Long-Term Outcome of Aortic Dissection With Patent False Lumen
Predictive Role of Entry Tear Size and Location

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Background—Patent false lumen in aortic dissection has been associated with poor prognosis. We aimed to assess the natural evolution of this condition and predictive factors.

Methods and Results—One hundred eighty-four consecutive patients, 108 surgically treated type A and 76 medically treated type B, were discharged after an acute aortic dissection with patent false lumen. Transesophageal echocardiography was performed before discharge, and computed tomography was performed at 3 months and yearly thereafter. Median follow-up was 6.42 years (quartile 1 to quartile 3: 3.31–10.49). Forty-nine patients died during follow-up (22 type A, 27 type B), 31 suddenly. Surgical or endovascular treatment was indicated in 10 type A and 25 type B cases. Survival free from sudden death and surgical-endovascular treatment was 0.90, 0.81, and 0.46 (95% CI, 0.36–0.55) at 3, 5, and 10 years, respectively. Multivariate analysis identified baseline maximum descending aorta diameter (hazard ratio [HR]: 1.32 [1.10–1.59]; P=0.003), proximal location (HR: 1.84 [1.06–3.19]; P=0.03), and entry tear size (HR: 1.13 [1.08–1.2]; P<0.001) as predictors of dissection-related adverse events, whereas mortality was predicted by baseline maximum descending aorta diameter (HR: 1.36 [1.08–1.70]; P=0.008), entry tear size (HR: 1.1 [1.04–1.16]; P=0.001), and Marfan syndrome (HR: 3.66 [1.65–8.13]; P=0.001).

Conclusions—Aortic dissection with persistent patent false lumen carries a high risk of complications. In addition to Marfan syndrome and aorta diameter, a large entry tear located in the proximal part of the dissection identifies a high-risk subgroup of patients who may benefit from earlier and more aggressive therapy. (Circulation. 2012;125:3133-3141.)

Key Words: aorta ▪ computed tomography ▪ prognosis ▪ transesophageal echocardiography

The long-term outcome of patients with successful initial treatment of acute aortic dissection and persistent patent false lumen in the descending aorta is not well established. Several studies have reported long-term overall survival of 50% to 80% at 5 years and 30% to 60% at 10 years,1–3 with no differences between Stanford type A and B dissections.3 Persistent patent false lumen in the descending aorta is common in both types and has been strongly associated with poor prognosis.3,5 However, the majority of series of type A and B dissections did not exclude cases with absence of residual dissection, total false lumen thrombosis, or intramural hematomas,3,5,7 which implies a different natural history.5,10

Clinical Perspective on p 3141

Advances in imaging techniques may provide significant information11–13 for identifying patients at higher risk of adverse events. The advent of thoracic endovascular aortic repair raised new expectations for the early management of complicated aortic dissection14–16 by occluding the intimal tear, restoring true lumen flow, and inducing false lumen thrombosis. However, to date, no study has shown that elective endovascular treatment in subacute phase of aortic dissection reduces mortality. Recent Investigation of Stent Grafts in Aortic Dissection (INSTEAD) trial16 results failed to show an improvement in 2-year survival and adverse event rates. Therefore, identification of clinical and imaging predictors of poor prognosis seems mandatory to select patients for whom more aggressive management may be beneficial.

The aim of the present study was to assess the long-term outcome of aortic dissection with persistent patent false lumen in the descending aorta and define the clinical and imaging variables obtained in subacute phase that could predict adverse events during follow-up.
Methods

Study Population

From January of 1994 to December 2009, 316 consecutive patients were discharged after an initial episode of acute aortic syndrome: 222 aortic dissections and 94 intramural hematomas. Of the aortic dissection group, 38 patients were not included: 27 did not have residual patent false lumen (12%), 9 had complicated acute type B dissection requiring surgical/endovascular treatment (11%), and 2 resided far from the hospital. Therefore, the study group comprised 184 patients, 108 surgically treated type A and 76 medically treated type B dissections, discharged with patent false lumen in descending aorta confirmed by transthoracic echocardiographic study (TEE).

Follow-Up Protocol

Patients underwent a strict clinical and imaging protocol, and no patient was lost to follow-up. All admitted patients underwent TEE before discharge, and computed tomography (CT) and/or magnetic resonance imaging (MRI) were performed during the first month of follow-up. The findings of these studies constituted the baseline information. Patients were discharged with β-blocker treatment, if not contraindicated, combined or not with other antihypertensive drugs aimed at achieving systolic blood pressure <130 mm Hg. Patients were followed by 2 clinical cardiologists (A.S. and A.E.), who checked for adequacy of blood pressure control and the presence of symptoms or complications in imaging tests (CT, TEE, or MRI depending on medical criteria) at 3 and 6 months and annually thereafter.

Surgical or endovascular treatment during follow-up was indicated according to a preestablished protocol. Intervention was considered expected, significantly different clinical variables between type A and B dissections were made by Student t test, Pearson χ² test, or Fisher exact test where appropriate. Individual aortic growth rates were calculated by dividing the change in aorta diameter measured in millimeters by time measured in years. For analysis purposes, entry tear location was dichotomized in proximal versus medial and distal, because the number of entry tears located in the distal part of the dissection was small.

Growth rates were compared by use of the Kruskal-Wallis rank test. Receiver operator characteristic curves were used to analyze the ability of entry tear size to predict adverse aortic events. Survival rates were estimated by the Kaplan-Meier method. Relationships between clinical and imaging variables and follow-up adverse events were assessed by use of univariate proportional hazards regression analysis. For the overall mortality end point, patients experiencing a nonfatal dissection-related event (need for surgical/endovascular treatment) were censored. For the dissection-related event end point, patients dying of other causes were censored.

Determinants of overall mortality rate or dissection-related events were also assessed by Cox proportional hazards regression analysis. Potential predictive variables were selected on the basis of clinical plausibility and their significant association with outcome in univariate analysis. Multivariable Cox proportional hazards regression and were retained in the final model when the P value was <0.2 (using the backward stepwise variable selection procedure). Because our goal was to develop a parsimonious prediction model from potential baseline clinical predictors, variables such as chest pain and blood pressure control assessed during follow-up were not considered for prediction purposes. First-order interaction terms were tested. All probability values were 2-sided and considered significant at the 0.05 threshold.

Results

Study Population and Baseline Characteristics

Population characteristics and baseline-imaging study results stratified by aortic dissection type are shown in Table 1. As expected, significantly different clinical variables between type
A and type B dissections were age, hypertension, and dyslipidemia, which were more prevalent in type B, and Marfan syndrome, which was more common in type A. Concerning imaging variables, differences were observed between type A and B groups (Table 1). Maximum descending aorta diameter was similar in both types. Most entry tears were located in the proximal part of the dissection in both types (44.4% versus 51.3%). However, medial location was more frequent in type B (46.1% versus 30.6%), whereas distal location was observed more in type A (25.0% versus 2.6%, \( P < 0.001 \)). Entry tear size ranged from 3 mm to 27 mm (median, 7 mm; Q1–Q3, 5–12 mm). Entry tear size was larger in type B than in type A (10.4 ± 5.2 mm versus 7.3 ± 4.2 mm, \( P < 0.001 \)). Entry tear diameter was ≥10 mm in 45 (59.2%) of type B and in only 31 (40.8%) of operated type A dissections (\( P < 0.001 \)). The frequency of true lumen compression was similar in both types.

Long-Term Outcome and Mortality Predictors
Median follow-up was 6.4 years (range, 0.5–17 years; Q1–Q3, 3.3–10.5 years). Type B dissections presented a higher enlargement rate of maximum aorta diameter than type A: 0.21 mm (0.09–0.76) versus 0.48 mm (0.12–1.57), \( P = 0.04 \), respectively (online-only Data Supplement Figure I). Seven patients underwent surgical and 28 underwent endovascular treatment, 10 type A and 25 type B, owing to severe aorta dilatation, impending rupture, and/or peripheral ischemia. Forty-nine patients died during follow-up (22 type A, 27 type B). Of these, 31 had died suddenly: 11 during readmission with signs of aortic rupture and 20 at home from unknown causes. Six hospitalized patients died during surgical (n=3) or endovascular (n=3) treatment performed for chest pain and severe aortic dilatation. The remaining 12 patients died of causes not directly related to aortic dissection: neoplasia (7),

Figure 1. Entry tear of aortic dissection visualized by 2-dimensional (left) and color-Doppler (right) TEE. A, Type B dissection with an entry tear located in the proximal part of the descending aorta (arrow) by tranverse view. B, Type A dissection with an entry tear in the proximal part of the residual dissection (arrow) in the upper ascending aorta by longitudinal view. TL indicates true lumen; FL, false lumen.

Figure 2. Entry tear of type A dissection in the mid part of the descending thoracic aorta. Entry tear diameter was larger on transverse (A) than longitudinal (B) views, 13 mm versus 7 mm, respectively, and 13 mm was considered to be the maximum entry tear diameter. TL indicates true lumen; FL, false lumen.
Long-Term Evolution in Type A and B Dissections With Patent False Lumen

This study shows that, in the long term, aortic dissection with patent false lumen in the descending aorta presents a high risk of complications. In addition to the well-known risk factors (Marfan syndrome, baseline maximum descending aorta diameter, and entry tear size predicted total mortality. Similarly, baseline descending aorta diameter, entry tear size, and also proximal location predicted aortic events. The association between entry tear location and size and aorta-related events is shown in Figure 4A and 4B. As shown in Figure 5, stratifying by entry tear size and location, those patients with proximal entry tear >10 mm trend to a higher rate of complications during follow-up, although this trend did not reach statistical significance.

Discussion

This study shows that, in the long term, aortic dissection with patent false lumen in the descending aorta presents a high risk of complications. In addition to the well-known risk factors (Marfan syndrome, baseline maximum descending aorta diameter, and entry tear size predicted total mortality. Similarly, baseline descending aorta diameter, entry tear size, and also proximal location predicted aortic events. The association between entry tear location and size and aorta-related events is shown in Figure 4A and 4B. As shown in Figure 5, stratifying by entry tear size and location, those patients with proximal entry tear >10 mm trend to a higher rate of complications during follow-up, although this trend did not reach statistical significance.
Suboptimal connection of the distal part of the graft implanted in the ascending aorta to the true lumen or presence of secondary tears may account for the persistence of flow into the distal residual false lumen after complete surgical resection of the primary entry tear. On the other hand, most studies evaluating the long-term outcome of type B dissection usually include intramural hematoma, a different entity with a different pathogenesis and evolution pattern, along with instances of aortic dissection with total false lumen thrombosis. No studies have compared the long-term evolution of types A and B dissections with persistent patent false lumen in a consecutive series treated with a preestablished protocol. In the present study, the aortic growth rate was higher in type B than in type A dissections (0.48 versus 0.21 mm/y, respectively). This growth rate was lower than in other series, probably because of a longer follow-up period. Nevertheless, 19% (9% type A and 33% type B) of our patients required surgical or endovascular therapy during follow-up with interventional mortality similar to those reported in other series. Overall mortality in our study was 5% at 3 years, 13% at 5 years, and 48% at 10 years (20% in type A and 36% in type B), similar to those of contemporary series from major aortic surgery institutions.

**Predictors of Complications**

Some clinical predictors of complications, such as Marfan syndrome, age, or atherosclerotic disease have been
reported previously. In our series, only Marfan syndrome was a clinical predictor of complications, with a 70% mortality rate at 10 years. Our study confirms the predictive value of maximum descending aorta diameter in subacute phase. Other groups reported that true lumen compression or large false lumen diameter had significant prognostic implications. Nevertheless, these variables have significant limitations, because true and false lumen size may vary considerably in the different aorta segments depending on several local factors such as tortuosities, spiral flap distribution, and intimal flap mobility. In the present series, true lumen compression was more frequent in the group of patients with major events, although it was not a predictor of complications after the inclusion of entry tear size in the multivariate analysis.

In the present study, size and proximal location of the entry tear were predictors of complications. Phantom studies have demonstrated that the larger the intimal tear in the proximal aorta, the greater the tendency to exacerbate true lumen collapse. Furthermore, Tsai et al showed that systolic pressure in the false lumen, in comparison with the true lumen, falls with decreasing tear size. Therefore, increased pressure with greater tear size will result in higher wall stress and risk of dilatation. They additionally suggested that proximal location of the entry tear was shown to cause a rise in false lumen diastolic pressure, thereby implying a tendency toward dilatation. Other studies suggested the possible predictive role of a proximal entry tear and poor BP control during follow-up increased from the third year of follow-up after acute aortic syndrome in patients with persistent patent false lumen, which suggests that structural and/or dynamic factors responsible for

### Table 2. Univariate Cox Regression Analysis Predicting Death and Dissection-Related Events Based on Demographic, Clinical, and Imaging Variables

<table>
<thead>
<tr>
<th>Clinical variables</th>
<th>HR Total Mortality (95% CI)</th>
<th>P</th>
<th>HR Dissection-Related Event (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (for 1-y increase)</td>
<td>1.01 (0.99–1.04)</td>
<td>0.39</td>
<td>0.99 (0.97–1.01)</td>
<td>0.34</td>
</tr>
<tr>
<td>Women (vs men)</td>
<td>1.19 (0.59–2.38)</td>
<td>0.63</td>
<td>1.26 (0.7–2.27)</td>
<td>0.45</td>
</tr>
<tr>
<td>Hypertension</td>
<td>1.16 (0.52–2.59)</td>
<td>0.72</td>
<td>0.81 (0.44–1.48)</td>
<td>0.49</td>
</tr>
<tr>
<td>Marfan syndrome</td>
<td>2.39 (1.19–4.83)</td>
<td>0.02</td>
<td>1.93 (1.03–3.63)</td>
<td>0.04</td>
</tr>
<tr>
<td>Atherosclerosis</td>
<td>1.43 (0.67–3.05)</td>
<td>0.36</td>
<td>0.74 (0.32–1.72)</td>
<td>0.49</td>
</tr>
<tr>
<td>Previous aortic disease</td>
<td>1.76 (0.9–3.45)</td>
<td>0.1</td>
<td>1.84 (1.04–3.29)</td>
<td>0.04</td>
</tr>
<tr>
<td>COPD</td>
<td>1.08 (0.52–2.22)</td>
<td>0.84</td>
<td>1.38 (0.77–2.46)</td>
<td>0.28</td>
</tr>
<tr>
<td>Renal failure</td>
<td>0.38 (0.14–1.06)</td>
<td>0.07</td>
<td>0.86 (0.45–1.64)</td>
<td>0.64</td>
</tr>
<tr>
<td>Type of aortic dissection (B vs A)</td>
<td>1.74 (0.99–3.05)</td>
<td>0.06</td>
<td>2.6 (1.56–4.32)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Poor BP control during follow-up</td>
<td>1.29 (0.69–2.39)</td>
<td>0.43</td>
<td>1.36 (0.8–2.32)</td>
<td>0.26</td>
</tr>
<tr>
<td>Chest pain during follow-up</td>
<td>2.58 (1.44–4.62)</td>
<td>0.001</td>
<td>2.62 (1.58–4.34)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Imaging variables</th>
<th>HR Total Mortality (95% CI)</th>
<th>P</th>
<th>HR Dissection-Related Event (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal vs medial or distal entry tear</td>
<td>1.71 (0.97–3.01)</td>
<td>0.07</td>
<td>2.6 (1.54–4.37)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Entry tear diameter (for 1-mm increase)</td>
<td>1.14 (1.08–1.2)</td>
<td>&lt;0.001</td>
<td>1.2 (1.15–1.26)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>True lumen compression</td>
<td>0.99 (0.91–1.94)</td>
<td>0.98</td>
<td>1.7 (1.02–2.85)</td>
<td>0.04</td>
</tr>
<tr>
<td>Baseline maximum descending aorta diameter (for each 5-mm increase)</td>
<td>1.08 (1.04–1.13)</td>
<td>&lt;0.001</td>
<td>1.09 (1.05–1.13)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

COPD indicates chronic obstructive pulmonary disease; HR, hazard ratio; and BP, Blood Pressure.

### Table 3. Predictors of Total Mortality and Dissection-Related Events: Results of Multivariate Cox Models

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total Mortality</th>
<th>Dissection-Related Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjusted HR (95% CI)</td>
<td>P</td>
<td>Adjusted HR (95% CI)</td>
</tr>
<tr>
<td>Age (for 1-y increase)</td>
<td>1.02 (0.99–1.05)</td>
<td>0.17</td>
</tr>
<tr>
<td>Type B (vs type A)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Marfan syndrome (vs rest)</td>
<td>3.66 (1.65–8.13)</td>
<td>0.001</td>
</tr>
<tr>
<td>Baseline maximum descending aorta diameter (for each 5-mm increase)</td>
<td>1.36 (1.08–1.7)</td>
<td>0.008</td>
</tr>
<tr>
<td>Entry tear diameter (for 1-mm increase)</td>
<td>1.1 (1.04–1.16)</td>
<td>0.001</td>
</tr>
<tr>
<td>Proximal entry tear (vs rest)</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

HR indicates hazard ratio.
Dissection complications require time to appear. This fact could explain the lack of benefit of endovascular treatment in the INSTEAD trial. In that randomized study, elective stent-graft placement in survivors of uncomplicated type B dissection failed to improve 2-year survival and adverse rates despite favorable aortic remodeling. Moreover, we believe that the hemodynamic implications of patent false lumen are probably too complex to be understood exclusively from baseline morphological imaging variables. In the future, other more dynamic variables such as flow patterns in true and false lumina assessed by contrast echocardiography or MRI should be considered in the hemodynamic assessment of patent false lumen.

Limitations
The present study had several limitations. The series was not large, because only patients with persistent patent false lumen following conventional treatment were included in an attempt to obtain a population as homogeneous as possible. Nevertheless, compliance with the protocol was excellent, and no patient was lost to follow-up. During the study period, advances in imaging techniques improved morphological and functional assessment. Although maximum entry tear diameter may not be representative of entry tear size, this parameter showed good reproducibility both by TEE and CT. However, the predictive value of this parameter should be validated in other series. Finally, partial false lumen thrombosis in subacute phase has been considered a predictor of mortality in type B dissection. In the present study, this variable was not analyzed, because assessment of the entire aorta by CT before discharge was not performed in all cases, and many patients with type A dissection were undergoing anticoagulation treatment. Future studies should analyze the relationship of this finding with entry tear size and its predictive value.

Clinical Implications
The optimal management of patients discharged with persistent patent false lumen after treatment for acute aortic dissection...
remains under debate.23,36,37 Although the short-term evolution is stable, the incidence of complications rises after 3 years of evolution, particularly in type B dissections. Surgical or endovascular entry tear closure promotes both thrombosis of the false lumen and remodeling of the entire aorta.14–16 It has been suggested that treatment efficacy should be greater in the subacute phase than in subsequent periods when the aorta is severely dilated and the intima less elastic.16,36,37 Our findings may help to identify patients at higher risk of complications by imaging techniques performed in the subacute phase of aortic dissection. In addition to dilated aorta, the clinical outcome is more likely to be poor in those with proximal and large entry tears. Thus, these patients may benefit from more aggressive surveillance and treatment. These results also emphasize the importance of resecting or closing any significant communication between true and false lumina in the distal ascending aorta or aortic arch in patients undergoing surgery for type A aortic dissection.

Conclusions
The long-term outcome of aortic dissection with patent false lumen shows a high risk of complications, sudden death, and need for surgery, particularly from the third year of evolution. In addition to Marfan syndrome, maximum aorta diameter and the presence of a large, proximal entry tear imply a higher incidence of complications during follow-up. Information obtained by imaging techniques in the subacute phase can help to identify patients at greater risk of complications and facilitate the indication of more aggressive treatment, including surgery or endovascular treatment, to improve their long-term prognosis.

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Disclosures
None.

References

CLINICAL PERSPECTIVE

Persistence of patent false lumen in descending aorta after acute aortic dissection is common in type A and type B dissections and has been associated with poor prognosis. However, to date, no study has shown that elective surgical or endovascular treatment in subacute phase of aortic dissection reduces mortality. Therefore, identification of clinical and imaging predictors of poor prognosis seems mandatory. We studied 184 patients, 108 surgically treated type A and 76 medically treated type B dissections, discharged with patent false lumen in descending aorta. Transesophageal echocardiography and computed tomography were performed to assess several imaging variables. During follow-up (median, 6.4 years) 49 patients died; 31 died suddenly, and 35 underwent surgical/endovascular treatment. Survival free from complications at 3, 5, and 10 years was 0.90 (95% CI, 0.84—0.94), 0.81 (95% CI, 0.75—0.87), and 0.46 (95% CI, 0.36—0.55), respectively. Marfan syndrome was the only clinical variable associated with mortality. Concerning imaging variables, patients with complications had a larger baseline maximum diameter in descending aorta and a larger proximal entry tear. Patients with entry tear size ≥10 mm presented a higher incidence of aortic-related events (hazard ratio = 5.8, 3.3—10; P < 0.001). Our findings may help to identify patients at higher risk of complications by imaging techniques performed in subacute phase of aortic dissection. Patients with dilated aorta and large entry tears may benefit from more aggressive surveillance and treatment, including surgical or endovascular therapy, to improve their long-term prognosis.
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SUPPLEMENTAL MATERIAL
FIGURE LEGENDS

Supplemental Figure 1. Severe enlargement of the descending aorta in a type B dissection. Maximum descending aorta diameter was 49 mm in subacute phase (a) and 64 mm with partial false lumen thrombosis at 9 years of follow-up (b). A large entry tear of 27 mm was located in the proximal descending aorta (c).

Supplemental Figure 2. ROC curve for adverse aortic events and entry tear size.