Growth Rate of Aortic Diameter in Patients With Type B Aortic Dissection During the Chronic Phase

Eijun Sueyoshi, MD; Ichiro Sakamoto, MD; Kuniaki Hayashi, MD; Tetsuji Yamaguchi, MD; Tatuya Imada, MD

Background—The purpose of this study was to evaluate the growth rate of type B double-barrel aortic dissection with computed tomography (CT) and the factors influencing its enlargement.

Methods and Results—Sixty-two patients were entered into this study, and regular follow-up CT studies (mean: 49.1 months) were performed. The affected aortas and iliac arteries were divided into 5 segments (aortic arch, descending thoracic, suprarenal abdominal, infrarenal abdominal aorta, and iliac artery). Fifty-two of 62 patients (83.9%) had 1 or more segments increased in size during follow-up period. In a total of 177 segments, the presence or absence of blood flow in the false lumen and aortic diameter were evaluated on CT during the follow-up period. The factors (gender, diabetes mellitus, atherosclerotic disease, smoking, entry site in arch, initial diameter, chronic obstructive pulmonary disease, blood pressure, and age) influencing increase in the diameter and growth rate were also evaluated. Of 177 segments, 132 segments (74.6%) increased in size during the follow-up period. The presence of blood flow in the false lumen was the only significant risk factor for increase in the diameter in the univariate and multivariate analysis. The group with blood flow in the false lumen had a significantly higher mean growth rate (3.3 mm/year) than the group without blood flow (-1.4 mm/year) (P<0.0001). The growth rate of aortic dissections in thoracic aorta and abdominal aorta were 4.1 and 1.2 mm/year, respectively. There was a significant difference in the growth rate between the 2 groups (P=0.0003).

Conclusion—In type B aortic dissection, the affected aortas have shown a high incidence of enlargement during the follow-up period, and more careful follow-up study is needed for aortic dissections in the thoracic aorta. The presence of blood flow in the false lumen is the most important risk factor for aortic enlargement. (Circulation. 2004;110[suppl II]:II-256–II-261.)

Key Words: aorta • aneurysm • risk factors • follow-up studies • tomography

Generally, patients who have Stanford type B double-barrel (classic) aortic dissection (AD) without complications are treated medically, but some of the affected aortas progress to aneurysmal dilatation and rupture during the chronic phase.1–5 Recently, using noninvasive imaging techniques such as computed tomography (CT), magnetic resonance (MR) imaging, and ultrasound, aortic diseases can be followed-up closely.4–8 In comparison with MR, CT may be a better technique for evaluating aortic disease because the use of MR is limited by the restricted availability of the magnets and by considerations of patient safety while undergoing study.9 Moreover, it takes longer to obtain MR images. In comparison with ultrasound, CT can provide superior images in obese patients and is not hindered by the lungs or intestinal gas.4 Ultrasound is not useful in imaging of the thoracic aorta. As a major disadvantage of CT, contrast media cannot be used for patients with severe renal dysfunction. However, CT has a major role in the diagnosis and follow-up evaluation of aortic diseases.

Recently, several articles have reported the growth rate of aortic aneurysms measured with CT.4–8 However, to our knowledge, there have been few reports on the growth rate of AD, and the natural history of the affected aorta in patients with type B AD is not clearly understood.10 The purpose of this study was to evaluate the growth rate of type B double-barrel AD with repeated CT examinations and the factors influencing its enlargement.

Materials and Methods

Patients

In this study, patients who were followed-up nonoperatively for >1 month after the onset with sequential CT scans were studied. Sixty-eight consecutive patients had Stanford type B AD diagnosed between 1986 and 2002 in 2 hospitals (Omura Municipal Hospital and Nagasaki University Hospital). Of the 68 patients, 62 patients were entered into this study. The reasons for the 6 exceptions included 4 cases of urgent surgery (aortic rupture in 3 and organ ischemia in 1) and 2 cases of early death (aortic rupture in 2) within 1 month of the onset. There were 41 men and 21 women between the
by guest on April 21, 2017 http://circ.ahajournals.org/ Downloaded from

intimal flap and contrast enhancement within the false lumen were

patients were current smokers.

patients have been followed-up continuously.

organ ischemia in 2, and renal failure in 1). The remaining 31

to 192 months after the onset (malignancy in 3, aortic rupture in 5,
ischemia in 2). Eleven of 42 patients without surgery died (from) 1

to 192 months after the onset (aneurysmal dilatation in aortic rupture in 2 and/or organ

ischemia in 2). Eleven of 42 patients without surgery died (from) 1
to 192 months after the onset (malignancy in 3, aortic rupture in 5,
organ ischemia in 2, and renal failure in 1). The remaining 31

patients have been followed-up continuously.

CT Examination

In 62 patients, a total of 411 studies were performed with conven-
tional (n = 151) or spiral (n = 260) CT scanners. The follow-up CT
studies were performed with nonenhanced and enhanced CT in all
patients. Enhanced CT was performed with a bolus injection of 100
mL of ionic or nonionic contrast material. CT was performed with a
8800, 9800, High Speed Advantage, Light Speed Q/i scanner (GE
Medical Systems) or Somatom Plus 4 scanner (Simens Medical
Systems) generating axial images with contiguous 5-mm-thick sec-
tions from the top of the aortic arch to the abdominal aorta. In the
spiral CT scanner, a power injector was used, and scanning began at
20 to 30 seconds and 120 to 150 seconds (2 phases) after the start
of the injection of the contrast material.

Image Analysis

CT images were evaluated by 2 experienced (E.S. and I.S.; >10
years of experience) cardiovascular radiologists. The affected aortas
were divided into 5 segments (aortic arch, 48; descending thoracic
aorta, 62; suprarenal abdominal aorta, 38; infrarenal abdominal
aorta, 19; and iliac artery, 10). Eight of 62 patients had AD limited
to 1 segment (descending thoracic aorta). The remaining 54 patients
had 2 or more affected segments. A total of 177 segments were
evaluated. In this study, the aortic arch was defined as the segment
between the brachiocephalic artery and the ligamentum arteriosum.
The descending aorta was defined as the segment between the
ligamentum arteriosus and the aortic hiatus of the diaphragm.

All 177 segments had blood flow in the false lumen on the initial
CT. The presence or absence of blood flow in the false lumen and
aortic diameter of each segment were evaluated during the follow-up
period. The absence of blood flow in false lumen was defined as no
contrast enhancement in the false lumen on postcontrast CT. Final
decisions regarding the findings were reached by consensus. Com-
paring the growth rate of AD in the thoracic aorta with that in the
abdominal aorta, we chose the higher value if AD involved 2
segments of thoracic or abdominal aorta. The growth rate of AD
in the thoracic and abdominal aorta were calculated independently
if AD involved both segments of thoracic and abdominal aorta.

The initial and final CT measurements were used to calculate
changes in aortic size at the same level in each segment. The largest
short-axial diameter of the outer contour of the affected segment
of aorta was measured (Figure a).5 In the aortic arch, the largest
diameter perpendicular to the curvature was measured (Figure b).4
The diameters were measured with direct-reading calibers from
hardcopy images and corrected for the appropriate scale.

The growth rate of each segment was obtained at the portion of
the largest diameter on the final CT. The growth rate was calculated in
the following manner:4 the difference in the diameter between initial
(D1) and final (D2) measurements was divided by the time interval
(T) between the 2 measurements, ie, growth rate = (D2 - D1)/T.

Statistical Analysis

All values are expressed as mean ± SD. Statistical analysis was
performed on clinical and morphological variables, with the χ²
or Fisher exact test used for categorical variables, and the paired
t test and the Mann–Whitney U test for continuous variables.

If the expected number of cells was <5, Fisher exact test was used
for categorical variables. Variables with statistical significance set at
P < 0.05 (2 side) were included in a multivariate logistic regression
model. Estimates of risk (odd ratios) were calculated based on
coefficients from the logistic models. In all tests, a value of P < 0.05
was considered significant. Data analysis was performed using

Results

Fifty-two of 62 patients (83.9%) had 1 or more segments
increased in size during follow-up period. Table 1 shows the
mean initial diameter, final diameter, and growth rate of the 177 segments. In all 177 segments, the mean initial diameter and final diameter were 33.9 ± 0.7 and 39.2 ± 0.1 mm, respectively. There was a significant difference between them (P < 0.0001). Of the 177 segments, 132 segments (74.6%) increased in size during the follow-up period. Forty-five segments (25.4%) remained unchanged or decreased in size. In 54 segments (30.5%), the false lumens were completely thrombosed (no blood flow) from 1 day to 72 months after the onset. However, 3 segments recanalized during the follow-up period. In remaining 51 segments (28.8%), the false lumens had been completely thrombosed until the final CT (aortic arch, 16; descending thoracic aorta, 13; suprarenal abdominal aorta, 7; infrarenal abdominal aorta, 2; and iliac artery, 3). Of the 51 segments without blood flow in the false lumen, 19 (37.3%) increased in size. In contrast, of 126 segments with blood flow in the false lumen, 113 (89.7%) increased in size during the follow-up period. Forty-five of 177 (25.4%) did not increase in size or unchanged during the follow-up period (aortic arch, 16; descending thoracic aorta, 13; suprarenal abdominal aorta, 8; infrarenal abdominal aorta, 6; and iliac artery, 2).

Of 62 patients, 28 (45.2%) had the segment with the largest diameter in the aortic arch, 33 (53.2%) in the descending aorta, and 1 (1.6%) in the suprarenal abdominal aorta. The mean largest diameter on the final CT was 49.0 ± 11.0 mm, COPD, and blood pressure >140 mm Hg during follow-up period, n (%) 9 (6.8) 1 (2.2) 0.61 0.4192 0.3571 0.226–61.591 3.733

Atherosclerotic disease including atherosclerotic aneurysm, ischemic heart disease, and cerebrovascular disease.
COPD indicates chronic obstructive pulmonary disease; BP, blood pressure; OR, odds ratios.

| TABLE 1. Mean Initial Diameter, Final Diameter, and Growth Rate of the 177 Segments |
|-----------------------------------|-------------------|-----------------|-----------------|
|                                   | Initial Diameter  | Final Diameter   | Growth Rate     |
|                                   | (mm)              | (mm)            | (mm/year)       |
| Aortic arch (n = 48)              | 39.4 ± 7.7        | 45.6 ± 11.0     | 2.2 ± 6.9       |
| Descending aorta (n = 62)         | 37.7 ± 9.3        | 45.0 ± 13.0     | 2.2 ± 10.1      |
| Suprarenal abdominal aorta (n = 38)| 29.6 ± 5.3        | 33.3 ± 5.9      | 1.0 ± 5.8       |
| Infrarenal abdominal aorta (n = 19)| 29.7 ± 4.7        | 26.8 ± 5.8      | 1.0 ± 2.2       |
| Iliac artery (n = 10)             | 17.5 ± 4.8        | 18.8 ± 3.9      | −0.4 ± 4.7      |

| TABLE 2. Risk Factors for Increase in Diameter of the 177 Segments |
|-------------------|-------------------|-----------------|-----------------|
| Patient Characteristics | Increase (n = 132) | No Increase (n = 45) | Univariate | Multivariate |
| Gender, male, n (%)  | 79 (59.8)        | 33 (73.3)       | 2.08 0.1492 | 0.5762 0.205–2.415 0.703 |
| Age < 60 y, n (%)    | 79 (59.8)        | 35 (77.8)       | 4.71 0.0301 | 0.4556 0.257–1.839 0.688 |
| Diabetes mellitus, n (%) | 8 (6.1)     | 6 (13.3)       | 1.55 0.2138 | 0.9537 0.217–4.215 0.957 |
| Atherosclerotic disease, n (%) | 27 (20.5) | 9 (20.0)       | 0 >0.9999 | 0.9313 0.328–2.779 0.954 |
| Smoking < 20 y, n (%) | 23 (17.4)       | 13 (28.9)      | 2.06 0.1508 | 0.8632 0.306–2.701 0.909 |
| Presence of blood flow in false lumen, n (%) | 112 (85.6) | 13 (28.9) | 49.92 <0.0001 | <0.0001 5.525–35.282 13.961 |
| Entry site in arch, n (%) | 117 (84.8) | 37 (82.2) | 1.22 0.2691 | 0.2729 0.662–4.293 1.686 |
| Initial diameter < 40 mm, n (%) | 22 (16.7) | 7 (15.6) | 0 >0.9999 | 0.3074 0.565–6.112 1.859 |
| COPD, n (%) | 20 (15.2)       | 2 (4.4)       | 3.35 0.0654 | 0.1261 0.673–24.913 4.093 |
| BP < 140 mm Hg during follow-up period, n (%) | 9 (6.8) | 1 (2.2) | 0.61 0.4192 | 0.3571 0.226–61.591 3.733 |

Univariate: X², P, OR; Multivariate: P, 95% CI, OR.
TABLE 4. Mean Initial Diameter, Final Diameter, and Growth Rate of 100 Lesions of the Thoracic and Abdominal Aorta

<table>
<thead>
<tr>
<th>AD Location</th>
<th>Initial Diameter (mm)</th>
<th>Final Diameter (mm)</th>
<th>Growth Rate (mm/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoracic aorta, n=62</td>
<td>39.6±9.9</td>
<td>48.7±13.7</td>
<td>4.1±6.5</td>
</tr>
<tr>
<td>Aortic arch, n=48</td>
<td>39.4±7.7</td>
<td>45.6±11.0</td>
<td>2.2±9.3</td>
</tr>
<tr>
<td>Abdominal aorta, n=38</td>
<td>28.7±5.4</td>
<td>32.5±6.1</td>
<td>1.2±5.9</td>
</tr>
</tbody>
</table>

There was a significant difference in the growth rate between the 2 groups ($P=0.0003$), and the AD in the thoracic aorta grew at a faster rate than those in the abdominal aorta. Of 62 AD in the thoracic aorta, 48 AD involved 2 segments (arch and descending aorta). In 24 of 48, distal (descending aorta) segments grew at a faster rate than proximal (arch) segment. Of 38 AD in the abdominal aorta, 19 AD involved 2 segments (suprarenal and infrarenal abdominal aorta). In 7 of 19, distal (infrarenal abdominal aorta) grew at a faster rate than proximal (suprarenal abdominal aorta) segments.

Discussion

The optimal treatment for patients with type B AD remains a matter of debate.$^{10,12}$ Medical and surgical treatment strategies are used in different populations. Usually, medical treatment is selected for patients with uncomplicated type B AD, and surgical treatment is selected for patients with complicated type B AD. Those complications typically include intractable pain, rapid expansion and/or rupture, and organ ischemia. Patients without complications are usually treated with hypotensive drugs during the acute phase because the mortality rate with this treatment was reported to be equal to or slightly better than that for surgical treatment during the acute phase.$^{1,3}$ Surgical treatment should be selected if the aortic diameter enlarges or if a new complication appears during the chronic phase.$^{1,3}$ Therefore, follow-up imaging studies for patients with type B AD is essential.

In the present study, 52 of 62 patients (83.9%) had 1 or more segments increased in size, and affected aortas of type B AD had a high incidence of enlargement (74.6%) during the follow-up period. However, in 13 patients (21.0%), the segments with the largest diameter did not show the fastest growth rate. These results suggest that the segment with the largest diameter does not always show the fastest growth rate, and the proximal portion of the aorta does not always show the fastest growth rate. Recognition of these results is useful for following-up patients with type B AD.

In this study, the presence of blood flow in the false lumen was the only significant risk factor for increase in the diameter in both univariate and multivariate analysis (Table 2).

In addition, segments with blood flow in the false lumen had a significantly higher mean growth rate (Table 3). Therefore, the presence of blood flow in the false lumen is considered to be the most important risk factor for aortic enlargement. In a segment with false lumen thrombosis, the aorta frequently becomes a single-barrel chamber, with dissected layers becoming a single layer. This may restore normal vessel wall strength. In addition, these results suggest that both structural weakness of the aortic wall and direct mechanical stress from blood flow cause progressive enlargement of the segment with blood flow in the false lumen.

Previously, a few articles reported the risk factors for rupture or aortic enlargement (diameter ≥60 mm) in chronic type B AD.$^{10–12}$ One article revealed that the presence of blood flow in the false lumen was not a risk factor for rupture of type B AD.$^{10}$ However, another article revealed that the presence of blood flow in the false lumen was a significant risk factor for aortic enlargement (diameter ≥60 mm) of
chronic type B AD. Although the results in these 2 articles were different, our results support the latter.

In this study, the presence of COPD was not a significant risk factor for increase in the diameter in the univariate or multivariate analysis (Table 2). However, segments in patients with COPD had a significantly higher mean growth rate than those without COPD (Table 3). Previous reports revealed that a history of COPD was a powerful predictor for rupture of aortic aneurysms. In this study, it is not clear that the presence of COPD is a sensitive indicator of intolerance in connective tissue in patients with AD. Further studies are needed.

Our results showed that age was a significant risk factor for increase in the diameter in the univariate analysis. According to previous studies, the risk that an aneurysm or AD will rupture increases with age. However, in this study, the incidence of increased diameter of the segments in patients 60 or younger was higher than in patients older than 60 (Table 2). In addition, segments in female patients had a significantly higher mean growth rate (Table 3). The reasons for these results are unknown. Anatomically, the elasticity and distensibility of the aorta decline with age. Such changes occur even in normal healthy adults and, for some reasons, these changes appear earlier and are more progressive in males than in females. We hypothesize that the loss of elasticity may limit enlargement of the aorta in patients with AD. However, further studies are needed to clarify this issue.

Previous studies revealed that aortic diameter was a predictor of rupture and increase in the diameter of aortic aneurysm, AD, and aortic intramural hematoma. These results can be explained by the La Place Law. It states that the perpendicular stress on a cylinder is directly proportional to the pressure exerted by the fluid contents and its radius and is inversely proportional to wall thickness. This means that the larger the diameter, the faster the growth rate if the pressure is constant. However, in our results, initial aortic diameter was not a significant risk factor for increase in the diameter. As a hypothesis, the perpendicular stress per unit area may be weaker in AD than aortic aneurysms and intramural hematomas, because the aortic lumen of AD is separated and the diameter of each true and false lumen is small. However, patients with AD usually undergo a more aggressive blood control than patients with aortic aneurysm. Further study is needed to clarify why initial aortic diameter was not a significant risk factor for increase in the diameter.

In the present study, there was a significant difference in the growth rate between the AD in the thoracic aorta and the AD in the abdominal aorta. The AD in the thoracic aorta grew at a faster rate than those in the abdominal aorta (Table 4). Regarding growth rate of AD, we found only 1 previous study that demonstrated the growth rate in no rupture or operation, rupture, and operation groups, respectively. However, this article does not show the mean growth rate of AD in all patients and does not include aortic arch AD. It may not be appropriate to compare these results with our results.

In contrast, there are several articles on the growth rate of aortic aneurysms, but most of them are related to abdominal aortic aneurysm (AAA). According to these results, the growth rate of AAA had a range of 2.2 to 5.7 mm/year. Although AD and aortic aneurysms ultimately have different natural histories, the growth rate of the abdominal aorta in our results was 1.2 mm/year, which was slower than previous reports. For this reason, the aortic diameter of AD may usually be smaller than that of AAA. However, there were only a few reports on the growth rate of thoracic aortic aneurysm (TAA) that demonstrated that the growth rate had a range of 1.3 to 4.3 mm/year. In the present study, the growth rate of AD in the thoracic aorta was 4.1 mm/year, and the ADs in the thoracic aorta grew at a faster rate than those in the abdominal aorta. These results were similar to some results in previous studies. One study showed that TAA significantly grew at a faster rate than AAA. In contrast, another study showed that the mean growth rate of TAA was significantly lower than that of AAA. In fact, it is still unclear whether the mean growth rate of TAA is significantly lower than that of AAA. Some articles suggested that the mechanism of slow growth rate of TAA could be explained by the aortic structure itself. Therefore, elevated tension per lamellar unit and excessive avascular media may be factors in the increased growth rate of AAA. However, in AD, the aortic wall is separated and directly damaged more than an aortic aneurysm. Our results suggest that the damage to the aortic wall by AD and mechanical stress are also great contributing factors for growth rate because the lesions in the thoracic aorta grow at a faster rate than those in the abdominal aorta.

A limitation of this study was the difficulty in obtaining accurate measurements of aortic diameter on axial CT images. We measured the largest short-axial diameter of the outer contour of the aorta to avoid any errors caused by tortuosity or the curvature of some aortas so that the measurement would be accurate on axial CT images. Although previous studies used a similar measurement method to ours, multiplanar reconstructed images or other modalities such as MR imaging and transesophageal echocardiography may be needed to obtain more accurate sizing of the aorta. Moreover, aortic growth in patients with AD is not always circular. The measurement of this study may underestimate growth rate in some cases. As another limitation, other anatomic factors such as the size of the primary tear, circumferential extent of dissection, and presence or absence of adequate re-entry tears that may contribute to late complication were not addressed in this study. As other limitations, the sample size was small, and the follow-up periods of patients varied. Further studies addressing other anatomic factors and involving larger numbers of patients with a longer follow-up period are needed.

Conclusion

In type B AD, the affected aortas have a high incidence of enlargement during follow-up period. The presence of blood flow in the false lumen is the most important risk factor for enlargement during the follow-up period. The ADs in the thoracic aorta can grow at a faster rate than those in the abdominal aorta. Therefore, more careful follow-up study is needed for ADs in the thoracic aorta. Additionally, we should keep in mind that the largest diameter or the proximal portion of the aorta does not always show the fastest growth rate.
References


Growth Rate of Aortic Diameter in Patients With Type B Aortic Dissection During the Chronic Phase
Eijun Sueyoshi, Ichiro Sakamoto, Kuniaki Hayashi, Tetsuji Yamaguchi and Tatuya Imada

Circulation. 2004;110:II-256-II-261
doi: 10.1161/01.CIR.0000138386.48852.b6

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/110/11_suppl_1/II-256

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org/subscriptions/