Diagnostic Accuracy of Transesophageal Echocardiography for Detecting Patent Ductus Arteriosus in Adolescents and Adults*

Kou-Gi Shyu, MD; Ling-Ping Lai, MD; Shen-Chang Lin, MD; Hang Chang, MD, PhD; and Jin-Jer Chen, MD

To compare the accuracy of transesophageal echocardiography (TEE) with that of transthoracic echocardiography (TTE) in the detection of patent ductus arteriosus (PDA) in the adolescent and the adult, 40 patients with PDA and 50 patients with other congenital heart diseases were studied. All echocardiograms were recorded before cardiac catheterization and surgery. The echocardiographic diagnosis of PDA was made by direct visualization of a shunt flow in the duct. A mosaic flow in the pulmonary artery without direct visualization of the duct was considered possible but not definitely diagnostic of PDA. TEE showed greater sensitivity and negative predictive value than TTE (97% vs 42%, and 98% vs 68%, respectively; p<0.001) in confirming the diagnosis of PDA. The specificity and positive predictive value in establishing the diagnosis of PDA were the same for both techniques. In the subgroup of patients with Eisenmenger’s syndrome, the sensitivity of TEE and TTE in confirming diagnosis of PDA was 100% and 12% (p<0.01), respectively. The sensitivity of monoplane and biplane TEE in the diagnosis of PDA was comparable (95% and 100%, respectively; p=NS). In conclusion, TEE was highly sensitive and specific in detecting PDA in adolescents and adults. It was also highly valuable for detecting the cause of pulmonary hypertension in patients with Eisenmenger’s syndrome.

(CHEST 1995; 108:1201-05)

PDA=patient ductus arteriosus; TEE=transesophageal echocardiography; TTE=transthoracic echocardiography

Key words: Eisenmenger’s syndrome; patent ductus arteriosus; transesophageal echocardiography; transthoracic echocardiography

Patent ductus arteriosus (PDA) is a frequent congenital cardiovascular abnormality connecting the origin of the left pulmonary artery with the descending aorta just distal to the left subclavian artery.1 PDA is usually identified early in life. However, there is an increasing awareness of PDA presenting in adulthood and even in the elderly.2-5 PDA in infants and children can often be diagnosed by transthoracic two-dimensional and color Doppler echocardiography through detecting a shunt flow from the descending aorta into the pulmonary artery through a ductal structure.6-9 However, since the PDA is far from the transducer on the chest wall and because of interference from lung tissue and ribs in adults, it is usually difficult to show clearly this structure and the flow in it.10,11 Thus, diagnosing PDA by transthoracic echocardiography (TTE) is difficult, highly technique-dependent, and sometimes even an impossible task in adolescents and adults.

With the advent of transesophageal echocardiography (TEE), there is a much better window to the posterior structures of the thoracic cardiovascular system.12-14 Although TEE has been employed to evaluate various cardiac anomalies,15,16 experience with its use in PDA is limited17,18 and its accuracy for the diagnosis of PDA is not known. Therefore, we conducted a prospective study to evaluate the sensitivity and specificity of TEE and to compare the accuracy of TTE and TEE in the diagnosis of PDA in adolescents and adults.

MATERIALS AND METHODS

Study Patients

This study was a prospectively designed study. A total of 90 patients form the basis of the study, and they were subdivided into two groups. Group 1 (40 patients) comprised all patients studied at our echocardiography laboratory with both TEE and TTE in whom PDA was proved by cardiac catheterization and surgery (n=21), cardiac catheterization alone (n=18), or surgery alone (n=1) in a 3-year period. Six patients who refused cardiac catheterization and did not undergo cardiac surgery were excluded in the same period. Patients referred for echocardiographic examination in our laboratory were above age 15. Group 2 (50 patients) comprised all patients with other congenital heart diseases studied with both TTE and TEE in whom absence of PDA was verified by cardiac catheterization. All group 2 patients underwent cardiac surgery.

*From the Department of Emergency Medicine, Shin-Kong Wu Ho-Su Memorial Hospital, Taipei, and the Division of Cardiology, Department of Internal Medicine, National Taiwan University Hospital, Taipei, Taiwan, Republic of China. Manuscript received February 15, 1995; revision accepted May 11. Reprint requests: Dr. Chen, Department of Internal Medicine, National Taiwan University Hospital, No. 7, Chung-Shan South Road, Taipei 100, Taiwan, ROC
Group 1 contained 10 men and 30 women (age range, 17 to 65 years; mean age, 33 years). The clinical diagnosis was PDA in 24, ventricular septal defect with pulmonary hypertension in 5, aortic regurgitation in 3, atrial septal defect in 3, ventricular septal defect with rupture of sinus of Valsalva in 1, unexplained pulmonary hypertension in 2, and cyanotic congenital heart disease in 2 patients. Only 20 patients had typical continuous murmurs. The clinical manifestations included dyspnea and exercise intolerance in 18, palpitation in 4, and chest pain in 3. Fifteen patients were asymptomatic. Eight of the 40 patients had Eisenmenger’s syndrome confirmed by cardiac catheterization. Of the eight patients, three had ventricular septal defect and one had coarctation of the aorta besides PDA. Of the 32 patients without Eisenmenger’s syndrome, 2 also had ventricular septal defect.

Group 2 was composed of 19 men and 31 women (age range, 17 to 64 years; mean age, 34 years). None of the patients had a clinically suspected PDA. The diagnosis, as confirmed by cardiac catheterization and surgery, was atrial septal defect in 37, ventricular septal defect in 9, Ebstein’s anomaly in 2, and pulmonary stenosis and pseudotruncus each in 1 patient.

**Echocardiographic Examinations**

Transthoracic and transesophageal echocardiograms were recorded for all patients before cardiac catheterization or cardiac surgery. An echocardiographic imaging system (Toshiba SSH-65A; Toshiba Corp; Tokyo) was used in 22 of the group 1 and 26 of the group 2 patients and another imaging system (Aloka SSD-870; Aloka Corp; Tokyo) was used in 18 of the group 1 and 24 of the group 2 patients. Transthoracic studies were performed prior to, but as on the same day as, transesophageal studies. These studies were performed after patients gave informed consent. All studies were recorded on ¼-in tapes (Sony U-matic) or ¼-in VHS tapes (Panasonic) for further analysis. The echocardiograms were interpreted by two experienced echocardiographers unaware of the results of cardiac catheterization or surgery. Any differences in the interpretation were resolved by a third observer who also did not know any findings.

**Transthoracic Echocardiographic Studies**

Both 2.5- and 3.75-MHz phased-array transducers connected to an echocardiographic imaging system (Toshiba SSH-65A or an Aloka SSD-870) machine were used for transthoracic echocardiographic examinations. Standard parasternal long-axis and short-axis views, apical four-chamber, and suprasternal long-axis views were used to examine every patient with both two-dimensional and color Doppler flow mapping methods. Special attention was paid to various high parasternal short-axis views at the level of the pulmonary artery. Any mosaic flow in the aorta and pulmonary artery was carefully sought. Both pulsed-wave and continuous-wave Doppler were used to analyse the flow pattern.

**Transesophageal Echocardiographic Studies**

A single-plane transesophageal 3.75-MHz transducer interfaced with the Toshiba SSH-65A imaging system was used in 22 of the group 1 and 26 of the group 2 patients and a biplane transesophageal 5.0-MHz transducer interfaced with the Aloka SSD-870 imaging system was used in 18 of the group 1 and 24 of the group 2 patients. The procedure of tranesophageal study has been described previously. After cardiac structures were systematically examined, the probe was rotated counterclockwise to visualize the descending thoracic aorta. A transverse scan transducer was used at a distance of 30 cm from the incisor. The probe was pulled out carefully and, at about 1-cm intervals, the probe was anteflexed and retroflexed to search for abnormal flow between the descending aorta and the pulmonary artery. Pulsed Doppler was then used to demonstrate the pattern of the abnormal flow. In biplane probe, a

![Figure 1: Comparison of the accuracy of TEE and TTE in the diagnosis of PDA. Diagnostic PDA by TTE means that direct visualization of the mosaic flow from the descending aorta into the pulmonary artery was obtained. Possible PDA by TTE means that there was only a mosaic pattern in the pulmonary artery without direct visualization of the duct; pv=predictive value.](image-url)

**Statistical Analysis**

The sensitivity, specificity, and positive and negative predictive values of TTE and TEE in the diagnosis of PDA were calculated. Statistical analysis was performed using χ² with Yates’ correction and unpaired t test, and a p value less than 0.05 was considered significant.

**RESULTS**

**Transthoracic Echocardiography**

A mosaic flow was detected in the pulmonary artery in 28 of the 40 group 1 patients. In the other 12 patients, no abnormal flow could be found in the pulmonary artery. Of the 28 patients with a mosaic flow in the pulmonary artery, the diagnosis of PDA could be confirmed by direct visualization of the mosaic flow...
Table 1—Comparison of 40 Patients With PDA With and Without Eisenmenger’s Syndrome*

<table>
<thead>
<tr>
<th></th>
<th>With (n=8)</th>
<th>Without (n=32)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex, F/M</td>
<td>4/4</td>
<td>6/26</td>
<td>NS</td>
</tr>
<tr>
<td>Age, yr</td>
<td>34±6</td>
<td>33±12</td>
<td>NS</td>
</tr>
<tr>
<td>PA pressure, Systole mm Hg</td>
<td>117±21</td>
<td>32±20</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Diastole</td>
<td>57±19</td>
<td>15±6</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Sensitivity of TTE, %</td>
<td>12</td>
<td>50</td>
<td>NS</td>
</tr>
<tr>
<td>TEE, %</td>
<td>100¹</td>
<td>97¹</td>
<td>NS</td>
</tr>
</tbody>
</table>

*NS=not significant; PA=pulmonary artery.
¹p<0.01 vs TTE.
¹p<0.001 vs TTE.

from the descending aorta into the pulmonary artery in 17 patients. In the other 11 patients, the presence of a mosaic flow in the pulmonary artery was a possible PDA, but the diagnosis could not be confirmed because the flow was not proved to come from the descending aorta. None of the group 2 patients had possible or diagnostic PDA. The sensitivity, specificity, and positive and negative predictive values of TTE in confirming the diagnosis of PDA were 42%, 100%, 100%, and 68%, respectively. When possible and confirmatory diagnosis of PDA was included, the sensitivity and negative predictive value increased to 70% and 81%, respectively (Fig 1).

In the subgroup of eight patients with Eisenmenger’s syndrome, the diagnosis of PDA was confirmed in one (sensitivity, 12%) and possible in two. No abnormal flow was detected in the other five patients with the syndrome. If these eight patients with Eisenmenger’s syndrome were excluded, the sensitivity of TTE in detecting confirmatory diagnosis of PDA increased to 50% (Table 1) and in detecting possible plus confirmatory diagnosis of PDA increased to 78%.

Transesophageal Echocardiography

The diagnosis of PDA (Fig 2) could be confirmed in 39 of the 40 group 1 patients. No PDA was diagnosed in the group 2 patients. The sensitivity, specificity, and positive and negative predictive values of TEE in confirming the diagnosis of PDA were 97%, 100%, 100%, and 98%, respectively. The sensitivity and negative predictive value of TEE were higher than that of TTE (Fig 1). In the subgroup of patients with Eisenmenger’s syndrome, diagnosis of PDA could be confirmed in all eight patients (sensitivity, 100%). A mosaic flow could be found by TEE to originate from the descending aorta, entering the pulmonary artery through the duct. The mosaic flow representing a flow acceleration near the duct could be easily detected by TEE in the descending aorta. Further manipulation of the probe could reveal the flow into the pulmonary artery through the duct.

Pulsed-wave Doppler studies were performed with sample volume at the ductal level. In the 31 patients without Eisenmenger’s syndrome, a continuous high-velocity flow with alias despite high-pulse repetition frequency was identified. In the eight patients with Eisenmenger’s syndrome, all pulsed Doppler studies revealed a bidirectional shunt with a relatively low-flow velocity. The shunt came from the pulmonary artery into the descending aorta during systole and from the descending aorta into the pulmonary artery during di-

![Figure 2](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21724/)

**Figure 2.** Monoplane TEE (transverse scan) demonstrating a mosaic flow from the descending aorta (DAO) into the pulmonary artery (PA) (right), a condition considered diagnostic of PDA. Pulsed-wave Doppler echocardiography with sample volume (arrow) at the ductal level showed a high-velocity continuous flow with alias (left).
astole in all eight patients with Eisenmenger’s syndrome (Fig 3). The sensitivity of TEE in detecting PDA with Eisenmenger’s syndrome was significantly higher than that of TTE (Table 1).

In the group 1 patients, diagnosis of PDA was confirmed in 21 of 22 patients studied by monoplane TEE. In the other 18 patients studied by biplane probe, PDA was confirmed in all. The sensitivity of monoplane and biplane TEE in the diagnosis of PDA was 95% and 100% (p=NS), respectively. The shunt flow from the aorta through the ductus into the pulmonary artery was visualized by both transverse and longitudinal scan transducer in all 18 patients studied by biplane TEE.

**Interobserver Variability**

In group 1, there was disagreement between the two observers as to the diagnosis of PDA in two patients by TTE and in one patient by TEE. There was no disagreement about the absence of PDA in group 2 patients.

**DISCUSSION**

In this study, we demonstrated that TEE was superior to TTE in the diagnosis of PDA in adolescents and adults. To the best of our knowledge, this is the first study to evaluate the sensitivity and specificity of TEE for detection of PDA.

For detecting PDA in adults, TEE was highly sensitive and specific. The sensitivity of TEE in detecting PDA was significantly higher than that of TTE (97.5% vs 42.5%, p<0.001; or 97.5% vs 70%, p<0.01). The specificity of TTE in establishing the diagnosis of PDA was the same as that of TEE (100%). In pediatric patients, PDA is demonstrated much better with precordial echocardiography than with TEE.20

A mosaic pattern was detected in the pulmonary artery without direct visualization of the duct by trans-thoracic Doppler echocardiography in 11 of 40 patients (27.5%). This is not diagnostic of PDA because a mosaic flow in the pulmonary artery can occur in many other disorders such as aortopulmonary septal defect, rupture of the sinus of Valsalva into the pulmonary artery, pulmonary stenosis, and coronary artery fistula draining into the pulmonary artery.21,22 Although the diagnosis of PDA could not be confirmed in these patients, this finding was compatible with PDA and implied the need for further study.

In patients with Eisenmenger’s syndrome due to PDA, the value of TEE was low. As expected, TTE did not show a significant mosaic pattern in the pulmonary artery in patients with Eisenmenger’s syndrome due to PDA. However, the shunt flow could be easily identified by TEE. Furthermore, pulsed-wave Doppler studies showed that the shunt flow was bidirectional with systolic flow from the pulmonary artery into the descending aorta and diastolic flow from the descending aorta into the pulmonary artery. To detect PDA as the pathologic entity resulting in the Eisenmenger’s syndrome is the key role of TEE.

Takenaka et al18 showed that diagnosis of PDA could be confirmed in four of eight patients (50%) by TTE. The sensitivity in our study was 42.5%. The lower
sensitivity in our study could be explained by the inclusion of patients with Eisenmenger’s syndrome in our study. The sensitivity increased to 50% if patients with Eisenmenger’s syndrome were excluded. Takenaka et al18 also showed that the longitudinal plane was superior to the transverse plane in detecting PDA (100% vs 62.5% detection rate). In our study, the sensitivity of monoplane (transverse plane only) TEE in detecting PDA was 95%, comparable to the sensitivity of biplane TTE (100%). Besides, PDA was detected by both transverse and longitudinal planes in all patients studied by biplane TEE. In our experience, careful manipulation of the probe was essential while performing the examination. To our knowledge, our report is the first to demonstrate that transverse plane TEE is adequate for the diagnosis of PDA. In face of the high-velocity shunt flow in PDA, the pulsed-wave Doppler showed a continuous flow with alias despite maximal pulse repetition frequency. With continuous-wave Doppler, there may be better delineation of the flow pattern and hemodynamic assessment in patients with PDA.

In an adult patient, a low index of clinical suspicion coupled with an often atypical murmur can make the diagnosis of PDA difficult. Fisher et al5 reported that only 60% of the adults presented with a continuous murmur and one third of adult patients with PDA were asymptomatic. In this study, 50% of patients had a typical continuous murmur and 15 of the 40 patients were asymptomatic.

In summary, TEE was highly sensitive and specific in the diagnosis of PDA in adolescents and adults. The accuracy of TEE in the detection of PDA in these patients was higher than that of TTE. In every adult patient with clinically suspected PDA, TTE should be performed as the initial examination. If the findings are not confirmative, TEE should be performed. If the diagnosis of PDA can be confirmed by either TTE or TEE, cardiac catheterization may be avoided if the patient is young and pulsed Doppler study reveals a left to right shunt through the duct. Actually, cardiac catheterization did not add much useful preoperative information in young adult patients with PDA, and preoperative cardiac catheterization is not necessary in these patients. In adult patients with unexplained pulmonary hypertension or Eisenmenger’s syndrome in congenital heart disease, TEE is highly valuable for detecting the cause of pulmonary hypertension.

REFERENCES

20 Neufeld HN, Lester RG, Adams PJ, et al. Congenital communication of a coronary artery with a cardiac chamber or the pulmonary trunk (‘coronary artery fistula’). Circulation 1961; 23:171-79