Restrictive bare stent for prevention of stent graft-induced distal redissection after thoracic endovascular aortic repair for type B aortic dissection

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Background: Stent graft-induced distal redissection (SIDR) is one of the major concerns in the durability of endovascular repair for complicated Stanford type B aortic dissection. The characteristics and means of prevention of this complication remain unknown.

Methods: From April 1997 to March 2010, 674 patients with type B aortic dissections were treated primarily by thoracic endovascular aortic repair (TEVAR) at our center. Criteria for inclusion in this study were treatment primarily with TEVAR and an estimated mismatch rate (ratio of distal diameter of stent graft to long diameter of true lumen) greater than 120%. By this protocol, 465 patients were included in this study and were retrospectively analyzed. Among them, 266 patients were treated in the acute phase, and 199 were treated in the chronic phase.

Results: A total of 311 patients were treated with standard TEVAR and 154 patients with TEVAR + restrictive bare stent (RBS). The preoperative mismatch rate (measured as the preoperative long diameter of the true lumen at the level of the intended distal end of the stent graft) of the SIDR was significantly higher than that of the non-SIDR (192.7 ± 54.9% vs 131.9 ± 10.4%; P < .05). The follow-up mismatch rate of the SIDR was significantly higher than that of the non-SIDR (145.4 ± 34.6 vs 120.3 ± 16.1; P < .05). Compared with the standard TEVAR, TEVAR + RBS was associated with a lower incidence of SIDR (0% vs 2.9%; P = .033) and less secondary intervention (3.9% vs 9.3%; P = .040). Placement of the RBS significantly expanded the true lumen at the level of the descending aorta with the narrowest true lumen and at the level of the distal end of the stent graft.

Conclusions: The mismatch between the distal diameter of the stent graft and the diameter of the compressed true lumen seems to be the major factor in the occurrence of SIDR. Placement of an RBS, as an adjunctive technique to TEVAR, could reduce the incidence of SIDR. On the basis of early- to midterm observations, RBSs may improve morphological remodeling of the dissected aorta at certain levels. (J Vasc Surg 2013;57:445S-528S.)

Endovascular stent graft repair was introduced as an alternative to conventional open surgery for the treatment of descending aortic dissections in 1999.1,2 Encouraging short- and midterm outcomes of endograft implantation increased the popularity of and interest in thoracic endovascular aortic repair (TEVAR). Despite this, endograft design and manufacture have not kept pace with rapidly growing clinical ambition to treat complex dissections affecting the distal arch and descending thoracic aorta. Studies reported various complications caused by stent grafts, such as retrograde type A dissection,3,4 rupture,5,6 stent migration,7 stent collapse,8,9 and aneurysmal degeneration of the aorta near the endograft.10 Dong et al11 reported the incidence and mortality of redissection at the proximal or distal end of the endograft to be 3.4 and 26.1%, respectively. In that cohort, 34.8% of the endograft-induced redissections were located at the distal end of the endograft; that is, these were stent graft-induced distal redissections (SIDRs). The mortality rate was reported to be 25% in patients with SIDR.11

As an infrequent but high-mortality complication, SIDR can be treated by secondary endovascular exclusion12,13 but the critical intercostal arteries at T-8 to T-12 might be compromised by endograft placement, which would increase the risk of paraplegia and paraparesis.14 If SIDR develops into a retrograde type A dissection, emergent open surgery might be mandatory.5,15,16 Therefore, preventing SIDR is an important issue. The mismatch between the size of the stent graft, which was determined by the proximal landing zone, and the remarkably small diameter of the compressed true lumen of the distal descending aorta was suggested to contribute to the occurrence of the SIDR.11,17 We have used the restrictive bare
stent (RBS) technique to reduce this mismatch for more than 4 years, beginning in March 2007. The technique is to place the bare stent of proper size into the intended distal part of the endograft, prior to deployment of the stent graft.

Studies focusing specifically on redissection at the distal edge of the stent graft are lacking. An effective way to reduce the risk of SIDR has not been reported. Thus, we initiated this study to compare the characteristics of SIDRs and non-SIDRs to analyze the risk factors for SIDR. We also compare the outcomes of TEVAR with and without a RBS to explore the feasibility of using RBSs and their effectiveness in preventing SIDR.

METHODS

Data collection. From April 1997 to March 2010, 674 patients with type B aortic dissections were treated primarily with TEVAR in our center. They were all retrospectively reviewed. Only patients who met the inclusion criteria entered the next stage of the study. Patients had to have a complicated type B aortic dissection treated primarily with TEVAR, either in the acute or chronic phase. The indications for intervention were as follows: visceral or leg ischemia (n = 83), aortic rupture or perforation (n = 91), failure of medical management (n = 122), and aneurysmal enlargement (n = 169). Aneurysmal enlargement was defined as a thoracic aneurysm ≥5 cm or an increase in maximal thoracic aortic diameter of 1 cm per year on follow-up computed tomography angiography (CTA). Failure of medical management refers to intractable chest pain and refractory hypertension despite adequate best medical treatment. Second, according to the measurements collected from preoperative CTA patients, the estimated mismatch rate of the intended distal margin of the stent graft must be >120% (mismatch rate was defined as ratio of the designed distal diameter of the stent graft to the long diameter of the true lumen, shown in Fig 1). In line with this protocol, 465 patients were included in this study.

Two kinds of mismatch rates were calculated in this study: the estimated preoperative mismatch rate, defined as the ratio of the distal diameter of the stent graft to the preoperative long diameter of true lumen at the level of intended distal end of the stent graft; and the follow-up mismatch rate, defined as the ratio of the distal diameter of the stent graft to the long diameter of the true lumen at the level of distal end of stent graft, measured at the last CTA before the occurrence of SIDR.

As for the measurement made before TEVAR, in addition to the preoperative mismatch rate, we measured...
the diameters of the aorta, true lumen, and false lumen on four planes: plane 1 (P1), at the level of the maximum aortic diameter; P2, at the level of the narrowest true lumen of the descending aorta; P3, at the level of distal end of the stent graft; and P4, at the distal re-entry point. We measured both long and short diameters of the true lumen and the short diameter of the false lumen. The long diameter of the true lumen was used to choose the size of the RBS and calculate the mismatch rate. The short diameters of the true and false lumens were used to evaluate aortic remodeling after TEVAR, in consideration of the inclined-plane error coming from the aortic curvature (Fig 1).

**Endovascular procedures in TEVAR + RBS.** We started to use the RBS technique from March 2007 on Stanford type B aortic dissections with estimated preoperative mismatch rates >120%. The procedures were conducted in a digital subtraction angiography suite, under spinal anesthesia. After femoral artery exposure and aortography, we chose the size of the RBS (Sinus-XL Stent, OptiMed, Ettlingen, Germany) on the basis of the preoperative measurement at the intended distal edge of the stent graft; no oversize was adopted for the selection of bare stent (Fig 1). The bare stent was placed into the compressed true lumen, reserving 30-40 mm for overlap with the stent graft. The size of the stent graft is the diameter of the proximal nondissected aorta, usually at the level between the ostia of the left common carotid artery and left subclavian artery. Then the stent graft, approximately 10% oversized, was deployed to seal the proximal entry tear (Fig 2). No postdeployment ballooning was used. Other details have been described in other studies.13,18

Eight cases of SIDR detected in this study were treated by secondary TEVAR (one patient was treated medically). To exclude the new entry of the redissection, we chose the size of the second stent graft on the basis of the distal diameter of the previous one, but we preferred shorter endografts in secondary TEVARs. If the descending aorta in the T-8 to T-12 segment was excluded, particularly if the left subclavian artery was covered by the primary TEVAR, we conducted the intraoperative cerebrospinal fluid drainage and maintained relative hypertension (mean arterial pressure between 90 and 100 mm Hg) in the immediate postoperative period. For patients with a delayed neurologic deficit, we perform emergent cerebrospinal fluid drainage, administer systemic steroid therapy, and pharmacologically support blood pressure. The drain usually remains in place for 24 hours, and is then moved. For high-risk patients, the spinal drain is kept in place longer, but usually no more than 3 days.14,19

**Follow-up protocol and measurement.** All patients were routinely followed by CTA at 3 months, 6 months, and 1 year after TEVAR or when SIDRs were detected. To assess aortic remodeling, we measured the diameter of the aorta, true lumen, and false lumen on the same four planes as used in the preoperative measurement. All measurements were made by two independent authors and the means were calculated.

**Statistical analysis.** Continuous variables in a Gaussian distribution are expressed as means ± standard deviations,
Table I. Characteristics of patients with SIDR after TEVAR for type B dissection

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age, years</th>
<th>Gender</th>
<th>Primary stent graft, a</th>
<th>Onset time, b</th>
<th>SIDR symptoms</th>
<th>CTA manifestation</th>
<th>Preoperative mismatch rate, c, %</th>
<th>Last mismatch rate, d, %</th>
<th>Treatment</th>
<th>Follow-up, e months</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>70</td>
<td>M</td>
<td>Talent 34-34-100</td>
<td>48</td>
<td>Asymptomatic</td>
<td>Pseudoaneurysm</td>
<td>258.3</td>
<td>130.8</td>
<td>TEVAR</td>
<td>69</td>
</tr>
<tr>
<td>2</td>
<td>57</td>
<td>F</td>
<td>Zenith 30-30-140</td>
<td>26</td>
<td>Back pain</td>
<td>Redissection</td>
<td>164.7</td>
<td>142.9</td>
<td>TEVAR</td>
<td>44</td>
</tr>
<tr>
<td>3</td>
<td>62</td>
<td>M</td>
<td>Hercules 30-28-160</td>
<td>23</td>
<td>Asymptomatic</td>
<td>Redissection</td>
<td>180.0</td>
<td>127.3</td>
<td>TEVAR</td>
<td>39</td>
</tr>
<tr>
<td>4</td>
<td>49</td>
<td>M</td>
<td>Zenith 30-30-200</td>
<td>27</td>
<td>Asymptomatic</td>
<td>Redissection</td>
<td>155.6</td>
<td>130.4</td>
<td>TEVAR</td>
<td>39</td>
</tr>
<tr>
<td>5</td>
<td>65</td>
<td>M</td>
<td>VALIANT 32-32-200</td>
<td>33</td>
<td>Asymptomatic</td>
<td>Redissection</td>
<td>241.7</td>
<td>139.1</td>
<td>TEVAR</td>
<td>45</td>
</tr>
<tr>
<td>6</td>
<td>51</td>
<td>M</td>
<td>Zenith 34-34-157</td>
<td>18</td>
<td>Back pain</td>
<td>Redissection</td>
<td>281.8</td>
<td>234.5</td>
<td>TEVAR + RI-F-F crossover</td>
<td>26</td>
</tr>
<tr>
<td>7</td>
<td>52</td>
<td>M</td>
<td>Hercules 38-36-140</td>
<td>7 days</td>
<td>Chest pain</td>
<td>Retrograde dissection</td>
<td>120.0</td>
<td>—</td>
<td>Medical</td>
<td>10 days (died)</td>
</tr>
<tr>
<td>8</td>
<td>57</td>
<td>M</td>
<td>VALIANT 30-30-200</td>
<td>24</td>
<td>Asymptomatic</td>
<td>Redissection</td>
<td>176.4</td>
<td>133.3</td>
<td>TEVAR</td>
<td>32</td>
</tr>
<tr>
<td>9</td>
<td>59</td>
<td>M</td>
<td>Zenith 30-30-200</td>
<td>25</td>
<td>Back pain</td>
<td>Redissection</td>
<td>158.8</td>
<td>150.0</td>
<td>TEVAR</td>
<td>33</td>
</tr>
</tbody>
</table>

C TA, Computed tomography angiogram; RI-F-F, right axial-femoral-femoral artery crossover; SIDR, stent graft-induced distal redissection; TEVAR, thoracic endovascular aortic repair.

aSize of stent graft: Proximal diameter-distal diameter-length. 
bTime from primary dissection to occurrence of SIDR. 
cMeasured on the preoperative computed tomography angiogram.
dMeasured on the last preoperative computed tomography angiogram before the occurrence of SIDR. The measuring method is described in Fig 1. 

eTime from first TEVAR to last follow-up.

RESULTS

Characteristics of patients and SIDRs. The age of the 465 patients was 59 ± 7 years (mean ± standard deviation [SD]). There were 365 males (78.5%) and 100 females (21.5%). Two hundred sixty-six patients were treated in acute phase (57.2%), and 199 were treated in the chronic phase (42.8%). The average preoperative mismatch rate was 132.5 ± 11.8%. Three hundred eleven patients (66.9%) were treated primarily with standard TEVAR, and 154 cases (33.1%) with TEVAR + RBS. Five stent graft systems were used in this series: Zenith TX2 (COOK, Bjaeverskov, Denmark; 192/465, 41.3%; proximal components: 112; proximal tapered: 80); Relay (Bolton, Barcelona, Spain; 77/465, 16.6%); Hercules (Microport, Shanghai, China; 64/465, 13.8%; TALENT (Medtronic, Santa Rosa, Calif; 68/465, 14.6%) and VALIANT (Medtronic; 64/465, 13.8%). The overall mortality rate of this group was 2.4% (11/465), and the aorta-related mortality rate was 1.5% (7/465). Thirty-five patients (7.5%) required repeat endovascular procedures, and two patents converted to open surgery because of significant endoleak. Nine cases of SIDR were detected in the TEVAR group, but none in the TEVAR + RBS group.

Data on the nine SIDRs are summarized in Table I. The SIDR and treatment strategy for patient 1 are reported elsewhere; the entire development of the SIDR was recorded for this case.13 Moderate type I endoleak was detected in patient 6 by CTA 3 months after primary TEVAR. The patient chose medical treatment without reintervention. However, at the 18th month, the patient presented with back pain, and a redissection at the distal edge of the stent graft was revealed by CTA. A special treatment strategy was used for this patient: we performed secondary TEVAR + RBS (stent-graft: Zenith TX2 30-30-200 mm, RBS: OptiMed 18-80 mm) through the right axillary artery, because the true lumen of infrarenal abdominal aorta was compressed by false lumen to occlusion and the blood supply to both lower limbs came from the false lumen. The secondary stent graft was deployed to the distal part of the previous one, with 50-mm overlap. Then a right axillary-right femoral-left femoral artery bypass was performed to prevent lower limb ischemia (Fig 3). At the 10-month follow-up after the secondary intervention, this patient was free from complications and the bypass (polytetrafluoroethylene prosthesis) was patent. Patient 7 suffered from sudden chest pain 7 days after the primary TEVAR. Immediate CTA revealed that the SIDR retrogradely involved the ascending aorta. Because of unwillingness to undergo open surgery, the patient was provided intensive care and medical treatment. Three days later, he died suddenly from the suspected aortic rupture. Thus the mortality from SIDR in this series is 11.1% (1/9).

Comparison between SIDRs and non-SIDRs. The median time of SIDR onset was 26 months. Most SIDRs (5/9, 55.6%) were asymptomatic and found by CTA.
during routine follow-up. One SIDR (1/9, 11.1%) was located at the lesser curve of the aorta; the others were located at the greater curve. All SIDRs were on the dissected flap. The patients with SIDRs were 58 ± 7 years of age, which was not significantly different from the age of patients without SIDRs (Table II). The preoperative mismatch rate of the SIDR, 192.7 ± 54.9%, was significantly higher than that of the non-SIDR, 131.9 ± 10.4% (P < .05). This observation suggested that preoperative mismatch rate might predict the risk of SIDR occurrence in the long term. The OR of the preoperative mismatch rate was 2.42, and the 95% confidence interval (CI) was 1.81 to 3.25 (P < .05). The follow-up mismatch rate for SIDRs was significantly higher than that for non-SIDRs (145.4 ± 34.6 vs 120.3 ± 16.1; P < .05), and the OR (95% CI) was 4.46 (3.22-4.91; P < .05). This indicated that consistent mismatch in the follow-up period might lead to excessive radial force, which could cause the SIDR. Three of the nine (33.3%) cases of SIDR were treated primarily with a stent graft with longitudinal connecting bar (TALENT, Hercules and Relay), but this did not significantly differ from the situation in the non-SIDR group (206/456, 45.1%; P = .524), which suggests that the design of the endograft with longitudinal bar does not increase the incidence of SIDR.

**Fig 3.** A, Preoperative computed tomography angiography (CTA) revealed a complicated type B dissection in patient 6. The true lumen was severely compressed by the false lumen. B, Moderate type I endoleak detected 3 months after primary thoracic endovascular aortic repair (TEVAR). C, D, The distal end of the stent graft perforated the flap. The stent graft-induced distal redissection and aneurysmal expansion of the false lumen were revealed by CTA at 18 months. E, The true lumen of the distal descending aorta was so narrow that the abdominal organs were in a state of ischemia. The blood supply to both lower limbs was from the false lumen. F, After the secondary TEVAR + RBS through the right carotid artery, the redissection was completely excluded, and the true lumen of the distal descending aorta was obviously expanded, which remarkably improved the blood supply to abdominal organs. CTA at 10 months after the secondary intervention confirmed the patency of the bypass and the original type I endoleak, which will be treated by further intervention.

**Follow-up and comparison between TEVAR and TEVAR + RBS.** A total of 154 RBSs were used; the median size was 24 mm (range, 20-28 mm). The overlapping length of stent graft and RBS was 36.5 ± 2.5 mm. No dislodging or disjointing of the RBS was observed in the follow-up period. A comparison between TEVAR and TEVAR + RBS is outlined in Table III. Preoperative mismatch rates did not significantly differ between the two groups. The incidence of SIDR was significantly lower in the TEVAR + RBS group (0% vs 2.9%; P = .033), and the need for secondary intervention was significantly less in this
group as well (3.9% vs 9.3%; \(P = .040\)), as compared with the TEVAR group. However, RBSs did not reduce all-cause mortality (\(P = .352\)) and aorta-related mortality (\(P = .434\)). The cumulative survival from SISR was calculated and is represented by the Kaplan-Meier curve in Fig 4.

Comparison between acute and chronic aortic dissection. The incidence of SISR in patients who were treated primarily in their acute phase was 2.3% (6/266), and that in chronic dissections was 1.5% (3/199). Although the incidence of SISR seemed to be higher in the acute group, the difference was not significant (\(P = .739\); Table II). 32.3% (86/266) acute dissections, and 10.7% (206/196456 (45.1%) \(P = .524\). The incidence of SISR in patients who were treated primarily in their acute phase was 2.3% (6/266), and that in chronic dissections was 1.5% (3/199). The difference was not significant (\(P = .739\); Table II). 32.3% (86/266) acute dissections, and 10.7% (206/196456 (45.1%) \(P = .524\). The overall mortality rate of the acute group was 3.0% (8/266), and that of the chronic group was 1.5% (3/199). The difference was insignificant (\(P = .366\)). Notably, the acute group had a significantly higher morbidity rate than the chronic group (15.4% vs 8.5%; \(P = .033\)). But when the focus is on acute and chronic dissections treated by TEVAR + RBS, the morbidity rates of the acute and chronic groups did not significantly differ (12.8% vs 7.4%; \(P = .302\)). Also, the morbidity rates for acute dissections treated by TEVAR and TEVAR + RBS did not significantly differ (16.7% vs 12.8%; \(P = .471\)).

Aortic remodeling. For all patients in this cohort, the true lumens at P1 (16.82 ± 5.01 vs 26.83 mm ± 5.01 mm; \(P < .001\)), P2 (13.12 ± 5.99 vs 19.02 ± 4.87 mm; \(P < .001\)), P3 (14.19 ± 6.12 vs 22.02 ± 3.83 mm; \(P < .001\)), and P4 (12.01 ± 4.12 vs 14.31 ± 3.93 mm; \(P < .001\)) were significantly expanded. Simultaneously, the false lumens at P1 (25.62 ± 14.01 vs 12.84 ± 14.00 mm; \(P < .001\)), P2 (23.81 ± 10.01 vs 14.76 ± 8.23 mm; \(P < .001\)), P3 (24.01 ± 10.76 vs 15.87 ± 9.03 mm; \(P < .001\)), and P4 (16.91 ± 6.91 vs 13.10 ± 7.36 mm; \(P < .001\)) significantly decreased at the 1-year follow-up. Table IV compares morphological evolution over time between the TEVAR group and TEVAR + RBS. To our notice, placement of the RBS could significantly expand the true lumen at the P2 level from 17.01 ± 5.07 to 22.44 ± 4.09 mm, and at the P3 level, from 20.01 ± 3.97 to 24.35 ± 3.27 mm at 1 year of follow-up (\(P < .001\)), but the RBS could not improve the remodeling course of the false lumen and aorta.

DISCUSSION
Since the application of endovascular devices in 1999 to treat aortic dissection, short- and midterm outcomes have been encouraging.\(^1\)\(^2\) hence TEVAR has become an important optional treatment for complicated dissections affecting the distal arch and descending aorta. Although the endovascular procedure allows less invasive access to repair aortic pathologies, the complications caused by stent graft devices remain a source of concern. As patients with thoracic dissections are relatively younger than those with aneurysms, the long-term durability of TEVAR for dissection might be paramount. Cases of re-dissection with new entries located on the proximal or distal edge of the stent

Table II. Comparison of the SISR and non-SISR groups

<table>
<thead>
<tr>
<th></th>
<th>SISR group (n = 9)</th>
<th>Non-SISR group (n = 456)</th>
<th>(P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age, years</td>
<td>58 ± 7</td>
<td>59 ± 7</td>
<td>&gt;.05</td>
</tr>
<tr>
<td>Gender (male), %</td>
<td>88.9%</td>
<td>78.3%</td>
<td>.985</td>
</tr>
<tr>
<td>Acute/chronic aortic dissection, n</td>
<td>6/3 (66.7%/33.3%)</td>
<td>260/196 (57.0%/42.8%)</td>
<td>.739</td>
</tr>
<tr>
<td>Preoperative mismatch rate, %</td>
<td>192.7 ± 54.9%</td>
<td>131.9 ± 10.4%</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Follow-up mismatch rate, %</td>
<td>145.4 ± 34.6%</td>
<td>120.3 ± 16.1%</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Stent graft with longitudinal bar, n</td>
<td>3/9 (33.3%)</td>
<td>206/456 (45.1%)</td>
<td>.524</td>
</tr>
<tr>
<td>Median follow-up period, months</td>
<td>39</td>
<td>44.5</td>
<td>—</td>
</tr>
</tbody>
</table>

SIDR, Stent graft-induced distal redissection.

Table III. Comparison of patient outcomes between the TEVAR and the TEVAR + RBS groups

<table>
<thead>
<tr>
<th></th>
<th>TEVAR group (n = 311)</th>
<th>TEVAR + RBS group (n = 154)</th>
<th>(P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute/chronic aortic dissection, n</td>
<td>180/131 (57.9%/42.1%)</td>
<td>76/68 (55.8%/44.2%)</td>
<td>.691</td>
</tr>
<tr>
<td>Preoperative mismatch rate, %</td>
<td>135.5 ± 13.6%</td>
<td>131.8 ± 10.7%</td>
<td>.172</td>
</tr>
<tr>
<td>Complications, n</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access problem</td>
<td>6 (1.9%)</td>
<td>2 (1.3%)</td>
<td>.910</td>
</tr>
<tr>
<td>Paraparesis/paraplegia</td>
<td>3 (1.0%)</td>
<td>1 (0.6%)</td>
<td>.729</td>
</tr>
<tr>
<td>SISR</td>
<td>9 (2.9%)</td>
<td>6 (3.9%)</td>
<td>.040</td>
</tr>
<tr>
<td>Secondary intervention for all causes</td>
<td>29 (9.5%)</td>
<td>29 (8.9%)</td>
<td></td>
</tr>
<tr>
<td>Conversion to surgery</td>
<td>2 (0.6%)</td>
<td>0</td>
<td>.807</td>
</tr>
<tr>
<td>Overall death</td>
<td>9 (2.9%)</td>
<td>2 (1.3%)</td>
<td>.352</td>
</tr>
<tr>
<td>Aorta-rated death</td>
<td>6 (1.9%)</td>
<td>1 (0.6%)</td>
<td>.434</td>
</tr>
</tbody>
</table>

RBS, Restrictive bare stent; SIDR, stent graft-induced distal redissection; TEVAR, thoracic endovascular aortic repair.

\(^{a}\)Significant, < .05.
graft after TEVAR for type B aortic dissections have been reported.20-28

The relative rigidity of the endograft and the fragile flap might contribute to the events on the margin of the stent graft. Acute aortic dissection, which is characterized by the unstable and fragile aortic wall, was associated with a higher incidence of SIDR, but the difference from chronic dissection is not significant. This may be ascribed to the low incidence of SIDR. Sudden death after endograft placement has been described previously,29 and has been considered to be induced by a lack of conformability and intimal injury. This was based on autopsy and open surgery evidence that the stent graft could protrude into the false lumen or even cause the perforation of the aortic wall.11,30

The new intimal tear might result in retrograde dissections or pseudoaneurysms, which were reported in 1.8% of acute and 3.4% of chronic dissection.31 In another report, the incidence of stent graft-induced new tear reached 3.4%, and the incidence of SIDR was 1.2% with a mortality as high as 25%.11 In our cohort, the incidence of SIDR was 1.3% (9/674), and the mortality rate was 11.1%.

Riambau et al suggested that SIDR might be caused by mechanical stress of the distal endograft against the descending aortic wall. They described two patients with type B dissections that were repaired primarily with relatively short stent grafts. The stent grafts were positioned and angulated with the longitudinal descending aorta. The distal end of the endograft, aligned with and protruding into the descending aorta, caused the SIDR.12

Kato et al thought that the disruption of the dissected aortic wall was related to endograft migration, prosthetic mechanic effect, and hemodynamic stress.10 Dong et al thought that the relatively larger stent graft, which was chosen according to the proximal landing zone, would exert excessive radial force on the fragile dissected flap.11 This theory can be supported by our study. Choosing an adequate size of stent graft in aortic dissection seems to be a subject of controversy. There is literature stating that a correctly sized stent graft is 10% larger than the diameters of the thoracic true lumen in acute dissection or 20% larger than these diameters in chronic dissection.32 The diameter of a stent graft is determined by the diameter of the proximal unaffected aorta as a baseline. But the remarkably small diameter of the compressed true lumen of the distal descending aorta made the oversize rate on the distal edge of the endograft larger than the largest suggested oversize rate, 20%. Thus, we thought that patients with estimated mismatch rates greater than 120% might be at high risk of local trauma on the distal edge of the endograft. We wanted to study this subgroup of type B aortic dissections and so chose the estimated preoperative mismatch rate greater than 120% as one of the inclusion criteria. And it also was the indication for RBS placement. We found that the preoperative mismatch rate of the SIDR group was significantly higher than that of the non-SIDR group. And the last mismatch rate before the occurrence of SIDR, which indicated the consistent mismatch between the distal end of the stent graft and the true lumen, also significantly differed between the two groups. Therefore, reducing the mismatch might prevent SIDR.

Several suggestions for preventing SIDR have been made. To decrease the misalignment between the device and the intima, a longer stent graft to cover the descending aorta until it fits the parallel portion has been

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Fig 4. Kaplan-Meier estimates of 48-month cumulative proportion surviving in the thoracic endovascular aortic repair (TEVAR) group and TEVAR + restrictive bare stent (RBS) group. SIDR, Stent graft-induced distal redissection.
The RBS is chosen on the basis of the preoperative measurement. In our study, we took the long diameter of the true lumen at the intended distal edge of the stent graft as the estimated diameter of the RBS. If we had chosen the RBS on the basis of the short diameter, the stent might have lost apposition and dislodged during follow-up when the false lumen collapsed and true lumen expanded. 1-year follow-up data, the mean diameter of the true lumen at P3 was 24.35 mm in the TEVAR + RBS group, which was consistent with the median diameter of the RBS (24 mm). No dislodging or disjointing of the RBS was observed. The outcomes supported the rationality of this method for choosing RBSs. And we found that the RBSs used in patients with acute aortic dissections did not increase the morbidity rate, so they could be safely placed in acute aortic dissections.

The distal component of Zenith TX2 has a distal bare stent too. But its distal bare stent is designed for distal anchoring, not restriction. In our study, the RBS could protect the aortic intima at the distal edge of the stent graft from aortic prosthetic trauma and improve aortic remodeling at certain levels. Determination of the hemodynamic significance of this promising remodeling requires further study. In addition, elucidation of the protective function of RBSs may require histological and pathologic studies.

**CONCLUSIONS**

Placement of restrictive bare stents, as an adjunct to thoracic endovascular aortic repair for complicated type B aortic dissections, may protect the intima at the distal edge of the stent graft from excessive radial force and reduce the incidence of stent graft-induced distal dissection. In addition, restrictive bare stents may expand the true lumen at certain levels. Elucidation of the underlying mechanism and long-term effectiveness requires further study.

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Conception and design: JF, QL, ZJ

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**REFERENCES**


