

## NONSURGICAL RECONSTRUCTION OF THORACIC AORTIC DISSECTION BY STENT-GRAFT PLACEMENT

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### ABSTRACT

**Background** The treatment of thoracic aortic dissection is guided by prognostic and anatomical information. Proximal dissection requires surgery, but the appropriate treatment of distal thoracic aortic dissection has not been determined, because surgery has failed to improve the prognosis.

**Methods** We prospectively evaluated the safety and efficacy of elective transluminal endovascular stent-graft insertion in 12 consecutive patients with descending (type B) aortic dissection and compared the results with surgery in 12 matched controls. In all 24 patients, aortic dissection was diagnosed by magnetic resonance angiography. In each group, the dissection involved the aortic arch in 3 patients and the descending thoracic aorta in all 12 patients. With the patient under general anesthesia, either surgical resection was undertaken or a custom-designed endovascular stent-graft was placed by unilateral arteriotomy.

**Results** Stent-graft placement resulted in no morbidity or mortality, whereas surgery for type B dissection was associated with four deaths (33 percent,  $P=0.09$ ) and five serious adverse events (42 percent,  $P=0.04$ ) within 12 months. Transluminal placement of the stent-graft prosthesis was successful in all patients, with no leakage; full expansion of the stents was ensured by balloon inflation at 2 to 3 atm. Sealing of the entry tear was monitored during the procedure by transesophageal ultrasonography and angiography, and thrombosis of the false lumen was confirmed in all 12 patients after a mean of three months by magnetic resonance imaging. There were no deaths or instances of paraplegia, stroke, embolization, side-branch occlusion, or infection in the stent-graft group; nine patients had postimplantation syndrome, with transient elevation of C-reactive protein levels and body temperature plus mild leukocytosis. All the patients who received stent-grafts recovered, as did seven patients who underwent surgery for type B dissection (58 percent) ( $P=0.04$ ).

**Conclusions** These preliminary observations suggest that elective, nonsurgical insertion of an endovascular stent-graft is safe and efficacious in selected patients who have thoracic aortic dissection and for whom surgery is indicated. Endoluminal repair may be useful for interventional reconstruction of thoracic aortic dissection. (N Engl J Med 1999;340:1539-45.)

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**M**ANAGEMENT of thoracic aortic dissection depends on the patient's prognosis. Whereas patients with proximal dissections clearly benefit from surgical repair, the therapeutic strategy for dissections of the aortic arch and descending thoracic aorta is far from settled. Given the high morbidity and intraoperative mortality associated with surgical resection,<sup>1,2</sup> the consensus is to reserve surgery for cases of persistent communication without thrombosis of the false lumen<sup>3,4</sup> or unstable (enlarging) Stanford type B dissection.<sup>5-7</sup> With both medical therapy (i.e., the use of antihypertensive agents) and surgery, however, the intermediate and long-term prognoses are poor. With medical therapy, thrombosis of the false lumen and stabilization of the aortic tube are unpredictable, and there is a risk of rupture or progression of the dissection. Conversely, surgical resection carries the risk of both paraplegia and death.<sup>5,8-10</sup>

We undertook this study to test aortic reconstruction for type B dissection by insertion of custom endoluminal stent-grafts to seal the entry site and induce thrombosis of the false lumen. With percutaneous placement, major surgery and the related morbidity and mortality were avoided in patients with classic indications for surgical repair. The technique of endoluminal aortic stent-graft placement has recently been introduced for repair of abdominal and thoracic aortic aneurysms.<sup>11,12</sup> In the high-risk setting of aortic dissection, however, endoluminal repair is a new therapeutic strategy.

### METHODS

#### Selection of Patients

Between October 1997 and March 1998, 12 of 24 consecutive patients who had subacute or chronic type B aortic dissection and who had at least one indication for surgical repair underwent elective transluminal endovascular stent-graft placement,<sup>9,13,14</sup> and the other 12 patients, who had similar demographic and clinical characteristics, underwent surgery and served as controls (Table 1). For stent-graft insertion, patients were required to meet the following anatomical criteria: an entry site at least 0.5 cm distal to the left subclavian artery, suitable access with no substantial iliac tortuosity, and one iliac artery without dissection. The protocol was approved by the institutional review boards of the university

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**TABLE 1. DEMOGRAPHIC AND ANATOMICAL CHARACTERISTICS OF THE PATIENTS.\***

VARIABLE	SURGERY GROUP (N=12)	STENT-GRAFT GROUP (N=12)	P VALUE
Male sex — no. (%)	10 (83)	11 (92)	>0.99
Age — yr			0.18
Mean	56±12	62±11	
Range	33–70	34–75	
History of hypertension — no. (%)	10 (83)	11 (92)	>0.99
Chronic obstructive pulmonary disease — no. (%)	4 (33)	4 (33)	>0.99
Previous aortic surgery — no. (%)	3 (25)	3 (25)	>0.99
Marfan's syndrome — no. (%)	1 (8)	1 (8)	>0.99
ASA classification†	3.2±0.6	3.1±0.5	0.21
Maximal diameter of aorta — cm	6.9±1.1	6.3±0.8	0.14
Thoracoabdominal dissection — no. (%)	7 (58)	5 (42)	0.68
Length of dissection — cm	30±12	32±10	0.74
No. of entry sites	1.6±0.7	1.8±0.9	0.60

\*Plus-minus values are means ±SD.

†The ASA (American Society of Anesthesiology) Classification of Physical Status<sup>15</sup> grades physical status on a scale from I to IV; the numerical mean (±SD) is shown here.

medical centers of Hamburg and Bologna, and written informed consent was obtained.

Three patients in each group had previously had surgery for type A dissection. The mean (±SD) diameter of the aorta at the entry level was 6.9±1.1 cm in the surgery group and 6.3±0.8 cm in the stent-graft group (P=0.14). The age of the patients was

56±12 years in the surgically treated group and 62±11 in the stent-graft group (P=0.18). The length of the dissecting lamella was 30±12 cm and 32±10 cm, respectively, with thoracoabdominal extension of the dissection in seven patients undergoing surgery and five patients undergoing stent-graft placement (P=0.68). Transfemoral stent-grafting was offered if the aortic dissection was distal to the left subclavian artery, there was a proximal entry to the false lumen, the true lumen was less than 4 cm in diameter, or a thrombus failed to form spontaneously in the false lumen (Table 2). All 24 patients had a maximal aortic diameter of 5.5 cm or more, luminal expansion, or recurrent pain.<sup>5,8,14</sup> Dissection extending to the aortic bifurcation, tortuosity, or kinking did not preclude stent-graft placement as long as the iliac artery allowed access of the 22-to-27-French delivery sheath. During the recruitment period, an additional 20 patients with Stanford type A dissection and 12 additional patients with type B dissection underwent emergency or early surgical repair at the two centers; thus, altogether, 21 percent of all patients, or 33 percent of patients with type B dissection, underwent stent-grafting.

**Imaging Protocol**

All the patients underwent spin-echo (anatomical) magnetic resonance imaging (MRI) and three-dimensional magnetic resonance angiography after the injection of a bolus of gadolinium-diethylenetriamine pentaacetic acid (gadolinium-DTPA; Magnevist, Schering, Berlin, Germany).<sup>16</sup> The use of gadolinium-DTPA during data acquisition produces contrast-induced T<sub>1</sub>-shortening effects and eliminates saturation problems due to slow flow or turbulence-induced signal voids. With the use of ultrafast gradients, acquisition was performed with the patients holding their breath. A FLASH (fast low-angle shot) three-dimensional sequence was used with or without intravenous contrast material to create maximal-intensity projections; echo and repetition times were as short as 1.9 and 4.0 msec, respectively. With a field of view of 390 to 450 mm, a 512-by-512 matrix provided an in-plane resolution of 1.1-by-1.6 mm. Slice thickness varied from 2 to 4 mm; a flip angle of 30 degrees was selected. Imaging of 64 interpolated contiguous slices

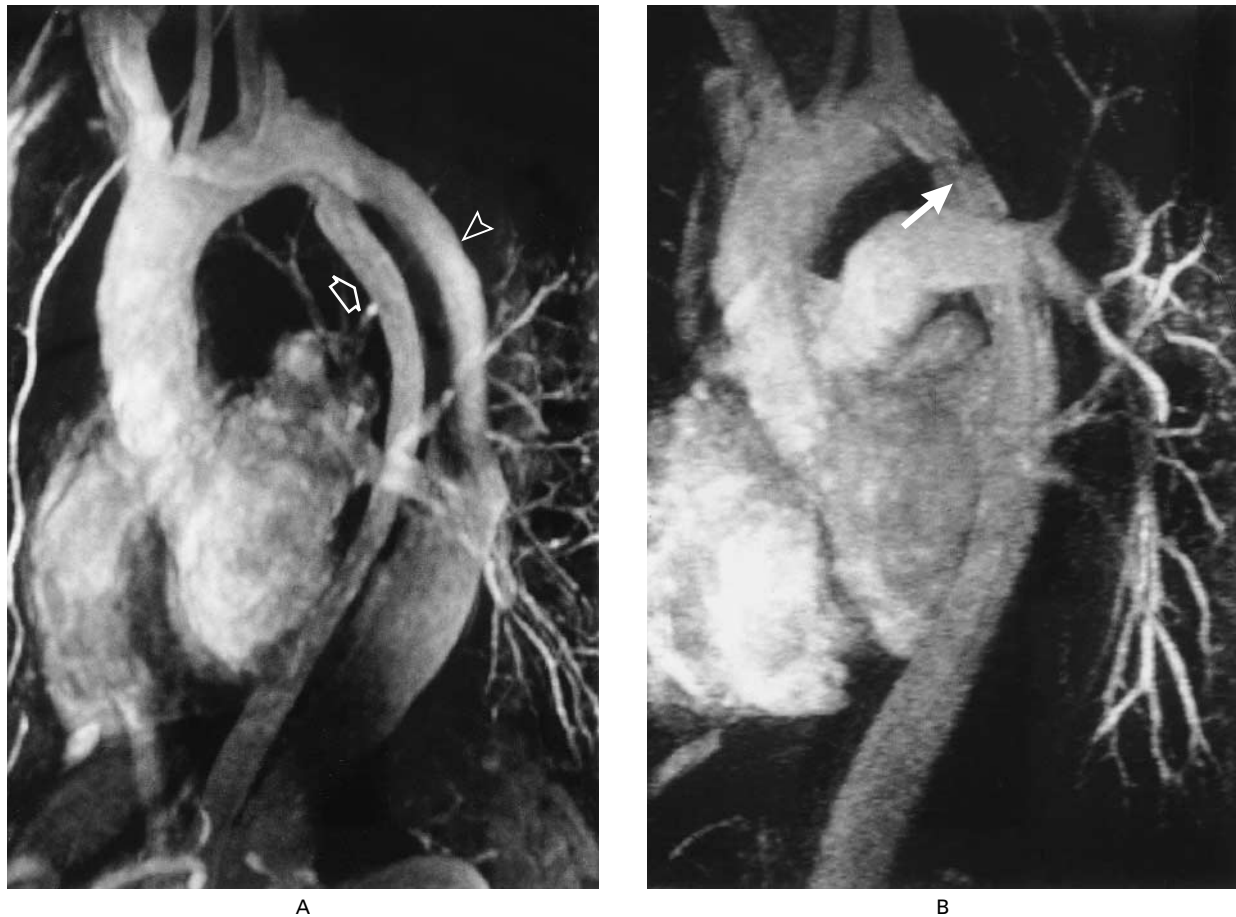
**TABLE 2. DEMOGRAPHIC AND ANATOMICAL CHARACTERISTICS OF THE PATIENTS WITH STENT-GRAFTS.**

PATIENT No.	AGE	SEX	ASA CLASSIFICATION*	DIAMETER			ENTRY SITES		THROMBOSIS OF FALSE LUMEN
				TRUE LUMEN	FALSE LUMEN	TOTAL†	NO.	DISTANCE FROM LSA‡	
				cm			cm		
1	60	M	III	2	4	6	3	10	No
2	54	M	III	1.5	4.5	6	1	1	No
3	67	M	IV	1.5	5	6.5	1	12	Partial
4	34	M	III	2	4	6	2	0.5	No
5	70	M	IV	1	5	6	1	14	No
6	67	M	II	3	3.5	5.5	2	11	No
7	65	F	III	2	3.5	5.5	1	18	No
8	64	F	III	3	2.5	5.5	3	6	Partial
9	71	M	III	2	6	8	1	6	No
10	75	F	III	2.8	4.2	7.5	1	5	Partial
11	51	M	III	0.5	6.5	7	3	0.5	No
12	61	M	II	2.2	4.2	6.5	3	4	No

\*The American Society of Anesthesiology (ASA) Classification of Physical Status<sup>15</sup> grades physical status on a scale from I to IV.

†The total diameter of the lumen does not necessarily equal the sum of the diameters of the true and false lumens, because the total diameter was measured at a slightly different angle.

‡LSA denotes left subclavian artery.



**Figure 1.** Magnetic Resonance Angiograms Obtained before and after Placement of a Stent-Graft.

Panel A shows a magnetic resonance angiogram in a three-dimensional, maximal-intensity projection after the injection of gadolinium-DTPA. There is a dual, open-lumen, type B dissection; the entry to the perfused false lumen (arrowhead) is located in the distal arch directly adjacent to the left subclavian artery. The open arrow indicates the true lumen. Panel B shows a follow-up magnetic resonance angiogram obtained in the same patient three months after successful placement of a Dacron-covered stent-graft directly onto the entry of the false lumen. The entry is completely sealed by the stent-graft, and the false lumen is thrombosed. The left subclavian artery is widely patent, and the true lumen (solid arrow) has widened as evidence of aortic remodeling.

with half-k-space data acquisition in the phase-encoding direction took 20 to 28 seconds.

Images were obtained with a 1.5-T magnetic resonance scanner (Magnetom Vision, Siemens Medical Systems, Erlangen, Germany) equipped with an ultrafast-gradient system; a body-array coil was used for signal transmission and reception. Optimal image quality was ensured by individual tracking of the bolus before the infusion of 0.25 mmol of gadolinium-DTPA per kilogram of body weight over a period of 10 to 14 seconds (approximately half the acquisition time). With subvolume multiplanar reconstruction, the dissecting lamella (the exact site of a communication and false-lumen flow) was identified in all cases. To design each stent-graft, MRI scans and angiograms were evaluated for morphometric measurements  $14 \pm 2$  days before stent implantation. Follow-up MRI was performed according to an identical protocol for all the patients to document complete closure of the interluminal communication or false-lumen thrombosis or leakage (Fig. 1A and 1B).

#### Endovascular Stent-Graft Prosthesis

The stent-graft prosthesis (Talent, World Medical Manufacturing, Sunrise, Fla.) was a self-expanding endoprosthesis consisting

of circumferential nitinol stent springs arranged as a tube for conformance to the lumen and covered on its exterior with a Dacron graft; the tube was customized with respect to width, length, and the configuration of each end (as a bare spring or a covered web) and was compressed in a 22-to-27-French polytetrafluoroethylene (Teflon) sheath; the nitinol rings were interconnected by a longitudinal wire to ensure stabilization and separation of all the rings and to prevent twisting. Each device was custom-made according to morphometric measurements obtained from each patient's MRI scan (Table 2).

#### Implantation Technique

Stent-graft placement was performed in the cardiac catheterization laboratory (University Hospital Hamburg) or operating room (University of Bologna) with the patients under general anesthesia and receiving ventilation. Patients were prepared to undergo surgery in case the procedure failed. The procedure was begun by injecting 5000 U of heparin and introducing a 6-French pigtail catheter (Cordis, Hamburg, Germany) into the left subclavian artery for precise guidance near the subclavian artery and for intraprocedural aortography. In all the patients, the femoral or distal

**TABLE 3.** PROCEDURAL DATA AND INTRAOPERATIVE AND LONGER-TERM OUTCOMES.\*

VARIABLE	SURGERY GROUP (N=12)	STENT-GRAFT GROUP (N=12)	P VALUE
Procedural measures			
Use of general anesthesia — no.	12	12	1
Duration — hr			<0.001
Mean	8.0±2.0	1.6±0.4	
Range	5–11	1.1–2.6	
Size of prosthesis — mm			
Length			<0.001
Mean	220±74	84±40	
Range	100–340	43–150	
Diameter			<0.001
Mean	27±2	38±3	
Range	22–28	30–40	
Duration of intensive care — hr	92±45	36±12	<0.001
Hospital stay — days			<0.001
Mean	40±24	7±3	
Range	14–96	4–15	
Body temperature >38°C — no. (%)	6 (50)	10 (83)	0.19
Mortality — no. (%)			
Perioperative	1 (8)	0	>0.99
After 30 days	1 (8)	0	>0.99
After 1 yr	4 (33; 95% CI, 10–65)	0 (0; 95% CI, 0–22)	0.09
Cumulative morbidity — no. (%)	5 (42; 95% CI, 15–72)	0 (0; 95% CI, 0–22)	0.04
Paraplegia	2 (17)	0	0.48
Neurologic defect	3 (25)	0	0.22
Respiratory complication	5 (42)	0	0.04
Renal failure	3 (25)	0	0.22
Physical recovery — no. (%)	7 (58; 95% CI, 28–85)	12 (100; 95% CI, 78–100)	0.04

\*Plus-minus values are means ±SD. CI denotes confidence interval.

iliac artery was surgically exposed, and a 0.89-mm (0.035-in.) guide wire was inserted. When the position of the wire in the true lumen of the aorta had been confirmed by fluoroscopy and ultrasonography, the sheath with the stent, a pusher, and a deflated large-bore latex balloon (the Talent prosthesis) was introduced. The compressed stent was advanced to the site of the interluminal communication, under guidance by simultaneous transesophageal color Doppler imaging.

Before the stent-graft was unloaded, systolic blood pressure was titrated to 50 mm Hg with sodium nitroprusside; as soon as blood no longer circulated through the false lumen, the stent was expanded by balloon molding (by inflation of the balloon at 2 to 3 atm); when the web struts were fully extended and there was no flow into the false lumen, the infusion of sodium nitroprusside was discontinued. With the Dacron shell centered on the interluminal communication, the stent-graft was unloaded by holding the pusher in place and gently pulling back the housing cartridge. To ensure optimal positioning, care was taken to seal the entry with Dacron and to protect the left subclavian artery with the bare-spring end of the stent-graft. Both the sheath and the guide wire were removed, and the incision was closed. No additional heparin or antiplatelet medication was administered after completion of the procedure.

### Surgical Resection

In all 12 patients who underwent surgery, access was by the left lateral approach, with direct exposure of the dissection.<sup>1,2,9</sup> After the induction of mild hypothermia, the aorta was cross-clamped, and in 11 patients (92 percent) atriodistal or femorofemoral bypass was instituted. The dissected and dilated descending aortic

segment was replaced with Dacron grafts, and in 8 of the 12 patients (67 percent) the intercostal arteries were reattached; spinal cord function was not evaluated intraoperatively. Intraoperative and follow-up outcomes are summarized in Table 3.

### Statistical Analysis

Continuous variables were expressed as means ±SD and were compared by analysis of variance. Rates of event-free survival (defined as survival without death, paraplegia, stroke, distal embolization, side-branch occlusion, or infection) were studied with use of the log-rank test.<sup>17</sup> Differences between the groups in categorical variables were analyzed by the chi-square test or Fisher's exact test; exact 95 percent confidence intervals were determined for proportions. All P values are two-sided, and a P value of less than 0.05 was considered to indicate statistical significance.

## RESULTS

### Procedural Success

Transfemoral stent-graft deployment was successful and free of complications in all 12 patients. Complete sealing of the entry to the false lumen was documented by color Doppler transesophageal echocardiography and aortography. One patient received two stent-grafts, but no patient required any adjunctive procedure. Initiation of thrombosis of the false lumen was observed by transesophageal ultrasonography during the procedure in 10 of the 12 patients

(83 percent). No patient in the stent-graft group required blood transfusion or inotropic support; on average,  $178 \pm 79$  ml of contrast material was used and fluoroscopic examination lasted  $19 \pm 5$  minutes (range, 9 to 30). In contrast to the surgically treated patients, none of the patients who received a stent-graft had a prolonged recovery from either the procedure or anesthesia; as shown in Table 3, their average length of stay in the intensive care unit was  $36 \pm 12$  hours (as compared with  $92 \pm 45$  hours in the surgery group,  $P < 0.001$ ), and their average length of stay in the hospital was  $7 \pm 3$  days (range, 4 to 15), as compared with  $40 \pm 24$  days (range, 14 to 96) in the surgery group ( $P < 0.001$ ). In the stent-graft group, no patient had an adverse event, and all were able to begin walking within three days.

#### Immediate and Longer-Term Outcomes

Both intraoperative and postoperative outcomes were uneventful after placement of the stent-grafts (Table 3). Transient postimplantation syndrome with mild leukocytosis, elevated levels of C-reactive protein, and moderately elevated body temperature occurred in 9 of the 12 patients (75 percent); the maximal C-reactive protein level was 148 mg per liter, and the leukocyte count was  $11 \pm 9 \times 10^6$  per cubic centimeter on day  $4 \pm 2$ . A nonspecific, slight-to-moderate back-pain syndrome was described by six patients (50 percent) and resolved within  $12 \pm 5$  days without the use of analgesics.

Among the 12 surgically treated patients, 4 (33 percent) died within 1 year after surgery (1 died perioperatively, 2 died within 6 months, and 1 died of aortic rupture at 10 months). Moreover, as compared with stent-graft implantation, surgery was associated with higher morbidity ( $P = 0.04$ ), longer hospitalization ( $P < 0.001$ ), a lower rate of physical recovery ( $P = 0.04$ ), and greater need for inotropic support and blood transfusions (in six patients [50 percent]).

#### Intraprocedural Imaging

In addition to repeated contrast angiography during the procedure, color Doppler transesophageal echocardiography provided useful information both for the exact positioning of the stent-graft and for the monitoring of flow to the entry to the false lumen: cessation of color flow indicated that the stent-graft had been deployed. In one patient who had previously undergone replacement of the ascending aorta, the communication was difficult to visualize, and intraprocedural success was documented by angiography only. Moreover, in all the patients both angiography and transesophageal ultrasonography confirmed expansion of the true lumen by 8 to 19 mm (27 to 202 percent expansion of preimplantation width) at the time of stent-graft deployment. Intraprocedural ultrasonography also detected thrombosis of the false lumen in 10 of the 12 pa-

tients (83 percent) by revealing high echodensity ("smoke") within minutes after the entry was sealed. Finally, one small leak and four persistent distal communications to the false lumen were identified, all of which had closed after three months of follow-up.

#### Follow-up Imaging

At three months, spin-echo MRI and three-dimensional magnetic resonance angiography documented widely patent stent-grafts and complete thrombosis of the false lumen in all 12 patients. No aortic side-branch occlusion and no evidence of migration or twisting of the stent-graft or leakage was noted. Moreover, at three months, there was clear evidence of expansion of the true lumen and shrinkage of the false lumen as a result of consolidation of thrombosis in all the patients, suggesting that the aortic tube had been remodeled with enlargement of the reconstructed true lumen.

#### Comparison between Surgery and Stent-Graft Implantation

All the patients with stent-grafts resumed an active life; eight of them received antihypertensive medication, and none was readmitted to the hospital. In contrast, the group treated surgically had a 12-month mortality rate of 33 percent (95 percent confidence interval, 9.9 to 65 percent) and a 42 percent rate of serious morbidity (95 percent confidence interval, 15 to 72 percent) ( $P = 0.09$  and  $P = 0.04$ , respectively, for the comparisons with the stent-graft group). Moreover, both the time spent in the intensive care unit and the overall hospital stay were markedly longer among patients who underwent surgery than among those who underwent stent-grafting (Table 3).

## DISCUSSION

Our findings suggest that nonsurgical reconstruction may be a viable therapeutic option for patients with descending dissection of the thoracic aorta and one or more indications for surgical repair, such as an aortic diameter greater than 5.5 cm, a patent primary entry site, an expanding false lumen, or recurrent pain.<sup>2,3,5,13,14</sup> In contrast to thoracic surgery for type B dissection, transfemoral stent-grafting was not associated with early or longer-term mortality or with serious morbidity. Our preliminary analysis even suggests that substantial cost savings could result from the reduced need for intensive care and the shorter hospital stay.

Even though nonsurgical (interventional) techniques have recently been introduced for the treatment of congenital aortic stenosis and coarctation and the treatment of abdominal and thoracic aneurysms,<sup>11,18</sup> medical or surgical management is usually the treatment chosen for dissection, and both have disappointing results.<sup>8,9,19</sup> Except for catheter fenestration,

tration of occlusive distal flaps, no interventions have proved useful for managing aortic dissection.<sup>20,21</sup>

Whereas emergency surgical repair is lifesaving in ascending (type A) aortic dissection,<sup>1-4,22</sup> both emergency surgery and deferred surgery for descending (type B) dissection are associated with a 6 to 67 percent mortality rate, depending on the patient group assessed, and neither offers a substantial advantage over medical therapy.<sup>1,6,9,14,23-26</sup> Also, paraplegia (or paresis) occurs in 7 to 36 percent of patients who undergo surgery, depending on the extent of aortic resection and the duration of cross-clamping.<sup>1,9,24,25,27</sup> Even with intraoperative atriodystol bypass, reattachment of all the critical intercostal arteries, and induction of mild hypothermia, early surgical mortality is 7.1 percent in patients with chronic type B dissection and 8.7 percent in those with acute type B dissection.<sup>28-31</sup> Similarly, surgery-related paraplegia or paresis occurs in 2.9 percent of patients with chronic type B dissection and in 19 percent of those with acute cases; advanced age, excessive cross-clamping time, and inappropriate reattachment of the great anterior radiculomedullary artery are predictors of these adverse outcomes.<sup>31-36</sup>

With the use of percutaneous stent-grafts in our study, however, the aorta was reconstructed with an excellent outcome and without the need for complex protective measures. Whereas both surgical resection and medical treatment failed to produce a convincing improvement in the natural course of distal dissection, sealing of the entry induced thrombosis of the false lumen and stable remodeling of the aorta.

#### Avoidance of Paraplegia or Paralysis

Although spinal cord dysfunction was expected to develop in approximately 8 percent of our patients with stent-grafts,<sup>34</sup> no neurologic complications were encountered, in contrast to the outcome in patients treated surgically. Preservation of the integrity of the aorta, rather than resection of the dissected segment, may be important to protect the spinal arteries. The use of short stent-grafts,  $84 \pm 40$  mm in length, and deployment far from vertebrae T8 to L2, further minimized the risk of paraplegia, as compared with the risk with surgical grafts, which were  $220 \pm 74$  mm in length ( $P < 0.001$ ). Most important, the stent-graft procedure took only  $1.6 \pm 0.4$  hours, as compared with  $8.0 \pm 2.0$  hours for surgery ( $P < 0.001$ ); it circumvented the need for circulatory arrest and cross-clamping of the aorta, and the associated ischemia and potential reperfusion injury; and it averted postoperative respiratory failure and prolonged hypotension and the associated risk of delayed paraplegia. Even successful reimplantation of the intercostal arteries and cross-clamping for less than 30 minutes have not eliminated the risk of paraplegia after surgery.<sup>25,26,31,35,37,38</sup>

#### Remodeling of the Aorta

With stent-graft implantation, aortic stability is induced both by thrombosis of the false lumen and by the endoprosthesis itself; a relatively short stent-graft can cover the proximal entry and induce false-lumen thrombosis over the entire length of the dissected aorta within three months. In our study the true lumen expanded substantially, from  $19 \pm 7$  mm to  $35 \pm 3$  mm, and the diameter of the false lumen was reduced by retraction of the thrombus. Thus, aortic remodeling comprises an active component (stent-induced expansion of the true lumen) and a passive component (retraction of the thrombus in the false lumen) and mimics the natural healing process. A thrombosed false lumen is known to be associated with a lower risk of future adverse events and with better survival than a patent false lumen.<sup>38</sup> Conversely, a persistently perfused false lumen, as documented by color Doppler ultrasonography, is known to be associated with higher mortality.<sup>3</sup>

#### Limitations

Although conceptually promising, the management of type B dissection by stent-grafting lacks the support of long-term follow-up data. During several years' follow-up after stent-graft placement for the treatment of both thoracic and abdominal aneurysms, late adverse effects were infrequent.<sup>11,12,18</sup> Thrombosis of repaired aneurysms was reported in 95 percent of patients, with a periprocedural mortality of 8 percent and a six-month mortality of 12 percent.<sup>39</sup> We recommend nonsurgical stent-graft placement for the treatment of type B dissection only in patients with an indication for surgical repair and with suitable anatomical characteristics (an accessible proximal entry, at least one femoral artery without dissection, and no substantial tortuosity). Moreover, the custom design of each stent-graft currently limits their placement to patients undergoing elective procedures; more versatile stent-grafts will be necessary to treat acutely ill patients. Finally, sophisticated imaging techniques, such as magnetic resonance angiography, intraprocedural transesophageal echocardiography, and digital angiography, appear to be necessary to ensure optimal results.

#### Clinical Application

Stent-graft placement may be a promising nonsurgical strategy for the treatment of type B dissection. The initiation of the natural healing process (false-lumen thrombosis) by sealing of the proximal entry induces both consolidation of the false lumen and remodeling of the aortic wall. If side-branch occlusion has not occurred and the dissecting process has not progressed, interventional stent-graft placement may be offered to selected patients in lieu of surgical repair; with further refinement of the technique, patients with severe coexisting conditions and

high surgical risk may be considered for the procedure. Although the initial results of stent-graft treatment of thoracic aortic dissection are promising, the concept of nonsurgical reconstruction must be subjected to a randomized long-term study.

*We are indebted to the staff members of the intensive care units and cardiothoracic units at the University Hospital Eppendorf and the Policlinico S. Orsola-Malpighi for their invaluable support and encouragement; and to Dr. P. Capasso, University of Lausanne, Professor H.G. Borst, Hannover Medical School, Dr. E. Isselbacher, Massachusetts General Hospital, Dr. B.M. Richards, Jena, and Professor T. Meinertz, University Hospital Eppendorf, for fruitful criticism.*

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