

**Fig. 7.** Illustrative case of different pulmonary valve echogram. Myocardial infarction, 59-year-old male.  
The same tendency as in Fig. 6 is observed.

| Table II. Right-sided PEP/ET and the Pulmonary Artery Pressure |
|------------------|-----------|-----------|-----------|-----------|-----------|
| PEP/ET           | 0.75      | 0.46      | 0.43      | 0.38      | 0.30      |
| PA press. (mmHg) | 76/11*    | 65/32     | 100/42    | 35/17     | 25/13     |

* RV pressure (PA pressure was not measured)

in which cardiac catheterization was performed. There was only a rough positive correlation between these 2 values (Table II).

**DISCUSSION**

Nanda et al⁵ and Weyman et al⁶ correlated the diastolic slope and the ‘a’ wave with pulmonary artery pressure and reported that echocardiogram was of value in the evaluation of pulmonary hypertension. Previous report⁷ from this laboratory also recognized diastolic plateau and systolic W-shaped pattern of the valve in cases with pulmonary hypertension.

However, the previous reports on the pulmonary valve echo scarcely mentioned about the variability of the valve echo. Goldberg et al¹² illu-
Fig. 8. Illustrative case of different pulmonary valve echogram. Progressive systemic sclerosis, 20-year-old female.

Diastolic position is horizontal at vertical position (2L) and negative at higher position (1L). Inferior angulation makes the valve closer to the chest wall. The 'a' dip is absent in both situations.

strated in their textbook the relation of the beam angle to the valve and stated that both pulmonary valves will be seen when the pulmonary artery arises perpendicularly from the heart. The amplitude of the 'a' dip in their cases with pulmonary stenosis was not well correlated with pressure gradient across the valve, although they made no comment on it. Hirschfeld et al13) emphasized the importance of rather right-sided PEP/ET than the echo pattern itself in the evaluation of pulmonary artery pressure and vascular resistance, chiefly because of the inconstant echo pattern in pulmonary hypertension. The results of the present study also disclosed the tricky aspects of the pulmonary valve echo pattern.

Fig. 10 illustrates why the variable echo patterns of the pulmonary valve are produced by the different beam angles to the valve. By the upward oblique beam direction from lower precordial position (Fig. 10 left), the valve motion is depicted as a gradual downward echo during diastole because the closed valve is thrust up corresponding to the right ventricular filling and finally the valve echo is recorded as 'a' dip by the presystolic inrush of the blood. At the onset of the right ventricular ejection, the left cusp rapidly
Fig. 9. Illustrative case of different pulmonary valve echogram. Mitral regurgitation due to posterior chorda rupture, 51-year-old male.

By downwardly directed echo beam from 2L laterally, the valve echo is similar to that of pulmonary hypertension, although its echo is not strong. From 3L laterally, the reasonable echo pattern is depicted. Pulmonary artery pressure is 25/13 mmHg.

Fig. 10. Diagrams illustrating the relation of the beam angle to the valve. See text for details.
opens posteriorly and perpendicularly to the beam, reflecting a dense echo. The anterior or right cusp, on the other hand, opens in parallel fashion to the beam, reflecting little ultrasound and will not be sensed by the transducer. When the echo beam is angulated inferiorly from higher position, however, the valve becomes closer to the chest wall, resulting in slower or negative diastolic slope and the indiscernible 'a' dip. The anterior cusp can be easily detected as it opens perpendicularly to the beam. Moreover, even if the valve echo is recorded from the same intercostal space, the various spatial relationships of the beam to the valve seem to produce the variable valve echo patterns (Fig. 10 right).

Owing to the above-mentioned reason, opening slope of the left cusp should be theoretically more rapid, whenever the transducer is set at higher intercostal space. However, our data failed to demonstrate such a tendency. The possible explanation is such that opening slope is too short and steep to permit accurate measurements.

The right-sided STI may be useful to exclude the pseudohypertensive cases as demonstrated by Hirschfeld et al., but the present data are not enough to make a conclusion, because of the small subset of the material.

The diastolic configuration of the valve echo in pulmonary hypertension has been understood as a strong and flat echo, because the valve moves little cranially under the raised diastolic pressure in the artery. Another explanation is such that the dilated pulmonary truncus becomes parallel to the chest wall, resulting in the vertically faced valve to the ultrasonic beam.

It should be emphasized that negative diastolic slope, sometimes reported in pulmonary hypertensive cases, is obtained by the inferiorly directed echo beam, so that this technique is not suitable for the estimation of pulmonary hypertension. Moreover, respiratory effect on the pulmonary valve echo should not be neglected for the assessment of the 'a' wave. During inspiration, the increased filling and forceful right atrial contraction make the 'a' dip larger, and finally, may induce 'presystolic opening'.

In consideration of all the situations, the echocardiographic diagnosis of pulmonary hypertension must be based on, 1) easy detectability of the valve echo throughout the cardiac cycle from different precordial areas, 2) diastolic, especially initial diastolic, straight flat and strong echo, 3) shallow 'a' dip or its absence, 4) mid-systolic semi-closure, and finally, 5) rapid opening slope. Again, care should be taken to the fact that the inferiorly directed beam from higher positioning of the transducer induces hypertensive pattern even in the normotensives, although the echo is not so strong.

In conclusion, the echocardiogram of the pulmonary valve should be carefully evaluated in the light of the spatial relationship of the beam and
the valve. The standard direction of the ultrasonic beam should not be downward but vertical or upward oblique to the valve, in order to eliminate the erroneously induced interpretation of pulmonary hypertension or other cardiac states.

REFERENCES