Differential Transesophageal Echocardiographic Diagnosis Between Linear Artifacts and Intraluminal Flap of Aortic Dissection or Disruption*

Philippe Vignon, MD; Kirk T. Spencer, MD; Geoffray Rambaud, MD; Pierre-Marie Preux, MD; Daniel Krauss, MD; Beth Balasia, BS; and Roberto M. Lang, MD

Background: The relatively low specificity of transesophageal echocardiography (TEE) for the diagnosis of aortic dissection (AD) or traumatic disruption of the aorta (TDA) has been attributed to linear artifacts. We sought to determine the incidence of intra-aortic linear artifacts in a cohort of patients with suspected AD or TDA, to establish the differential TEE diagnostic criteria between these artifacts and true aortic flaps, and to evaluate their impact on TEE diagnostic accuracy.

Methods and results: During an 8-year period, patients at high risk of AD (n = 261) or TDA (n = 90) who underwent a TEE study and had confirmed final diagnoses were studied. In an initial retrospective series, linear artifacts were observed within the ascending and descending aorta in 59 of 230 patients (26%) and 17 of 230 patients (7%), respectively. TEE findings associated with linear artifacts in the ascending aorta were as follows: displacement parallel to aortic walls; similar blood flow velocities on both sides; angle with the aortic wall > 85°; and thickness > 2.5 mm. Diagnostic criteria of reverberant images in the descending aorta were as follows: displacement parallel to aortic walls, overimposition of blood flow, and similar blood flow velocities on both sides of the image. In a subsequent prospective series (n = 121), systematic use of these diagnostic criteria resulted in improved TEE specificity for the identification of true intra-aortic flaps.

Conclusions: Misleading intra-aortic linear artifacts are frequently observed in patients undergoing a TEE study for suspected AD or TDA. Routine use of the herein-proposed diagnostic criteria promises to further improve TEE diagnostic accuracy in the setting of severely ill patients with potential need for prompt surgery.

Key words: aorta; diagnosis; echocardiography; imaging

Abbreviations: AD = aortic dissection; CI = confidence interval; TDA = traumatic disruption of the aorta; TEE = transesophageal echocardiography

Spontaneous acute aortic dissection (AD) and traumatic disruption of the thoracic aorta (TDA) are life-threatening conditions that require rapid and accurate diagnosis. Transesophageal echocardiography (TEE) has been proposed as a first-line imaging technique for the evaluation of patients with suspected AD and for the screening of victims sustaining blunt chest trauma who are at high risk for TDA. However, the diagnostic accuracy of TEE in both of these entities has been limited by relatively low specificity, predominantly because of the presence of intraluminal linear artifacts.

Multiple-path artifacts are the result of reverberations between strongly reflective surfaces. Multiple reflections occur when the ultrasound beam strikes an interface with large impedance mismatch between media (e.g., soft tissue or fluid–gas), particularly if the interface is oriented perpendicular to the direction of sound propagation. Reverberations between the interface and the esophageal transducer...
may occur, resulting in linear artifacts that do not correspond to anatomic structures. When located within the thoracic aorta, linear artifacts may be misinterpreted as intraluminal flaps and lead to false-positive diagnoses and needless thoracotomy. Linear artifacts within the ascending aorta are commonly encountered in patients with suspected AD. Little information is currently available on the TEE diagnostic criteria required to distinguish linear artifacts from true aortic flaps. In addition, to our knowledge, the incidence of these artifacts within the descending thoracic aorta and their potential impact on TEE diagnostic accuracy have not yet been studied. Accordingly, the aims of the present study were (1) to determine the incidence of intravascular linear artifacts within the ascending and descending thoracic aorta in a large cohort of patients undergoing a TEE study for a suspected acute aortic condition; (2) to establish the differential TEE diagnostic criteria that distinguish intra-aortic linear artifacts from true aortic flaps associated with AD or TDA; and (3) to prospectively evaluate the impact of these criteria on the TEE diagnostic accuracy of aortic flaps.

Materials and Methods

Population and Study Design

Between January 1991 and December 1998, 469 patients undergoing a TEE examination for suspected AD or TDA were recruited from two tertiary referral teaching hospitals (Duquesne University Hospital, Pittsburgh, Pennsylvania, and the University of Chicago Medical Center, Chicago, Illinois). Patients were excluded when the diagnostic confirmation of TEE findings was not obtained by an alternative imaging modality or at surgery (n = 102), or when TEE was performed to exclude a potential complication involving a previously repaired AD or disruption (n = 16). Thus, 351 patients (248 men and 103 women; mean ± SD age, 57 ± 16 years; range, 17 to 85 years; 97 patients receiving mechanical ventilation) were studied. In all these patients, confirmation of the aortic condition was obtained using an alternative imaging technique, such as (1) CT scan or MRI (n = 193), (2) aortography (n = 76) in patients sustaining severe blunt chest trauma at high risk of aortic disruption, or (3) at the time of surgery (n = 81), or (4) necropsy (n = 7).

In order to determine the incidence of intra-aortic linear artifacts and to establish the differential diagnostic criteria that would allow differentiation between multiple-path artifacts and true aortic flaps, we retrospectively studied 230 patients (172 men and 58 women; mean age, 56 ± 16 years; range, 17 to 85 years) who underwent TEE to rule out an AD or a TDA (protocol A). Subsequently, TEE diagnostic criteria that were independently predictive of the presence of underlying linear artifacts were prospectively tested in a second cohort of 121 patients (76 men and 45 women; mean age, 56 ± 17 years; range, 17 to 81 years) referred for suspicion of an acute aortic lesion (protocol B).

In all patients, TEE interpretations were compared with the results of the reference methods.

TEE

All TEE studies were performed using either a 5-MHz monoplane (n = 144) or multiplane probe (n = 207) connected to an ultrasound system (Sonos 1500, 2500, or 5500; Hewlett-Packard; Andover, Massachusetts) and recorded on videotape for off-line analysis. During the prospective study (protocol B), all procedures were performed with a multiplane TEE probe. Arterial BP, heart rate, and oximetry were monitored throughout the procedure.

The TEE study was conducted as previously described, with particular attention directed toward the examination of the ascending, horizontal, and descending segments of the thoracic aorta, using two-dimensional echocardiography in conjunction with color Doppler echocardiographic flow mapping. Image depth and sector width were set to maximize frame rate, and the velocity scale was set between 60 cm/s and 80 cm/s in order to enable detection of low intra-aortic blood flow velocities, while limiting the aliasing effect. Gain settings were carefully adjusted to avoid the presence of color clutters outside the vascular lumen. When using the multiplane probe, the 110° to 140° echocardiographic plane was routinely used to visualize the ascending aorta to its fullest extent, while the descending thoracic aorta was examined in both the transverse (0°) and longitudinal views (80° to 110°). In addition, the TEE examination was also focused on excluding the presence of an associated cardiac abnormality (e.g., pericardial effusion, aortic regurgitation).

Data Analysis

Protocol A: Two experienced observers blinded to both the clinical history and final diagnosis jointly reviewed the TEE studies. In each patient, the ascending and descending segments of the thoracic aorta were evaluated separately. The observers determined whether a persistent linear intra-aortic image was present or absent, using adequate gain settings. Accordingly, nonlinear artifacts such as mirror images or reflection or comet tail artifacts were not studied, because they usually do not resemble intra-aortic flaps. Each linear intravascular image was then described using the following qualitative and quantitative parameters.

Qualitative two-dimensional TEE parameters included the following: (1) mobility; (2) if mobile, the type of displacement (i.e., free or parallel displacement to the aortic wall); (3) sharpness of the image borders; (4) image confined to the aortic lumen or extending outside the aortic wall; (5) presence of a pericardial effusion; and (6) presence of a left pleural effusion. Additional qualitative parameters were obtained from the color Doppler echocardiographic flow mapping of the thoracic aorta and aortic valve: (7) overimposition of blood flow on the linear image, or not; (8) different or similar blood flow velocities on both sides of the intra-aortic image; (9) presence of blood flow turbulence as reflected by a mosaic of colors surrounding the linear image, or normal laminar blood flow pattern; (10) presence of an entry or reentry tear defined as the presence of blood flow through a typical communication of the linear image, or not; and (11) presence of more-than-mild aortic regurgitation.

Quantitative parameters were then measured independently by a third experienced observer who did not have access to the clinical charts and was unaware of qualitative data recordings. All measurements were performed at end-diastole (identified by the peak R wave of the ECG) in the transverse view, using electronic calipers. The following measurements were performed at the level of the ascending aorta: (1) diameter of the aorta obtained immediately above the sinuses of Valsalva; (2) diameter of the anatomic structure located posteriorly, ie, the left atrium or the right pulmonary artery according to the level of the tomographic plane (Fig 1, left, A); and (3) in the presence of an intra-aortic...
linear image, the distance between the transducer (or the posterior wall of the left atrium or right pulmonary artery) and the posterior wall of the ascending aorta, and the distance separating the latter from the leading edge of this linear image in the same tomographic plane, along an axis perpendicular to the ascending aorta (Fig 1, center, B). The ratio between the diameter of the ascending aorta and the adjacent posterior anatomic structure was calculated. The following measurements were performed at the level of the descending thoracic aorta: (1) diameter of the aorta at the level of the aortic isthmus, (2) and distance between the esophageal scope and the anteromedial descending aortic wall. Finally, when an intra-aortic linear image was observed, the maximal thickness of this image as well as the descending aortic wall. Finally, when an intra-aortic linear image was observed, the maximal thickness of this image as well as the angle between the image and the vertical axis tangential to the aortic wall (right, C). RV = right ventricle; LV = left ventricle; SVC = superior vena cava; PA = right pulmonary artery; Ao = descending thoracic aorta.

Figure 1. Transesophageal transverse view of the ascending (left, A; center, B) and the descending thoracic aorta (right, C). In all patients, the diameter of both the left atrium (LA) and the ascending aorta (AA) was measured (left, A). In the presence of an intra-aortic linear image, the following measurements were also performed: the distance separating the transducer or the posterior wall of the anatomic structure located posteriorly from the ascending aorta (ie, the left atrium or the right pulmonary artery); the distance between the posterior aortic wall to the leading edge of the linear image (center, B, arrow); the angle between the linear image and the vertical axis tangential to the aortic wall (right, C).

After this analysis was completed, the results of the reference imaging technique were disclosed to the investigators. In each patient, the ascending and descending thoracic aortic segments were classified into one of the following categories: (1) aortic flap, defined as the presence of a linear image noted during the TEE study represented a true intimal flap of AD or a medial flap of TDA; (2) linear artifact, the presence of a linear intra-aortic image not confirmed by the reference technique in the corresponding aortic segment; or (3) absence of linear image, when both the TEE examination and reference diagnosis modalities were negative for the presence of an abnormal linear intra-aortic image. In the latter case, the thoracic aorta might have appeared normal or not, but aortic lesions were not associated with an intraluminal flap (eg, intramural hematoma, traumatic intimal tear, aortic aneurysm, atherosclerosis). The diagnostic accuracy of TEE (ie, sensitivity, specificity, positive and negative predicting values) for the identification of aortic flaps was then determined and compared to that obtained in protocol A.

Statistical Methods

Protocol A: In order to determine the independent TEE parameters predictive of the presence of a linear artifact in patients exhibiting an intra-aortic linear image, a logistic regression model was developed for both the ascending and descending thoracic aorta. Initially, continuous variables were compared between patients with linear artifacts and patients with true flaps, using the nonparametric Mann-Whitney test. Qualitative variables were compared using the chi-squared test or the Fisher’s Exact Test, when appropriate. Parameters with a probability value < 0.25 in the univariate analysis were then included in the regression model. Odd ratios and 95% confidence intervals (CIs) were calculated for each parameter.

To confirm the origin of multiple-paths linear artifacts, the diameters of both the ascending aorta and the anatomic structure located posteriorly (ie, the left atrium or the right pulmonary artery), as well as the ratio between these two measurements were compared between patients with linear artifacts and patients with normal ascending aortas, using the Student’s t test. Results were expressed as mean ± SD, and p < 0.05 was considered statistically significant. All tests of significance were two tailed.

Finally, the sensitivity and specificity, as well as the positive and negative predictive values, were determined by comparing the initial interpretation of TEE studies with the corresponding results of the reference imaging techniques, or with anatomic findings. Ranges were obtained by considering initially inconclusive TEE studies as either positive or negative results.

Protocol B: The frequency of intra-aortic linear artifacts and true flaps in the ascending and descending segments of the
Thoracic aorta was compared between protocols A and B, using the Z test. The diagnostic accuracy of TEE for the identification of aortic flaps was determined using the diagnostic criteria established in protocol A. Diagnostic accuracy was obtained using either a single or a combination of TEE criteria. The combination providing the highest diagnostic accuracy was then established.

RESULTS

Protocol A

Among the 230 patients studied, 188 patients (82%) underwent TEE to rule out a spontaneous AD, while the remaining 42 patients (18%) were examined for a suspected TDA after sustaining severe blunt chest trauma. The TEE findings are summarized in Figure 2.

Frequency of Aortic Flaps and Linear Artifacts: In the 81 patients with proven AD (Stanford type A, n = 36; Stanford type B, n = 45), an intimal flap was visualized within the ascending (Fig 3, top left, A) and the descending thoracic aorta (Fig 3, top right, B) in 36 patients and 72 patients, respectively (Fig 2). Traumatic disruption of the aortic isthmus was diagnosed by the presence of a medial flap within the proximal descending aorta in 11 victims of violent deceleration accidents (Fig 2, 3, bottom left, C).

Linear artifacts were observed in the ascending and descending segments of the thoracic aorta in 59 of 230 patients (26%) and 17 of 230 patients (7%), respectively. Of patients with reverberant images within the ascending aorta, 42 of 59 patients (71%) had a normal thoracic aorta. In contrast, no evidence of associated AD or TDA was found in patients with linear artifacts located in the descending thoracic aorta. Of these, four patients (2%) with an otherwise normal thoracic aorta exhibited a linear artifact in both the ascending and descending thoracic aorta. In 13 of 45 patients (29%) with confirmed Stanford type-B aortic dissection and 4 of 11 patients (36%) with proven traumatic disruption of the aortic isthmus, a linear artifact was also evidenced in the ascending aorta (Fig 3, bottom right, D).

Diagnostic Criteria Associated With Linear Artifacts: TEE parameters predictive of the presence of a linear artifact within the ascending aorta using univariate analysis are presented in Table 1. Linear artifacts were thicker than aortic flaps (3.9 ± 1.6 mm vs 2.6 ± 1.2 mm; p < 0.001) and consistently appeared nearly horizontal in the aortic lumen in the transversal view (Fig 4, top left, A, and top right, B), as reflected by a larger angle between the linear image and the ascending aortic wall (91 ± 10° vs
72 ± 39°; p < 0.001). None of the patients in whom a linear artifact was noticed within the ascending aorta had an associated pericardial effusion or evidence for an entry tear. In the presence of an intimal flap in the ascending aorta (Fig 4, bottom left, C), the flap had different orientations within the aortic lumen and overimposition of blood flow was never observed using color Doppler echocardiographic

Table 1—Univariate Analysis of TEE Parameters Used To Distinguish Between Intraluminal Linear Artifacts and Flaps of Ascending Aorta*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Artifact (n = 59)</th>
<th>Flap (n = 36)</th>
<th>Odds Ratio</th>
<th>95% CI</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immobility</td>
<td>14 (24)</td>
<td>4 (11)</td>
<td>2.5</td>
<td>0.7–8.3</td>
<td>0.14</td>
</tr>
<tr>
<td>Displacement parallel to aortic walls</td>
<td>55 (93)</td>
<td>8 (22)</td>
<td>47.6</td>
<td>13.3–166.7</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Poorly defined borders</td>
<td>35 (59)</td>
<td>6 (17)</td>
<td>7.3</td>
<td>2.6–20.0</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Image not confined to aortic lumen</td>
<td>35 (59)</td>
<td>6 (17)</td>
<td>7.3</td>
<td>2.6–20.0</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Similar blood flow velocities on both sides</td>
<td>58 (98)</td>
<td>10 (28)</td>
<td>142.8</td>
<td>18.2–1000.0</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Absence of blood flow turbulence</td>
<td>52 (88)</td>
<td>11 (31)</td>
<td>16.9</td>
<td>5.5–47.6</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Absence of significant aortic regurgitation</td>
<td>54 (82)</td>
<td>19 (53)</td>
<td>9.7</td>
<td>3.1–29.4</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Thickness &gt; 2.5 mm</td>
<td>44 (75)</td>
<td>12 (33)</td>
<td>7.0</td>
<td>2.7–18.1</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Angle &gt; 85°</td>
<td>36 (61)</td>
<td>9 (25)</td>
<td>5.2</td>
<td>2.0–13.2</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

*Data are presented as No. (%) unless otherwise indicated.
mapping (Fig 4, bottom right, D). Using the logistic regression model, the following criteria were selected as independent predictors of the presence of linear artifact in the ascending aorta: (1) displacement of the linear image parallel to aortic walls (odds ratio, 7.2; CI, 1.3 to 40.0; p = 0.02); (2) similar blood flow velocities on both sides of the linear image (odds ratio, 47.6; CI, 3.4 to 500.0; p = 0.004); (3) thickness of the linear image > 2.5 mm (odds ratio, 4.8; CI, 0.9 to 26.2; p = 0.06); and (4) an angle between the linear image and the aortic wall > 85° (odds ratio, 5.9; CI, 1.1 to 32.2; p = 0.04).

The TEE criteria found to be predictive of the presence of linear artifacts within the descending thoracic aorta are shown in Table 2. Both the thickness of linear artifacts and the angle between the aortic wall and the linear image tended to be larger than those noticed in true aortic flaps (3.3 ± 1.5 mm vs 2.6 ± 1.1 mm, p = 0.08; and 90 ± 14° vs 72 ± 40°, p = 0.1, respectively; Fig 5, top left, A, and bottom left, C). None of the patients with linear artifacts in the descending thoracic aorta had evidence for entry tears. Logistic regression analysis identified the following criteria as predictors of the presence of a linear artifact in the descending thoracic aorta: (1) displacement of the linear image parallel to the aortic walls (odds ratio, 15.9; CI, 1.8 to 142.8; p = 0.01); (2) overimposition of blood flow on the linear image (odds ratio, 6.9; CI, 1.3 to 38.3; p = 0.03); and (3) similar blood flow velocities on both sides of the linear image (odds ratio, 7.6; CI, 1.3 to 43.5; p = 0.02; Fig 5, top right, B, and bottom right, D).

**Origin of Linear Artifacts**: The diameter of the ascending aorta was larger in patients with linear artifacts (n = 59) when compared to patients without (n = 135) intraluminar artifacts (39.9 ± 12.0 mm
vs 33.9 ± 6.2 mm; p < 0.001). In contrast, the mean diameter of the posterior structure (ie, the left atrium or the right pulmonary artery) was larger in patients without linear artifacts (34.3 ± 6.9 mm vs 28.8 ± 6.1 mm; p < 0.001). Consequently, the ratio between the diameter of the ascending aorta and

<table>
<thead>
<tr>
<th>Variables</th>
<th>Artifact (n = 17)</th>
<th>Flap (n = 81)</th>
<th>Odds Ratio</th>
<th>95% CI</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immobility</td>
<td>10 (59)</td>
<td>15 (19)</td>
<td>6.2</td>
<td>2.9–18.9</td>
<td>0.001</td>
</tr>
<tr>
<td>Displacement parallel to aortic walls</td>
<td>16 (94)</td>
<td>24 (30)</td>
<td>37.0</td>
<td>4.7–333.3</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Poorly defined borders</td>
<td>9 (53)</td>
<td>12 (15)</td>
<td>6.4</td>
<td>2.1–19.6</td>
<td>0.001</td>
</tr>
<tr>
<td>Image not confined to aortic lumen</td>
<td>9 (53)</td>
<td>6 (7)</td>
<td>13.9</td>
<td>3.9–50.0</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Overimposition of blood flow</td>
<td>9 (53)</td>
<td>3 (4)</td>
<td>28.9</td>
<td>6.5–128.9</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Similar blood flow velocities on both sides</td>
<td>15 (88)</td>
<td>21 (26)</td>
<td>21.3</td>
<td>4.4–100.0</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Absence of blood flow turbulence</td>
<td>16 (94)</td>
<td>49 (60)</td>
<td>10.1</td>
<td>1.3–83.3</td>
<td>0.03</td>
</tr>
<tr>
<td>Absence of left pleural effusion</td>
<td>15 (88)</td>
<td>64 (79)</td>
<td>1.9</td>
<td>0.4–9.0</td>
<td>0.43</td>
</tr>
<tr>
<td>Thickness &gt; 2.5 mm</td>
<td>10 (59)</td>
<td>30 (37)</td>
<td>3.0</td>
<td>0.9–9.7</td>
<td>0.06</td>
</tr>
<tr>
<td>Angle &gt; 85°</td>
<td>7 (41)</td>
<td>30 (37)</td>
<td>1.2</td>
<td>0.4–3.6</td>
<td>0.72</td>
</tr>
</tbody>
</table>

*Data are presented as No. (%) unless otherwise indicated.

![Figure 5](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21963/)

**Figure 5.** Two-dimensional TEE (top left, A; bottom left, C) and color Doppler echocardiographic imaging (top right, B; bottom right, D) of the descending aorta in a patient with an intraluminal linear artifact (top left, A; top right, B), and in a patient sustaining a type-B AD (bottom left, C; bottom right, D), for comparison. The linear artifact (top left, A, arrow) is thicker than the intimal flap associated with the AD (bottom left, C, arrow). near horizontal, and showed displacement parallel the aortic walls in real time. Using color Doppler echocardiographic mapping, blood flow velocities appear similar on both sides of the artifact, laminar, and overimposed on the linear image (top right, B). Conversely, blood flow is not overimposed on the intimal of the distal AD, and velocities are higher in the true lumen than in the false lumen (bottom right, D).
adjacent posterior structure was higher in the presence of linear artifacts (1.4 ± 0.6 vs 1.0 ± 0.2; p < 0.001). In patients with intra-aortic linear artifacts, the mean distance between the transducer and the posterior wall of the right pulmonary artery or the left atrium, and the posterior wall of the ascending aorta was similar to that separating the latter from the leading edge of the intraluminal artifact (28.8 ± 6.1 mm vs 28.6 ± 5.7 mm; p = 0.9, matched t test; Fig 6, top left, A).

The mean diameter of the descending thoracic aorta was similar between patients with linear artifacts (n = 17) and those without intraluminal artifacts (n = 132; 25.2 ± 4.8 mm vs 27.6 ± 8.3 mm; p = 0.8). Conversely, the distance separating the esophageal scope from the anteromedial aortic wall was greater in the presence of a linear artifact within the descending thoracic aorta (6.9 ± 2.7 mm vs 5.2 ± 5.2 mm; p < 0.001; Fig 6, right, B).

**TEE Diagnostic Accuracy:** The diagnostic accuracy of TEE for the identification of true intra-aortic flap is detailed in Table 3. Three false-negative TEE diagnoses were attributed to the presence of limited dissections involving the descending thoracic aorta or the aortic arch, and one false-negative TEE diagnosis was attributed to the presence of a small traumatic medial tear confined to the aortic isthmus. Two patients underwent unnecessary thoracotomy based on the presence of a linear intraluminal image erroneously diagnosed as an intra-aortic flap. The first patient sustaining a type-B AD also had a dilated ascending aorta (65 mm), but without evidence of proximal dissection (Fig 6, left, A). The second patient was suspected of sustaining a traumatic disruption of the aortic isthmus (Fig 6, right, B), but visual inspection during surgery revealed only the presence of a hemomediastinum with a normal proximal descending thoracic aorta.

**Protocol B**

Among the 121 patients studied, 73 patients (60%) underwent the TEE study to rule out a spontaneous AD, while the remaining 48 victims of violent deceleration accidents (40%) were examined for suspected TDA.

Of 33 patients with proven AD, 14 patients (42%) sustained a Stanford type-A AD while the remaining 19 patients (58%) had a type-B AD. Traumatic disruption of the aortic isthmus was confirmed in eight patients sustaining severe blunt chest trauma. Linear artifacts were observed in the ascending and descending segments of the thoracic aorta in 22 of 121 patients (18%) and 7 of 121 patients (6%), respectively. No acute associated aortic condition was found in 12 of 22 patients (54%) with a linear artifact in the ascending aorta, and in all patients with a reverberant image within the descending thoracic aorta. Of them, a single patient exhibited a linear artifact in both segments of the thoracic aorta. In 8 of 19 patients (42%) with proven Stanford type-B AD and in 2 of 8 patients (25%) with confirmed traumatic laceration of the aortic isthmus, a linear artifact in the ascending aorta was also observed. The frequency of linear artifacts and true flaps associated with either AD or TDA was similar between protocols (data not shown).

In two patients with true flap, all TEE diagnostic accuracy was confirmed.

![Figure 6](http://journal.publications.chestnet.org/pdfaccess.ashx?url=data/journals/chest/21963/ on 06/21/2017)
criteria individually predictive of linear artifacts were observed. One patient sustained a type-A acute AD, without evidence for an entry tear. In this case, the diagnosis was based on the presence of an associated significant aortic regurgitation and pericardial effusion, and on TEE findings consistent with a dissection of the descending thoracic aorta with a thrombosed false lumen. The other patient had a traumatic disruption of the aortic isthmus. TEE clearly disclosed the presence of a false aneurysm formation with a medial flap. The systematic use of the above-described TEE diagnostic criteria resulted in the absence of false-positive results. The combination of three of the four TEE criteria that were independent predictors of the presence of a linear artifact in the ascending aorta yielded the highest diagnostic specificity (Table 3). Similarly, the presence of a single TEE criterion identified using the logistic regression model provided the highest diagnostic accuracy (Table 3). When compared to protocol A, TEE specificity for the identification of true flaps in both segments of the thoracic aorta improved, and no patient underwent unnecessary surgery.

**Table 3**—Influence of Systematic Use of TEE Diagnostic Criteria To Distinguish Linear Artifacts From True Intra-aortic Flaps (Protocol B) on Its Diagnostic Accuracy for the Diagnosis of Spontaneous AD and TDA

<table>
<thead>
<tr>
<th>Variables</th>
<th>Sensitivity, %</th>
<th>Specificity, %</th>
<th>Positive Predictive Value, %</th>
<th>Negative Predictive Value, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protocol A (n = 230)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ascending aorta (range)</td>
<td>97.2–97.2</td>
<td>92.9–99.5</td>
<td>71.4–97.2</td>
<td>99.4–99.5</td>
</tr>
<tr>
<td>Descending thoracic aorta (range)</td>
<td>93.8–97.5</td>
<td>93.3–99.3</td>
<td>98.8–98.7</td>
<td>96.7–99.6</td>
</tr>
<tr>
<td>Protocol B (n = 121)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ascending aorta</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At least one criterion†</td>
<td>92.9</td>
<td>68.2</td>
<td>65.0</td>
<td>93.8</td>
</tr>
<tr>
<td>At least two criteria</td>
<td>92.9</td>
<td>95.5</td>
<td>92.9</td>
<td>95.5</td>
</tr>
<tr>
<td>At least three criteria</td>
<td>92.9</td>
<td>100.0</td>
<td>100.0</td>
<td>95.7</td>
</tr>
<tr>
<td>All four criteria</td>
<td>42.9</td>
<td>100.0</td>
<td>100.0</td>
<td>73.3</td>
</tr>
<tr>
<td>Descending thoracic aorta</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At least one criterion‡</td>
<td>97.1</td>
<td>100.0</td>
<td>100.0</td>
<td>87.5</td>
</tr>
<tr>
<td>At least two criteria</td>
<td>82.4</td>
<td>100.0</td>
<td>100.0</td>
<td>53.8</td>
</tr>
<tr>
<td>All three criteria</td>
<td>64.7</td>
<td>100.0</td>
<td>100.0</td>
<td>36.8</td>
</tr>
</tbody>
</table>

*Ranges obtained by considering doubtful TEE studies as either positive or negative results.
†Any of the following: (1) displacement of the linear image parallel to aortic walls, (2) similar blood flow velocities on both sides of the linear image, (3) thickness of the linear image > 2.5 mm, and (4) angle between the linear image and the aortic wall > 85°.
‡Any of the following: (1) displacement of the linear image parallel to the aortic walls, (2) overimposition of blood flow on the linear image, and (3) similar blood flow velocities on both sides of the linear image.

**Discussion**

In this study, we describe comprehensive TEE criteria that allow accurate differentiation between intra-aortic linear artifacts and true aortic flaps, resulting in improved diagnostic specificity. This may have a relevant clinical impact when considering the high prevalence of multiple-path artifacts noted in our cohort of patients undergoing a TEE to rule out an acute aortic condition. Because these artifacts are mostly observed in the ascending aorta, the routine use of these criteria could potentially avoid additional diagnostic workup and unnecessary surgery. Finally, the origin of these multiple-path artifacts recently demonstrated in vitro17 was confirmed in the present study using in vivo TEE measurements.

**Incidence of Intra-aortic Linear Artifacts**

The incidence of linear artifacts within the ascending aorta has been reported16–18 to be as high as 44 to 55% in patients undergoing a TEE study to rule out an acute aortic abnormality. In the present series, the incidence of linear artifacts was lower (81 of 351 patients; 23%). This difference is conceivably due to the larger size of our study population and to our use of strict criteria to select artifacts that needed to be differentiated from true intimal or medial flaps. As a result, easily identifiable pitfalls, such as reverberations of aortic wall calcifications or comet tail artifacts, were not recorded. As previously reported,7 linear artifacts were less commonly present in the descending thoracic aorta, being identified in only 24 of 351 of our patients (7%) studied for an AD or TDA. Interestingly, these linear artifacts were more frequently observed in victims of severe blunt chest trauma at high risk for TDA (13 of 90 patients vs 11 of 261 patients; p < 0.001). This finding is of particular relevance because linear artifacts appear to be more frequent in the vicinity of the aortic isthmus, where TDA predominantly occur.3–5
The presence of a thick linear image (> 2.5 mm) and similar blood flow velocities on both sides of the image were strong individual predictors of an underlying ultrasound reverberation artifact within the ascending aorta. Nevertheless, these TEE findings may be present in certain patients suffering from type-A AD. Indeed, when involving a substantial part of the media, aortic intimal flaps may at times appear as thick linear images, similar to multiple paths artifacts. In addition, blood flow velocities may be similar on both sides of the intimal flap, particularly when a large entry tear located in the proximal ascending aorta results in a circulating false channel. In these cases, the use of the remaining TEE diagnostic criteria associated with linear artifacts (i.e., angle > 85°, and parallel displacement to the aortic walls) remains useful, because in the current series linear artifacts were consistently found to be nearly horizontal within the ascending aorta. In contrast, aortic flaps had various orientations across the vascular lumen. As previously described, intra-aortic artifacts did not display the oscillatory movement frequently seen in intraluminal flaps, but rather exhibited a regular displacement that was parallel to aortic walls. Using M-mode echocardiography, Evangelista et al. demonstrated the clinical value of this sign to improve the diagnostic accuracy of TEE for the identification of ascending AD. Finally, the presence of oppositely directed blood flow in the two lumina delimited by the intra-aortic linear image is suggestive of an underlying AD.

In the current study, displacement of the intra-aortic linear image parallel to the aortic walls in conjunction with overimposition of blood flow with similar velocities on both sides of the suspect image were individually predictive of the presence of a linear artifact within the descending thoracic aorta. Importantly, these TEE criteria may not be as valid in patients with suspected TDA, in whom multiple paths linear artifacts were more frequently encountered. In this condition, medial flaps are usually thicker than the intimal flaps associated with AD because they commonly involve the entire depth of the medial layer of the aorta. Although the medial flap fails to delimit two distinct channels with different blood velocities, high-velocity blood flow turbulence is usually observed in the surroundings of the disrupted aortic wall. In contrast, a near-normal laminar descending aortic flow pattern is consistently noted in the presence of linear artifacts. Finally, subadventitial TDA is frequently associated with false aneurysm formation, whereas the aortic contour usually remains normal in the presence of intraluminal linear artifacts.

Impact on TEE Accuracy

Although highly sensitive for the diagnosis of AD and disrupted aortic isthmus, the major widely acknowledged drawback of TEE is its relatively poor specificity. Interestingly, this relative lack of specificity has been predominantly reported for the diagnosis of Stanford type-A AD, whereas TEE diagnostic specificity is usually higher when the dissecting process is confined to the descending thoracic aorta. The presence of linear artifacts within the ascending aorta has been hypothesized to be responsible for most of the false-positive TEE results.

With the exception of one TEE study limited by suboptimal imaging quality, all inconclusive examinations encountered in protocol A of the current series (n = 24) were retrospectively attributed to the difficult interpretation of the presence of intra-aortic linear images. Of them, 21 images (87%) were linear artifacts, while only 3 images (13%) were related to the presence of an underlying intimal flap in the descending thoracic aorta. Interestingly, 13 of 21 linear artifacts (62%) were located in the ascending aorta. In this protocol, TEE diagnostic accuracy was similar to that reported in previous studies, and the use of multiplane TEE probes in 37% of patients included in this protocol. In contrast with previous studies, we found a similar TEE diagnostic accuracy for the identification of intimal or medial flap in both the ascending and descending segments of the thoracic aorta (Table 3). Although in the latter anatomic segment of the aorta the incidence of linear artifacts was lower (7%), TEE has frequently been inconclusive when such images were encountered in patients with suspected TDA.

A false-positive diagnosis of intra-aortic flaps in the setting of patients who undergo a TEE for a suspected acute aortic condition may lead to unnecessary surgery, as shown in two of our patients from the retrospective series. Accurate identification of multiple-path artifacts is crucial in the presence of a linear image located in the ascending aorta, because surgical treatment of a dissection, or rarely a traumatic disruption, of this anatomic segment of the thoracic aorta is unequivocally advocated. In the present study, 21 of 64 patients (33%) sustaining a type-B AD also exhibited linear artifacts in the ascending aorta. As previously described, this image has been misdiagnosed as a true flap, resulting in unnecessary surgery in one patient who had a type-B AD rather than a type-A AD (Fig 6, left,
Origins of Linear Artifacts

Using in vitro experiments, Appelbe et al\textsuperscript{17} confirmed the origin of multiple-path linear artifact by imaging two water-filled latex balloons of varying size placed in series in a water tank. A linear artifact was only observed within the balloon representing the ascending aorta when its size exceeded that of the second balloon representing the left atrium. In addition, the distance between the transducer and balloon interface was equal to the distance separating this interface from the linear artifact.\textsuperscript{16} Using M-mode echocardiography, Evangelista et al\textsuperscript{16} recently described three distinct types of linear artifacts within the ascending aorta: type-A artifacts (53%), which were located twice as far from the transducer as the posterior aortic wall; type-B artifacts (40%), which were located at the same distance from the posterior aortic wall as the latter was from the right pulmonary posterior wall; and type-C artifacts (7%), which were located at the same distance from the posterior aortic wall as a reverberation from the right pulmonary artery posterior wall. All these artifacts exhibited a movement parallel to the posterior aortic wall, as in the current series. The reverberation images observed in the present study were type A (Fig 6, left, A) and type B (Fig 1, center, B; Fig 3, bottom right, D; Fig 4, top left, A) artifacts. Type-A artifacts are thought to be generated when the echo of the posterior aortic wall is partly reflected back by the transducer,\textsuperscript{16,17} while type-B artifacts correspond to ultrasound reverberations from a moving target (ie, the right pulmonary posterior wall) and a moving mirror (ie, the posterior aortic wall).\textsuperscript{16}

The origin of type-A and type-B artifacts was confirmed in vivo in the present study. In patients with intraluminal linear artifacts, the diameter of the ascending aorta consistently exceeded that of the adjacent posterior anatomic structure (diameters ratio $> 1$), and was significantly greater than that seen in patients without intra-aortic linear images. As a result, reverberation images were more commonly observed when relative aortic dilatation was present (Fig 6, left, A), a finding commonly associated with aortic dissection.\textsuperscript{3,13,18} These results are in keeping with those recently reported by Losi et al\textsuperscript{18} who showed that a diameter of the ascending aorta ($> 5$ cm) that exceeds the diameter of the left atrium (with a ratio $\leq 0.6$), was predictive of the presence of an underlying linear artifact. In addition, in our patients with intra-aortic linear artifacts, the mean distance between the transducer (type-A artifacts), or the posterior wall of the right pulmonary artery (type-B artifacts), and the posterior wall of the ascending aorta was similar to that separating the latter wall from the leading edge of the intraluminal image ($28.8 \pm 6.1$ mm vs $28.6 \pm 5.7$ mm; $p = 0.9$; Fig 1, center, B; Fig 3, bottom right, D; Fig 4, top left, A; Fig 6, left, A). Similarly, Losi et al\textsuperscript{18} reported that linear artifacts were consistently located in the aortic lumen twice as far from the transducer as the posterior aortic wall, such as type-A artifacts.\textsuperscript{16}

In patients with linear artifacts within the descending thoracic aorta, the mean diameter of this vessel was similar to that of patients without reverberation images. However, in the presence of misleading linear artifacts, the descending thoracic aorta was consistently shifted anteriorly. This explains probably the higher incidence of linear artifacts within the descending thoracic aorta in patients with severe blunt chest trauma in whom a traumatic hemomediastinum, which usually results in an increased distance between the esophageal probe and the anteromedial aortic wall,\textsuperscript{28} was frequently observed (Fig 5, top left, A; Fig 6, right, B). Because hemomediastinum is frequently associated with TDA,\textsuperscript{3} accurate diagnosis of linear artifacts within the aortic isthmus in this clinical setting is critical to avoid false-positive TEE results.

Limitations

Because multiplane TEE probe was not available in all patients in protocol A, the additional diagnostic value of various tomographic planes for accurate identification of reverberation images was not spe-
specifically studied. However, most of the proposed diagnostic criteria may also be used in other TEE planes, as shown in Figure 7. In addition, because of the inability of monoplane TEE probes to adequately image the distal ascending aorta, the aortic arch was not studied. Because linear artifacts may be confounding images only when interpreted as aortic flaps, patients sustaining acute aortic condition without associated intraluminal flaps were not studied. Therefore, the reported diagnostic capability of TEE for the diagnosis of spontaneous AD and TDA did not take into account certain clinical presentations (e.g., thrombosed false lumen, intramural hematoma, traumatic intimal tear) for which a diagnosis may be challenging.

Although the learning curve could have influenced TEE diagnostic accuracy in protocol B, the systematic application of predefined diagnostic criteria to intra-aortic linear images probably minimized this potential bias. In addition, both the retrospective and prospective series were comparable in terms of frequency of intra-aortic linear artifacts and true flaps (data not shown). The comparison of TEE diagnostic accuracy between these two cohorts of patients is therefore clinically relevant.

Other types of multiple-path artifacts, such as mirror artifacts, are frequently encountered during TEE examination of the descending thoracic aorta.17 We did not study these reverberation images because they are rarely misleading and visualized only if the field of view is expanded to accommodate a second signal.29

**CONCLUSION**

In the present study, misleading intraluminal linear artifacts within the ascending aorta were observed in one fourth of the patients undergoing a TEE examination for a suspicion of AD or TDA. These multiple-path artifacts that originate in the left atrium of the right pulmonary artery were encountered when the ascending aorta exceeded the size of the adjacent posterior anatomic structure, and were less frequent within the descending thoracic aorta. The use of differential echocardiographic diagnostic criteria that allowed reliable identification of reverberation images resulted in improved TEE specificity for the diagnosis of AD or TDA. Routine use of these diagnostic criteria promises to further improve the diagnostic accuracy of TEE for accurate identification of acute aortic conditions in the setting of severely ill patients with potential need for rapid surgery.

ACKNOWLEDGMENT: We gratefully thank Isham Hojeij, MD; the colleagues of the Department of Cardiology and Cardiovascular Surgery of the Dupuytren Hospital of Limoges; and the cardiac sonographers and nurses of the Noninvasive Cardiac Imaging Laboratories of the University of Chicago hospitals and of the Service de Réanimation Polyvalente of the teaching hospital of Limoges.

**REFERENCES**


FIGURE 7. Example of linear images (arrows) observed in the longitudinal view of the descending thoracic aorta. Color Doppler TEE discloses the overimposition of a laminar blood flow on both sides of the linear artifact (left, A), whereas it has opposite directions in the two lumina of the AD (right, B).
3 Vignon P, Gue´ret P, Vedrinne JM, et al. Role of transesopha-
4 Vignon P, Lagrange P, Boucoeur MP, et al. Routine trans-
esophageal echocardiography for the diagnosis of aortic dis-
7 Nienaber CA, Spielmann RP, Von Kodolitsch Y, et al. Diagnosis of thoracic aortic dissection: magnetic resonance imaging versus transesophageal echocardiography. Circula-
tion 1992; 85:434–447