

## Midterm Results of Transluminal Endovascular Grafting in Patients with DeBakey Type III Dissecting Aortic Aneurysms

Shinichi Suzuki, MD,<sup>1</sup> Kiyotaka Imoto, MD,<sup>1</sup> Keiji Uchida, MD,<sup>1</sup>  
Yoshinori Takanashi, MD,<sup>1</sup> and Kimihiko Kichikawa, MD<sup>2</sup>

**Objective:** Transluminal endovascular grafting (TEG) is less invasive than conventional operative procedures for the treatment of DeBakey type III dissecting aortic aneurysms (DAA). We have used two different kinds of stent grafts covered with woven Dacron grafts, a Gianturco Z-stent graft (G-SG) and a Spiral Z-stent graft (S-SG). Because the G-SG lacks adequate flexibility, the end of the graft may injure the intima after long-term deployment in the proximal descending aorta. We have used S-SGs, which are more flexible than G-SG, to improve outcome. We report our late midterm results and discuss treatment policy.

**Subjects and Methods:** We studied 45 patients with DeBakey type III DAA. Thirty-two G-SGs and 13 S-SGs were used. Follow-up ranged from 1 year 6 months to 8 years 5 months (mean, 5 years 2 months).

**Results:** 1) Surgical outcome: (a) TEG was technically successful in all patients. There was no operative mortality. (b) One week after surgery, 36 patients had no endoleaks, 5 had minor endoleaks, and 4 had major endoleaks. 2) Late midterm results: (a) Four patients with residual major endoleaks, underwent replacement of the descending thoracic aorta. (b) Intimal injury occurred at the distal end of the stent graft 4 to 18 months (mean, 10.5 months) after surgery in 12 patients with G-SG and 1 with S-SG. One of these patients had recurrent dissection, and 12 had ulcer like projections (ULP). Two patients underwent additional stent implantation to block blood flow. (c) Four patients with S-SG had major endoleaks 3 to 6 months after surgery. In 3 of these patients, the Spiral Z-stents were compressed and occluded, and thrombus had formed in the lumen. Three patients underwent replacement of the descending thoracic aorta. (d) Additional replacement of the descending thoracic aorta was done in 9 of the 45 patients (20%) 4 to 24 months after TEG. All patients responded to treatment and were discharged from the hospital.

**Conclusion:** Intimal injury was caused by Gianturco Z-stents because of inadequate flexibility, and endoleaks and stent-graft occlusion were caused by Spiral Z-stents because of insufficient radial force against the aortic wall. The development of stents with these improved properties is expected to further improve outcome. (*Ann Thorac Cardiovasc Surg* 2006; 12: 42–9)

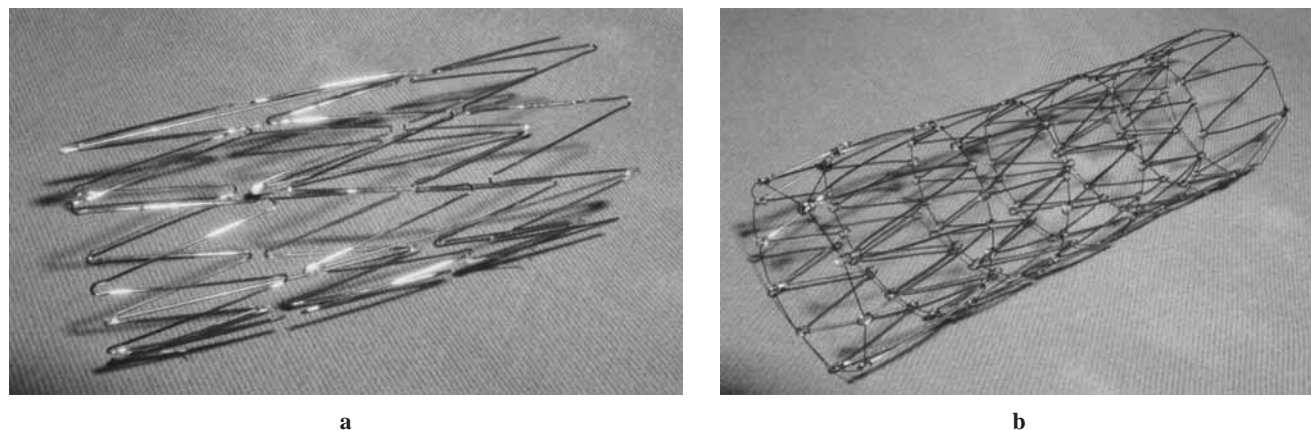
**Key words:** transluminal endovascular grafting, DeBakey type III dissecting aortic aneurysms, midterm results

From <sup>1</sup>Department of Cardiovascular Surgery, Yokohama City University School of Medicine, Yokohama, and <sup>2</sup>Department of Radiology, Nara Medical University, Nara, Japan

Received June 3, 2005; accepted for publication August 15, 2005. Address reprint requests to Shinichi Suzuki, MD: Department of Cardiovascular Surgery, Yokohama City University School of Medicine, 4-57 Urafune-cho, Minami-ku, Yokohama, Kanagawa 232-0024, Japan.

### Introduction

Transluminal endovascular grafting (TEG) for the treatment of DeBakey type III dissecting aortic aneurysms (DAA) has attracted considerable attention because it is less invasive than conventional operative procedures. Surgical outcomes of TEG have been reported,<sup>1-6</sup> but late



**Fig. 1.** Stents.  
**a:** A Gianturco Z-stent.  
**b:** A spiral Z-stent.

results remain unclear. We previously reported that grafts prepared from Gianturco Z-stents (Cook Inc., Bloomington, IN, USA) (Fig. 1-a) may not adequately accommodate to the curvature of the aortic arch near the origin of the subclavian artery and may injure the intima in the late midterm when used in patients with extensive aortic dissections.<sup>7)</sup> To solve these problems and to improve surgical outcome, we used grafts prepared from Spiral Z-stents (Nara Medical Univ., Nara, Japan) (Fig. 1-b), which are more flexible than Gianturco Z-stents, for transluminal endovascular stent-graft placement in the proximal descending aorta. We report our midterm results and discuss future policies for the treatment of DeBakey type III DAA.

## Subjects and Methods

### Subjects

TEG was performed in 45 patients with DeBakey type III DAA (37 men and 8 women). The mean age was  $57.4 \pm 10.9$  years (range, 33 to 82 years). Of the 45 patients, 8 had Stanford type A (IIIbR) dissections, 31 had Stanford type B dissections with a patent false lumen, and 6 had thrombosed-type ulcer like projections (ULP). The indications for TEG was double barreled aortic dissections or dissecting aneurysms (diameters  $>4.5$  cm). TEG was done 3 days to 120 months (mean,  $21.9 \pm 32.9$  months) after the onset of aortic dissection. Two patients had acute dissections (less than 2 weeks after onset), and 43 had chronic dissections (2 weeks or more after onset). The mean maximum diameter of the aneurysms was  $4.6 \pm 0.8$  cm (range, 3.5-7.0 cm). Informed

consent for TEG was obtained from all patients in accordance with the guidelines of our hospital's ethics committee.

### Preparation of stent grafts

We used 32 Gianturco Z-stents and 13 Spiral Z-stents (Fig. 1), covered with UBE woven polyester graft material (porosity, 50 ml/min/cm<sup>2</sup>/120 mmHg; thickness, 0.15 or 0.18 mm) secured with 5-0 polypropylene sutures. The diameter of the true lumen at the site of the entry or ULP was measured by aortography and computed tomography (CT). The size of the vascular graft was equivalent to 1.2 times the true lumen diameter.

### Stent-graft implantation

Stent-graft implantation was done in the operating room with the patients under general anesthesia. The procedure was monitored by transesophageal ultrasonography and fluoroscopy. A retroperitoneal approach via the femoral artery or iliac artery was used for access. The Seldinger technique was used to place a guide wire into the access route via the right brachial artery. An 18-22-French delivery sheath (Teflon sheath; Cook Inc., Bloomington, IN, USA) was introduced over the guide wire to the descending thoracic aorta (tug of wire technique).

Before stent-graft implantation, the site of the stent graft was confirmed by aortography (Fig. 2-a). Adenosine 5'-triphosphate (ATP)-induced cardiac arrest<sup>8)</sup> was used to prevent migration of the stent graft on exposure to blood flow when the graft was pushed out of the sheath and deployed within the aortic lumen. After the induction of anesthesia, a right ventricular pacing electrode was



**Fig. 2.** Aortogram.

- a: An entry tear (arrow) on aortography before stent-graft placement.
- b: Aortogram after stent-graft placement.

deployed. If ATP-induced cardiac arrest persisted after placement of the endovascular stent graft, pacing was done to prevent cardiac complications. Aortography was repeated after stent-graft placement (Fig. 2-b) to assess the presence and degree of residual blood flow (endoleaks) into the lumen of the dissection. The minor endoleak means that the degree of blood flow into the false lumen was decreased, and the major endoleak means that it was same as before surgery.

Since 1999 we have used Spiral Z-stents for placement in the proximal descending aorta near the left subclavian artery. Spiral Z-shaped grafts are relatively easy to deploy at the proximal descending aorta near the left subclavian artery. Our policy is to block flow to the entry while preserving the flow of the left subclavian artery.

Postoperative evaluation and follow-up comprised CT scanning and aortography. CT scanning was done on the day of surgery, 1 week after surgery, every 3 months within the first year after surgery, and every 6 months thereafter. Aortography was performed 1 week after surgery and whenever CT scans showed abnormalities. The duration of postoperative follow-up ranged from 1 year 6 months to 8 years 5 months (mean, 5 years 2 months). A 2-tailed P value <0.05 was considered statistically significant. All statistical analyses were conducted with SPSS software.

## Results

### Surgical outcome

a) TEG was successfully accomplished in all patients. No patient died after surgery or had paraplegia.

b) Thirty-two patients had no endoleaks, 9 had minor endoleaks, and 4 had major endoleaks immediately after surgery, and 36 had no endoleaks, 5 had minor endoleaks, and 4 had major endoleaks 1 week after surgery. Flow into the false lumen was successfully obliterated 1 week after surgery in 84% (38/45) of the patients. Major endoleaks occurred in 4 patients (2 with Gianturco Z-stents and 2 with Spiral Z-stents).

### c) Stent-graft migration during surgery (2 patients)

In 1 patient with an entry 18 mm from the origin of the subclavian artery, the subclavian artery was obstructed by proximal migration of a Gianturco Z-stent graft during placement (Fig. 3). The inflexible Gianturco Z-stent apparently could not accommodate to the curvature of the aortic arch and migrated proximally. Among 3 patients with an entry 15 mm from the origin of the subclavian artery, the entry was successfully sealed in 1 by the placement of a Spiral Z-stent; the flow of the left subclavian artery was preserved (Fig. 2-b). However, in a pa-



**Fig. 3.** Angiogram showing occlusion of the left subclavian artery (arrow) by a stent graft.

tient with a large ULP who underwent placement of a Spiral Z-stent, the stent graft migrated distally into the ULP; and a placement of a Gianturco Z-stent in the proximal aorta was required. Spiral Z-stents may be more compatible with the proximal descending aorta than Gianturco Z-stents, but have lower radial force against the aortic wall and therefore provide less frictional seal.

### Mid-term results

#### a) Endoleaks and change in aneurysmal size

Four patients had evidence of major endoleaks on Aortogram 1 week after surgery. These patients underwent replacement of the descending thoracic aorta.

In the 36 patients without endoleaks, the false lumen was thrombosed, obliterating blood flow. With consolidation of the thrombus, the false lumen shrank and the diameter of the true lumen increased (Fig. 4). As compared with the value before surgery, aortic aneurysmal size decreased in 28 patients, and was unchanged in 8.

#### b) Stent-graft-related intimal injury

Four to 18 months after operation (mean, 10.5 months), dissection recurred in 1 patient and ULP newly developed in 12 patients at the distal end of the stent graft (Figs. 5-a, b). The incidence of these complications was significantly higher in patients with Gianturco Z-stents (38%, 12/32) than in those with Spiral Z-stents (8%, 1/13;  $P < 0.05$ ). These complications were attributed to intimal injury by the distal end of the stent graft. Additional stent implantation was done in the patient with recurrence of dissection and in 1 patient with an aortic diameter of more than 50 mm at the site of the ULP; flow was successfully obliterated (Fig. 5-c). In the patient who underwent addi-

tional stent implantation for recurrence of dissection, paraparesis developed 1 day after surgery, but the patient was able to walk unaided after rehabilitation.

Four patients underwent replacement of the descending thoracic aorta.

The other 8 patients were observed because the aortic diameter at the site of ULP was less than 50 mm.

#### c) Stent-graft-related thrombotic occlusion

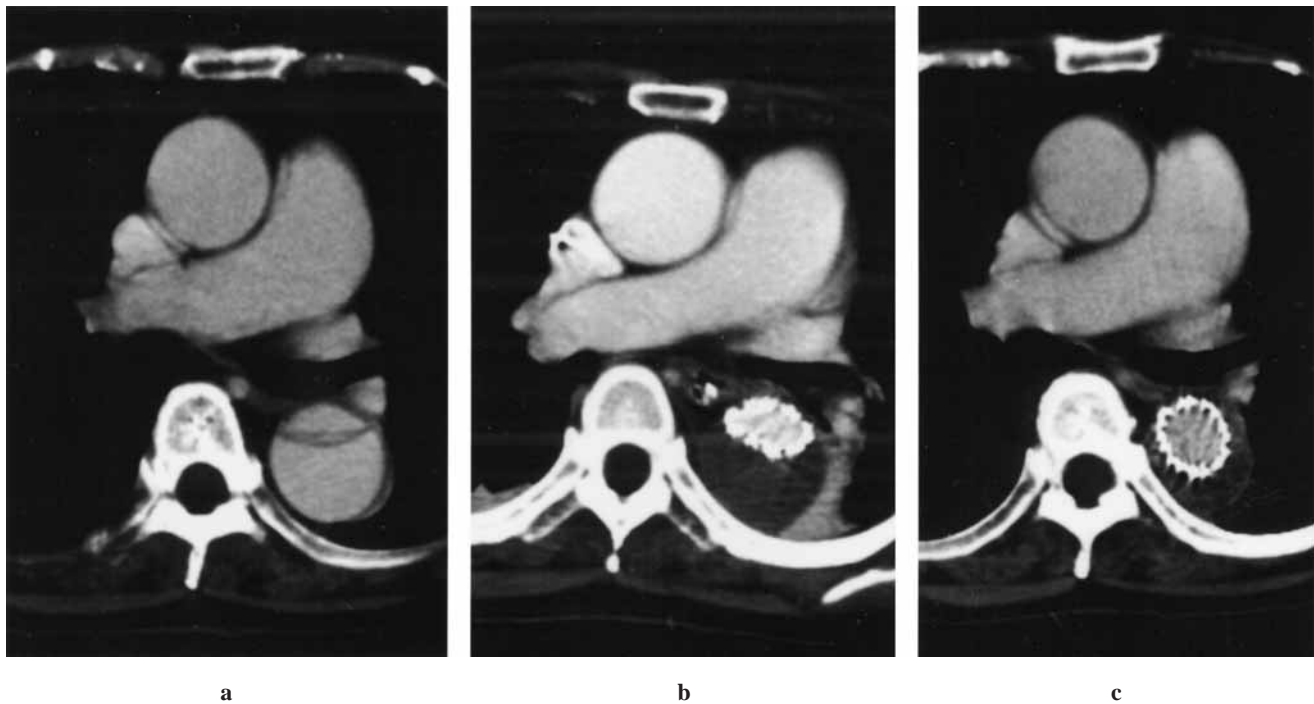
Four patients with Spiral Z-stents had new major endoleaks 3 to 6 months (mean 3.8 months) after surgery, but no major endoleaks immediately after surgery. In 3 of these patients, the major endoleaks were accompanied by occlusion of Spiral Z-stents, and thrombus formed in the lumen (Fig. 6). Three patients underwent replacement of the descending thoracic aorta, and the other was observed because of no increase in aneurysmal size and no disturbance of flow distal to the stent graft.

#### d) Removal of stent grafts and replacement of the descending thoracic aorta

Nine of the 45 patients (20%) underwent replacement of the descending thoracic aorta 4 to 24 months after surgery.

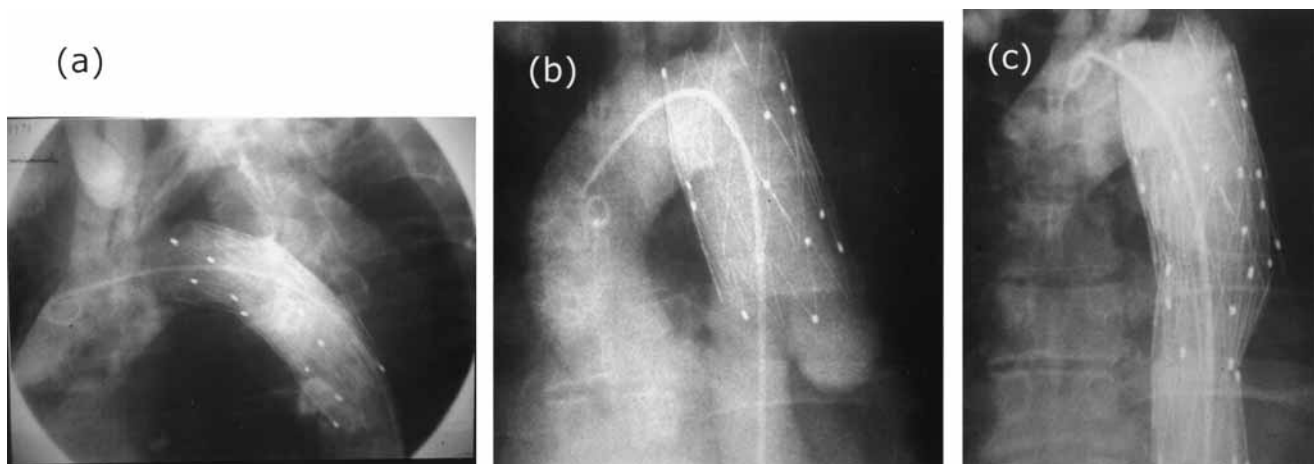
Four of 32 patients (13%) with Gianturco Z-stents, and 5 of 13 patients (39%) with Spiral Z-stents underwent replacement of the descending thoracic aorta. No patient died after surgery or had paraplegia. One patient who underwent emergency operation because of a ruptured aneurysm had a stroke but was able to walk after rehabilitation.

All patients improved after treatment and were discharged from the hospital.



**Fig. 4.** CT scans before and after stent-graft placement.

- a: Before stent-graft placement.
- b: Immediately after stent-graft placement.
- c: Three months after stent-graft replacement.



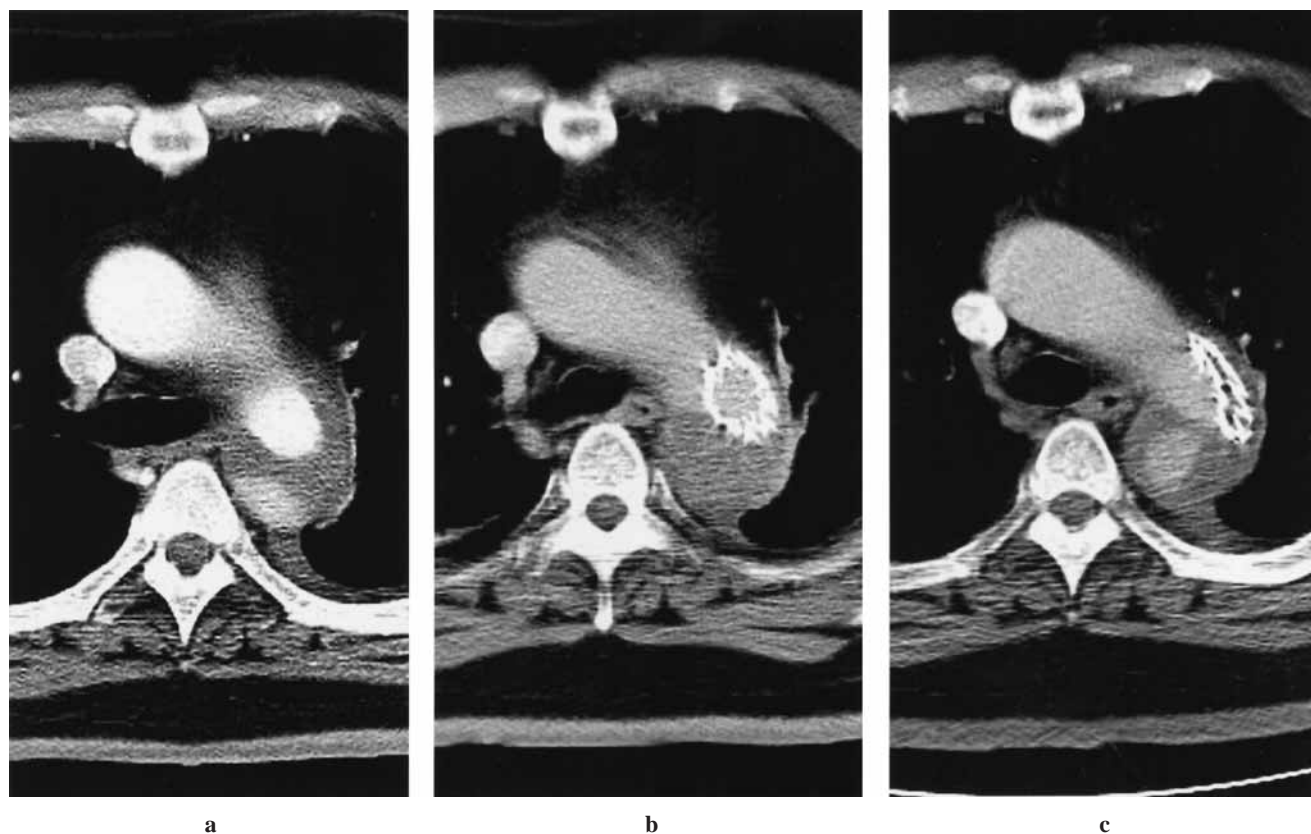
**Fig. 5.** Aortogram.

- a: Aortogram immediately after stent-graft placement.
- b: Aortogram 1 year after stent-graft placement, showing ulcer-like projections at the distal portion of the stent graft.
- c: Aortogram showing successful blockage of flow to ulcer-like projections after additional stent-graft placement.

*e) Late mortality*

There were 5 late deaths. The causes of death were as follows: rupture of a pseudoaneurysm at the base of the aorta after ascending thoracic aortic arch replacement for

a Stanford type A dissection in 1 patient (7 months after surgery for dissection and 4 months after TEG); cerebral hemorrhage in 1 (5 months after surgery); pneumonia in 1 (6 months after surgery); cancer in 1 (2 years 1 month



**Fig. 6.** CT scans showing occlusion of a stent graft.

**a:** Before stent-graft placement.

**b:** Immediately after stent-graft placement.

**c:** After stent-graft placement (an endoleak and occlusion of the lumen of the stent graft).

after surgery); and sudden death in 1 (2 years 6 months after surgery). No death was clearly related to stent-graft placement.

## Discussion

Stent-graft treatment of the aorta was initially proposed by Parodi et al. as a minimally invasive technique for endovascular surgery in high-risk patients with abdominal aortic aneurysms.<sup>9,10</sup> This technique was successfully used to treat thoracic aortic aneurysms by investigators from Stanford University in 1992.<sup>11,12</sup> In 1999, they reported the outcomes of thoracic aortic aneurysm repair with a self-expanding Gianturco Z-stent covered with woven Dacron graft material in 103 patients.<sup>12</sup> Aneurysms were completely thrombosed in 86 patients (83%). The rate of early mortality (within 30 days) was  $9\pm 3\%$  (7 patients died of perioperative cerebral complications and 3 of paraplegia).

Antihypertensive therapy has been the treatment of choice for acute Stanford type B acute aortic dissection in patients with no complications. The indications for surgery in patients with Stanford type B acute aortic dissection include impending rupture, rupture, malperfusion due to dissection, and persistence of pain after effective antihypertensive therapy. However, the results of urgent surgery in patients with these complications have been poor. Recently, endovascular stent-graft prostheses have been successfully used to repair entry tears in the descending thoracic aorta; this procedure has attracted considerable interest and performed with more frequency.

The outcome of surgical treatment for aneurysms of the descending thoracic aorta and the thoracoabdominal aorta associated with chronic Stanford type B dissection remains poor. Surgical therapy can lead to complications such as paraplegia due to spinal ischemia, brain injury, dyspnea, and abdominal malperfusion.

Less than 20% of patients with Stanford type B dis-

section who receive conservative therapy in the acute phase have been reported to require surgery for false-lumen aneurysms after about 5 years.<sup>13)</sup> Patients who have an aortic diameter of 40 mm or greater in the acute phase are highly likely to require surgical treatment in the late phase.<sup>14)</sup>

The objectives of TEG in patients with DeBakey type III aortic dissection are to cover the entry in the descending thoracic aorta with the stent graft, cause thrombosis of the false lumen, and prevent the formation and rupture of false-lumen aneurysms. At our center, TEG was first used for the treatment of aortic diseases in 1996. Between October 1996 and October 2003, TEG was performed in 45 patients with aortic dissection. The early results of TEG in patients with DeBakey type III DAA were satisfactory. Nine patients (20%) required replacement of the descending thoracic aorta during the midterm period. All of these patients improved and were discharged from the hospital. A history of stent-graft implantation did not appear to increase the risk of reoperation. In 36 patients with no endoleaks, thrombosis of the false lumen and absorption of the thrombus were associated with an increase in the size of the true lumen. The aortic aneurysmal diameter decreased in 28 patients and was unchanged in 8. TEG thus prevented the enlargement and rupture of aneurysms in 36 of the 45 patients (80%). In the midterm phase, new dissections were caused by intimal injury in patients with Gianturco Z-stents, and new endoleaks and stent-graft occlusion were caused by lack of radial force against the aortic wall in those with Spiral Z-stents.

In patients with closure of the entry of dissecting aortic aneurysms, the aortic wall in contact with the stent graft remains frail until consolidation of the thrombosed false lumen, even if flow is successfully obliterated by the stent graft. During this period, the diameter of the true lumen also changes. Gianturco Z-stents are somewhat inflexible and return to their original straight structure when deployed in the arch of the descending thoracic aorta. Stent inflexibility may increase the radial force of the distal end of the stent graft against the aortic wall and injure the aortic intima, leading to the development of new ULP and recurrent dissection at the site of injury. Such complications were seen in 38% (12/32) of the patients with Gianturco Z-stents 6-12 months after surgery, when the false lumen was thrombosed but not completely consolidated and the true lumen was not adequately enlarged.

In patients with Spiral Z-stents, the incidence of intimal injury was low (8%, 1/13). This lower incidence may

be ascribed to the fact that Spiral Z-stents are more flexible and compatible with the curvature of the aortic arch than are Gianturco Z-stents. However, major endoleaks occurred in the early phase after surgery, although not immediately after surgery, in patients with Spiral Z-stents. The resulting blood flow compressed and occluded the stent graft, causing thrombosis of the lumen. Although Spiral Z-stents are very flexible, they lack adequate radial force against the aortic wall. This lack of radial force may have led to endoleaks after the proximal side of the stent graft was exposed to blood flow or the true lumen had enlarged.

The two problems of intimal injury and stent-graft occlusion, occurring in the midterm period, commonly occur after TEG in patients who have aortic dissection with a patent false lumen. In such patients, stent grafts have to be placed at the site of dissection to block flow to the false lumen, thereby causing its thrombosis and absorption. These events change the diameter of the true lumen. During this period, it is important to maintain sufficient radial force of the stent graft against the aortic wall. Gianturco Z-stents are associated with the risk of excessive local radial force, whereas spiral Z-shaped stents may provide too little radial force.

To solve these problems, changes in the true lumen diameter after TEG should be closely examined. The true lumen diameter may differ depending on the time from dissection onset and on hemodynamics; the intimal flap undergoes histological changes. Moreover, the true lumen diameter after TEG and changes in the diameter of the thrombosed false lumen also depend on the individual patient. Careful examination of these issues will most likely increase the rate of entry closure and promote the development of stent grafts with minimal late complications. The development and further study of stent grafts should take into account problems during the late midterm phase, extending from the thrombosis to consolidation of the false lumen.

In conclusion, the development of new stent grafts with radial force able to withstand changes in true lumen diameter after entry closure would improve outcome in patients undergoing TEG for DeBakey type III DAA.

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