METHODS

Assessment of Transesophageal Doppler Echography in Dissecting Aortic Aneurysm

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To assess the clinical value of transesophageal Doppler echography in the diagnosis of dissecting aortic aneurysm, both transesophageal and conventional echograms were performed in 22 cases of dissecting aortic aneurysm. Of the 22 patients, 17 underwent angiography; 8, X-ray computed tomography; 4, both; and 12, surgery. The performance of each method was assessed in the following four segments: A, ascending aorta; B, aortic arch; C, thoracic descending aorta; and D, upper abdominal aorta. The results by angiography were presumed to be correct.

In the group of 17 patients who underwent angiography, the rate of correct detection of an intimal flap using the transesophageal approach was 100% in all four segments, significantly better than detection by the conventional approach (segment A, 65%; segment B, 47%; segment C, 35%; segment D, 53%) (p < 0.01), and the rate of correct detection of the entry sites using the transesophageal approach was 100%, significantly better than that by conventional approach (42%) (p < 0.05). X-ray computed tomography was not capable of detecting the site of entry in all cases.

The presence of thrombus, aortic regurgitation and pericardial hemorrhage were all revealed clearly by the transesophageal approach, and the results were partly proved by other methods.

In conclusion, transesophageal Doppler echography provides a rapid and accurate method of diagnosing and evaluating dissecting aortic aneurysm and permits prompt initiation of appropriate treatment.

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The mortality rate of untreated patients suffering from dissecting aortic aneurysm is remarkably high (1,2); it has been reported (3) to be 60% within 24 h of an acute attack, 80% within 2 weeks and 90% within 3 months. To initiate appropriate treatment as soon as possible, early, accurate diagnosis is essential. The potential consequences of this condition—aortic rupture, pericardial tamponade, coronary dissection and acute aortic regurgitation—often can be prevented by surgical treatment, such as replacement of the aortic area surrounding the primary intimal tear with a tubular artificial graft (4-6). Successful treatment (surgical or otherwise) requires knowledge of several conditions, such as the location of communications between the two channels, the extent of the dissection, the differentiation of the two channels and the extent of aortic regurgitation and pericardial hemorrhage (detected as pericardial effusion) (7,8).

Until recently, dissecting aortic aneurysm was mainly diagnosed with use of angiography (8-10), echocardiography (11-14), X-ray computed tomography (15,16) and nuclear magnetic resonance imaging (17,18). Of these methods, only echocardiography can provide two-dimensional real time imaging and can be performed at the bedside noninvasively. When combined with the Doppler color flow mapping technique, it provides information on blood flow through the dissected vessel (12,19,20). However, in many cases clear images of most parts of the aorta, especially from the arch to the descending aorta, cannot be obtained because of interference from thoracic tissues.

To circumvent this shortcoming, the technique of transesophageal two-dimensional echography was developed (21-26). Through modern technology it has become possible to produce Doppler color flow imaging from the transesoph-
Table 1. Findings in 22 Cases of Dissecting Aortic Aneurysm

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<tr>
<th>Case No.</th>
<th>Age (yr)</th>
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Acute = examination and/or operation were performed within 72 h of the onset of the symptoms; Angio = angiography; AR = aortic regurgitation; Chronic = examination and/or operation were performed >1 month after the onset of symptoms; COE = conventional Doppler echography; F = female; M = male; OPE = surgical operation; PE = pericardial effusion; segment A = ascending aorta; segment B = aortic arch; segment C = thoracic descending aorta; segment D = upper abdominal aorta; TEE = transesophageal Doppler echography; Type = De Bakey classification; XCT = X-ray computed tomography; + = examination or operation was performed with positive findings; - = examination or operation was performed with negative findings; * = examination or operation was not performed.
Figure 1. Schema of the examination of the aorta by transesophageal probes. **Left panel.** The tip of the probe can be angulated upward and downward by using the knob installed at the proximal end of the probe. **Middle panel.** The longitudinal probe has the scanning plane parallel to its axis to provide longitudinal views of the aorta (Ao). **Right panel.** The lateral probe has the scanning plane perpendicular to its axis to provide horizontal views of the aorta. Eso = esophagus; FL = false lumen; LA = left atrium; LV = left ventricle; RV = right ventricle; TL = true lumen.

Methods

**Study patients** (Table 1). The study group included 22 patients suffering from dissecting aortic aneurysm (DeBakey type 1, 15 cases; type 3, 7 cases). Their ages ranged from 29 to 80 years (mean, 63). They were referred to our hospitals for further examination or intensive treatment that included surgery, or both.

Transesophageal Doppler echography and conventional two-dimensional and Doppler echocardiography were used to examine all patients. Sixteen patients were examined in the acute phase (within 24 h of the onset of symptoms), and six patients in the chronic phase (1 month after the onset of symptoms). No patient underwent examination in the subacute phase (between 24 h and 1 month of symptom onset). The data obtained by these two methods were compared with those by other methods (angiography in 17 cases and X-ray computed tomography in 8 cases) and with surgical findings in 12 cases. To assess the capability of transesophageal Doppler echography subjectively, the patients and type of examination used were selected randomly, as the patient’s condition permitted.

**Echography.** Two-dimensional echographic and Doppler color flow mapping images were obtained with use of commercially available, real time, two-dimensional, color-coded Doppler flow imaging systems (Aloka SSD 880). These systems provided information about the flow dynamics in a color-coded format. The flow dynamics were superimposed as two-dimensional images with respect to flow direction (toward the transducer or away), flow velocity and flow dispersion. The flow toward the transducer was conventionally coded in red and the flow away from it in blue. Variations in flow velocity were represented by the brightness and intensity of color. In addition to the underlying red or blue color, turbulent flow was expressed in green. This resulted in changes in the basic color tonality, thus forming a mosaic pattern (27-29).

**Transducer.** Transesophageal Doppler echographic examinations were performed with a wide angle, phased array transducer using a frequency of 2.5 or 3.5 MHz. The transesophageal studies were performed with use of two sector scanning probes (UST-5220-5 and UST-5222-5). The former was a lateral scanning probe with a scanning plane perpendicular to its axis (Fig. 1) and the latter was a longitudinal scanning probe with a scanning plane parallel to the axis of the probe. A knob at the proximal end of the probe enabled upward and downward maneuvering of the distal end of the probe where the transducer was installed (Fig. 1). The Doppler units operated at a frequency of 5.0 MHz in the pulsed Doppler mode.

Echographic data were recorded on a 0.5 in. (1.27 cm) VHS type videotape recorder. Photographs were taken either with a Polaroid camera, which was used to take pictures from a small color TV monitor during the examination, or with a 35 mm camera, which was used to take pictures directly from the main screen, during playback of the examination.

**Data analysis and definitions.** The entire aorta was divided into four segments as follows: A, ascending aorta; B, aortic arch; C, thoracic descending aorta; and D, upper abdominal aorta. In assessing each segment, the following questions were asked: 1) can the intimal flap be identified? 2) can the site of entry be detected, if it exists? and 3) can the presence of aortic regurgitation, pericardial effusion or thrombus be identified?
Procedures

Conventional Doppler echography. To study the entire aorta by conventional Doppler echography, the patients were examined systematically by combining the five viewing approaches: 1) the left parasternal long and short axes of the ascending and descending thoracic aorta; 2) the second or third right intercostal long and short axes of the ascending aorta; 3) the suprasternal notch of the aortic arch; 4) the subcostal long and short axes of the distal descending thoracic and abdominal aorta; and 5) the paravertebral long and short axes of the descending thoracic and abdominal aorta.

Transesophageal Doppler echography. Patients fasted for about 4 h before the transesophageal examination and then...
Table 2. Segmental Line Score of Each Imaging Method in Relation to Detection of the Intimal Flap

<table>
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<th>Segment</th>
<th>TEE</th>
<th>COE</th>
<th>XCT</th>
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<tr>
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<td>Correct</td>
<td>False</td>
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<tr>
<td>A</td>
<td>17 (100%)</td>
<td>6 (35%)</td>
<td>7 (100%)</td>
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<tr>
<td>B</td>
<td>17 (100%)</td>
<td>8 (47%)</td>
<td>7 (100%)</td>
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<tr>
<td>C</td>
<td>17 (100%)</td>
<td>6 (35%)</td>
<td>7 (100%)</td>
</tr>
<tr>
<td>D</td>
<td>17 (100%)</td>
<td>9 (53%)</td>
<td>7 (100%)</td>
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*Scores are based on the assumption that the angiographic findings are correct. The figures in parentheses indicate rates of correct detection. For every segment, transesophageal echocardiography (TEE) and X-ray computed tomography (XCT) findings were accurate; results of conventional echography (COE) were weak especially for segment C, in which the rate of correct detection was only 35%. NS = not significant.

Transesophageal Doppler echography provided clear, reliable images of the thoracic and upper abdominal aorta in all cases (Fig. 2), although conventional echography was sometimes disturbed by “poor echo.” However, when the transducer entered the gastric cavity, it became difficult to obtain clear images because the transducer could not make proper contact with the gastric wall. The trachea and bronchi, coursing between the aorta and esophagus, interfered with imaging of the upper margin of the aortic arch, where major aortic branches originate, making it difficult to observe the orifice of each branch. In most cases, this dead angle disappeared when the transducer was inserted slightly deeper and when the angle of the sector scan plane was changed. There was no case in which the intimal flap, confirmed by angiography, was missed by transesophageal Doppler echography.

Diagnosis of dissecting aortic aneurysm by Doppler echography was made by the presence of aortic dilation, an intimal flap that separated the true and false lumens, inward flow into the false lumen through the entry site, and outward flow from the false lumen through the reentry site, if existent.

Detection of the intimal flap. Table 1 shows the accuracy of detection of the intimal flap in all 22 cases. With use of transesophageal Doppler echography, the intimal flap was detected in segment A in 15 cases, in segment B in 15, in segment C in 22 and in segment D in 22 cases. However, with use of conventional echography, the intimal flap was detected in segment A in 7 cases, in segment B in 5, in segment C in 6 and in segment D in 11 cases. There was no segment exhibiting an intimal flap in addition to those found by transesophageal Doppler echography. With respect to the detection of the intimal flap in any segment, transesophageal Doppler echography provided results identical to those of angiography (Table 1) and X-ray computed tomography.

The line score for each method at each segment showed significantly superior performance with transesophageal Doppler echography and X-ray computed tomography over that of conventional echography (p < 0.05) (Table 2). This is based on the presumption that the results of angiography were correct in the detection of an intimal flap.

Detection of the site of entry. With transesophageal and conventional Doppler echography, a site of entry was identified as a defect of the intimal flap (Fig. 3) or as a jet flow signal passing through the entry synchronous with the cardiac cycle (Fig. 4). With angiography, an entry site was detected as a flow of contrast medium passing into the false lumen (Fig. 5). X-ray computed tomography failed to detect the site of entry in all eight cases studied.

With transesophageal Doppler echography, sites of entry were detected in 14 (5 in segment A, 2 in segment B, 7 in segment C) of the 16 cases studied in the acute phase (within
Figure 3. Case 2. Upper panel. Systolic and diastolic images of the ascending aorta obtained by transesophageal Doppler echography (longitudinal scanning probe). Lower panel. Schematic drawing of the upper left panel. Small arrows indicate the intimal flap (I.F.). The entry was identified as the defect of the intimal flap appearing in systole (large arrow). In diastole, the true lumen was compressed by the false lumen.

24 h of the onset of symptoms). Entry sites were also detected in 3 (1 in segment B, 2 in segment C) of the 6 cases studied in the chronic phase (more than 1 month after the onset of symptoms) (Table 1). On the other hand, with conventional echography, sites of entry were detected in 4 (2 in segment A, 1 in segment B, 1 in segment C) of the 16 cases studied in the acute phase, and in 1 (segment C) of the 6 cases studied in the chronic phase. The findings of conventional echography were not different from or supplementary to those of transesophageal Doppler echography. Angiography detected the site of entry in 12 (10 acute, 2 chronic) of the 17 cases studied, a finding that was correlated directly with that by transesophageal Doppler echography. In 1 of the 5 cases in which angiography missed a site of entry, transesophageal Doppler echography detected it (Table 1).

The line score of each method on the detection of entry disclosed a significant superiority of transesophageal Doppler echography over conventional echography and X-ray computed tomography. These results are based on the assumption that the angiographic findings were correct (Table 3).

Detection of thrombus. Thrombus in the false lumen adhering to the intimal flap was detected by transesophageal Doppler echography in 7 of the 22 cases (2 acute, 5 chronic) (Fig. 6), although it was not detected by conventional echography in any case. This lesion was detected by X-ray computed tomography in 3 of 7 cases, by operation in 2 of 12 cases and by both in 1 case.

Other complications. Aortic regurgitation and cardiac tamponade were detected respectively in 7 and 8 of all 22 cases by both transesophageal Doppler and conventional echography (Table 1). Angiography was performed in all seven "aortic regurgitation positive" cases and proved the presence of the lesion in all cases. Angiography was not able to detect pericardial hemorrhage. X-ray computed tomography was performed in two cases of "pericardial hemorrhage positive cases" and confirmed the presence of hemorrhage, but tomography failed in two cases to detect aortic regurgitation that had been detected by echography.

Discussion

Early, accurate diagnosis and appropriate selection of treatment for each patient with dissecting aortic aneurysm are essential for improving the survival rate of these patients in the acute phase of dissection, however, the data required for a proper diagnosis often have not been obtainable.

Role of angiography. Although angiography is generally accepted as the reference standard in diagnosing dissecting aortic aneurysm, it is time consuming and involves the risks...
Figure 4. Case 2. The Doppler color image of Figure 3 in systole (upper panel) and its schema (lower panel). Flow through the site of entry (large arrow) is indicated as red color signals flowing through the entry site from the true lumen and directed to the false lumen.

Advantages of transesophageal echography. In this study, two patients underwent operation without prior angiography because of the rapid development of cardiac tamponade. However, transesophageal Doppler echography was per-
formed with only a minor anesthetic procedure that was not time consuming and, thus, not detrimental to the patient. As far as the detectability of the site of entry, the results obtained by transesophageal Doppler echography coincided completely with those obtained by angiography. However,

Table 3. Line Score of Each Method in Relation to Detection of the Site of Entry*

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<th>XCT</th>
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<tr>
<td>False</td>
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<td>6</td>
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*p < 0.01 \( \text{NS} \)

*Scores are based on the assumption that the angiographic findings are correct. Transesophageal echocardiography (TEE) was significantly superior to conventional echography (COE) and X-ray computed tomography (XCT) in the ability to detect entry sites.

Results of computed tomography. X-ray computed tomography is a noninvasive procedure and is highly sensitive in detecting intimal flap and pericardial hemorrhage (effusion). In some cases, it has been reported (15,31) to be even more sensitive than angiography in detecting intimal flap. In the present study, X-ray computed tomography provided the same results as those obtained with angiography and transesophageal Doppler echography in detecting intimal flap and pericardial hemorrhage (effusion); however, it did not recognize the site of entry and reentry. This was due partly to the shortage of information about blood flow velocity.

Comparison with conventional transthoracic echocardiography. Conventional echocardiography is a valuable noninvasive procedure in the detection of intimal flap in ascending

Figure 5. Case 2. Patched angiographic image (left) and its schema (right). Small arrows indicate the outline of the false lumen (FL). Large arrowhead indicates the site of entry. Note the flow of contrast medium passing into the false lumen. AV = aortic valve; FE = blood flow into the false lumen through the entry; FL1, FL2 and FL3 = false lumen of, respectively, the ascending aorta, aortic arch and descending aorta; TL1 and TL2 = true lumen of, respectively, the ascending and descending aorta.
Figure 6. Case 21. Six consecutive cross-sectional echographic images of the thoracic descending aorta (segment C) in a patient with dissecting aortic aneurysm, DeBakey type I. **Upper panel,** The number in the upper right corner of each image indicates the distance from the tooth line to the probe tip. Thrombus in the false lumen is observed in the cross sections 24 to 34 cm from the tooth line. The blue color signals indicate the flow through the entry site observed in the section 36 cm from the tooth line. **Lower panel,** Schema indicating the level of the cross sections in the upper panel. Abbreviations as in Figure 2.

When the entry is located in the ascending aorta, the site of entry can be identified easily by conventional echography. However, when the area from the aortic arch to the descending aorta is examined by this method, the distance between the probe and the aorta makes it difficult to obtain clear images of the aorta and intimal flap. In addition, arteriosclerotic degeneration of large vessels can sometimes produce echoes resembling flap echoes, which can result in false positive readings. Furthermore, in spite of its convenience,
the clinical performance of conventional echography is sometimes hindered by "poor echo" because of the patient's body conditions. Even under the most favorable conditions, the conventional method cannot provide clear images of the aorta in segments B and C (aortic arch and thoracic descending aorta). In fact, an intimal flap in segment C was detected by conventional echography in only 6 of 17 cases in our study.

The presence of thrombus could be revealed using transesophageal Doppler echography in one acute phase case and in six chronic phase cases. These were confirmed by X-ray computed tomography in three cases, by operation in two cases and by both in one case. The presence of thrombus could not be confirmed by angiography and conventional echography.

Conclusions. Transesophageal Doppler echography is generally superior to other methods for the examination of dissecting aortic aneurysm, which requires rapid diagnosis and assessment of its range and site of initial tear.

We express our gratitude to Daniel Mrozek and Mike Perrine for their kind linguistic advices. We also thank Masumi Kishi for her secretarial expertise.

References


