

# One-Stage Repair of Extensive Chronic Aortic Dissection Using the Arch-First Technique and Bilateral Anterior Thoracotomy

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**Background.** We evaluated a one-stage technique for extensive replacement of the thoracic aorta in patients with chronic aortic dissection.

**Methods.** Fifty-one patients with chronic expanding thoracic aortic dissections (48 type A, 3 type B with proximal extension) were treated with a single procedure using a bilateral anterior thoracotomy, hypothermic circulatory arrest, and reperfusion of the arch vessels first to minimize brain ischemia. Forty-six patients had previous operations: for acute type A aortic dissection (n = 36), aortic valve disease (n = 6), or coronary artery disease (n = 4). The ascending aorta and entire arch were replaced in all patients combined with varying lengths of the descending aorta.

**Results.** Hospital mortality was 3.9% (2 patients). Five patients (10%) required reoperation for bleeding. Two patients were discharged on ventilatory support and 2 on

dialysis. No patient sustained a stroke, and paraplegia developed in one. The 5- and 7-year survival rates were 79% and 68%. Freedom from reoperation on the thoracic or abdominal aorta was 92% at 5 and 7 years postoperatively. Serial tomograms have documented substantial enlargement of the residual dissected aorta in only 2 patients (reoperated).

**Conclusions.** The technique is a safe and suitable alternative to the two-stage (elephant trunk technique) and hybrid procedures for treatment of chronic dissection with aneurysm of the thoracic aorta. It eliminates the risk of rupture in the interval between staged procedures and the risks associated with a second thoracic aortic procedure, and is associated with a low rate of reoperation on the remaining aorta.

(Ann Thorac Surg 2008;86:1502–9)

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Progressive dilatation of the thoracic aorta after successful repair of type A aortic dissection is not uncommon, and operative intervention on the remaining dissected thoracic aorta is required in up to 30% of patients in the 5 to 10 years after the initial repair [1–6]. Some of these patients may also have aortic valve regurgitation or dilated or dissected aortic sinuses that requires operative treatment [3, 6]. Unrecognized aortic dissection occurs spontaneously or after operations on the coronary arteries or cardiac valves and may also result in aneurysmal dilatation of the dissected thoracic aorta that requires operative treatment [7, 8].

The optimal surgical management of patients with these conditions who have substantial enlargement of the remaining ascending aorta, the aortic arch, and part or all of the descending thoracic aorta is not clearly established. Therapeutic options include staged procedures, commonly using the elephant trunk technique [9–11], hybrid procedures using endovascular grafts to exclude the descending thoracic aneurysmal segments at the time of or after graft replacement of the ascending aorta and aortic arch [12, 13], and one-stage procedures

replacing all of the aneurysmal dissected aorta through one or several incisions [14–16].

We present here our experience with one-stage repair for patients with chronic type A aortic dissection and extensive enlargement of most or all of the remaining dissected thoracic aorta, using a bilateral anterior thoracotomy approach and early perfusion of the brachiocephalic arteries (arch-first technique) to minimize the duration of brain ischemia.

## Patients and Methods

### *Patient Characteristics*

During a 10-year interval ending in November 2007, 51 patients with chronic, expanding type A aortic dissection underwent one-stage resection and graft replacement of the ascending aorta, the aortic arch, and varying lengths of the descending thoracic aorta. This study was reviewed by the Institutional Review Board of the Missouri Baptist Medical Center and was exempted from board approval.

The mean patient age was 58 years (range, 22 to 81 years), and 38 (74%) were men. Thirty-six patients had previously undergone repair of acute type A aortic dissection. A type A dissection developed in 10 patients, in 6 during or after aortic valve replacement or repair and in

Accepted for publication July 21, 2008.

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Table 1. Previous Operations in 36 Patients With Type A Aortic Dissection

Operation	Patients, No. <sup>a</sup>
Ascending aortic replacement	21
Isolated	9
Aortic valve suspension	9
Aortic valve replacement	3
Ascending aorta and root replacement	15
Total	36

<sup>a</sup> Four patients had concomitant coronary artery bypass grafting.

4 after coronary artery bypass grafting (CABG). Three patients had type B aortic dissections that were initially managed with medical therapy and developed proximal extension of the dissection into the aortic arch and ascending aorta. The remaining 2 patients had chronic type A dissections that were initially managed without operation. Six patients (11.7%) had Marfan syndrome, and 1 (2%) had both Loeys-Dietz syndrome and type I Ehlers-Danlos syndrome.

Among the 46 patients undergoing reoperation, the mean interval between the initial and the second procedure was 73 months (median, 60; range, 3 to 249 months). The previous operations among the 36 patients with type A aortic dissection are reported in Table 1. At the time of reoperation, the dissection extended into the abdominal aorta in all but 1 patient.

The indications for operation were progressive enlargement of the involved aortic segments documented

by serial computed tomography (CT) scans or magnetic resonance imaging (MRI) studies in all patients (Figs 1 and 2), and the presence of symptoms (chest pain, back pain, congestive failure, hoarseness) in 27 patients (53%). Contained rupture of the dissected aorta was present in 2 patients, who required urgent operation. The area of maximal enlargement in most patients was the proximal portion of the descending thoracic aorta (Fig 1).

All patients undergoing elective operation underwent preoperative cardiac catheterization, assessment of pulmonary and renal function, and carotid duplex imaging. Other diagnostic studies (thoracic aortography, cerebral angiography, CT or MRI of the brain) were performed when indicated. No patient was denied operation because of severe pulmonary dysfunction.

During the study interval, no patient with extensive aneurysmal dilatation of a chronically dissected aorta sufficient to require operation, but with the aneurysmal segment confined to the thoracic aorta, was managed by any other technique. Patients in whom the aneurysmal enlargement extended into the abdominal aorta were treated with staged procedures.

#### Operative Technique

Our current operative technique has been previously reported [14]. In brief, it involves use of a bilateral anterior thoracotomy through the fourth intercostal space, transverse sternotomy, peripheral venous cannulation through the right common femoral vein using a two-stage cannula with the tip positioned in the superior

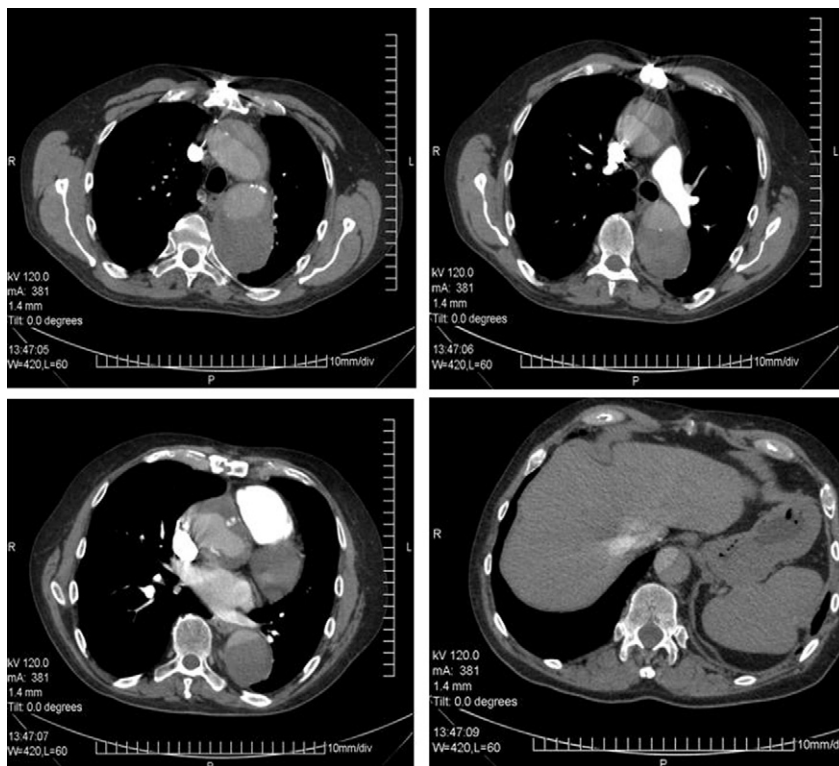
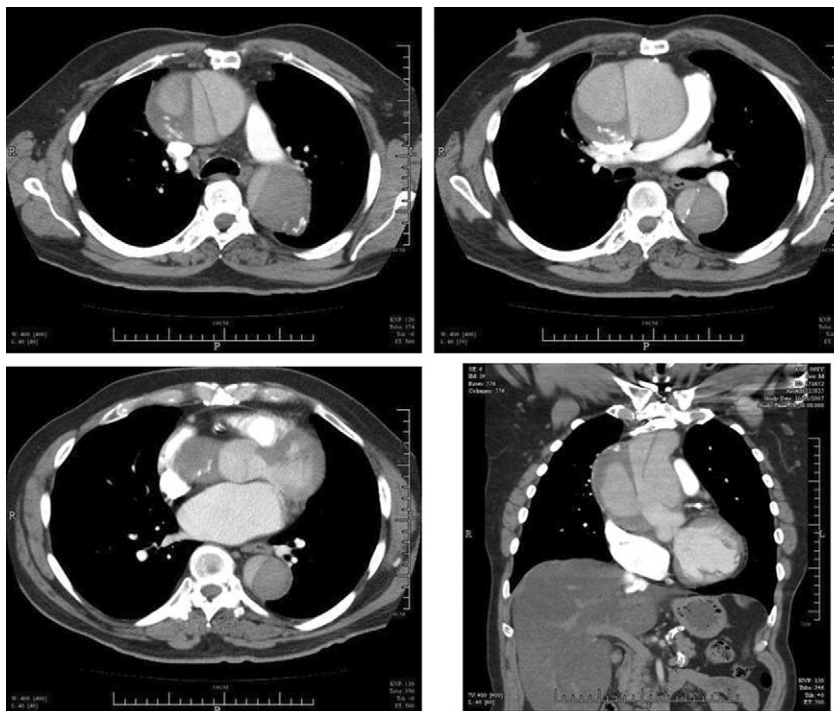


Fig 1. Computed sequential tomographic images of a 69-year-old man who underwent repair of an acute type A aortic dissection 8 months previously. The aneurysmal enlargement is confined to the upper two-thirds of the descending thoracic aorta.

Fig 2. Computed sequential tomographic images of a 68-year-old man who underwent coronary artery bypass grafting 5 years previously and sustained a postoperative aortic dissection. The aortic diameter was 3.5 cm, near the aortic hiatus.



vena cava, and cannulation of both the right common femoral artery and the right axillary artery.

In our initial experience, a cuff of aortic tissue was excised around the brachiocephalic arteries, and this cuff was sutured to an opening in a collagen-impregnated polyester aortic graft during circulatory arrest [17, 18]. This technique was used in 26 patients. Our current and preferred technique, which was used in the most recent 25 patients, involves use of a branched aortic graft and perfusion of the brain through the axillary artery to minimize the duration of circulatory arrest [19]. Cerebral oxygen saturation in both hemispheres is monitored using the Invos Cerebral Oximeter (Somanetics Corp, Troy, MI).

After completion of the arch anastomosis by either of these techniques, the site for anastomosis of the graft to the descending thoracic aorta is selected. This is generally where the diameter of the aorta does not exceed 3 to 3.5 cm. A segment of the septum between the true and

false aortic lumens of the distal aorta is excised to permit perfusion of both channels. Patent intercostal arteries above the seventh intercostal space are ligated. If the aorta is divided below this level, the distal aorta is beveled to preserve the lower intercostal arteries. After completion of the anastomosis and removal of air from the graft, flow to the lower body is established in the antegrade direction from the axillary artery, and rewarming is initiated.

During rewarming, aortic valve or aortic root replacement and CABG, if indicated, are performed. The proximal end of the aortic graft is sutured to the ascending aorta just above the level of the aortic commissures, to an existing ascending aortic graft, or to a newly inserted

Table 2. Extent of Descending Thoracic Aortic Replacement and Concomitant Procedures

Operative Details	Patients, No.
Extent of descending thoracic aortic replacement	
Proximal 1/3	8
Proximal 2/3 to 3/4	36
All	7
Concomitant procedures	
Aortic root replacement	7
Aortic valve replacement	16
Coronary artery bypass grafting	6

Table 3. Perfusion Data

Variable	Time, Mean $\pm$ SD, min	Range
Cooling	35 $\pm$ 7	25-50
Circulatory arrest		
Aortic cuff technique (n = 26)	41 $\pm$ 8	28-59
Axillary artery perfusion with branched graft technique (n = 25)	12 $\pm$ 7	6-38
Arch perfusion (hypothermic)	33 $\pm$ 9	15-64
Spinal cord and lower body ischemia	65 $\pm$ 16	20-109
Myocardial ischemia	145 $\pm$ 44	43-237
Rewarming	72 $\pm$ 16	35-120
Total cardiopulmonary bypass <sup>a</sup>	195 $\pm$ 52	103-332

<sup>a</sup> Excludes duration of circulatory arrest.

SD = standard deviation/.

Table 4. Mode of Late Death

Cause	Patients, No.
Sepsis	3
Cardiac failure	3
Sudden death	1
Renal failure	1
Multiple system organ failure	1
Intestinal infarction	1
Unknown	2
Total	12

composite graft. Saphenous vein bypass grafts, if present, are anastomosed to the aortic graft.

*Extent of Resection and Concomitant Procedures*

The ascending aorta, the entire aortic arch, and varying lengths of the descending thoracic aorta were resected and replaced in all patients. The extent of descending thoracic aortic replacement and the concomitant procedures performed are summarized in Table 2.

*Perfusion Data*

An Optima XP membrane oxygenator (Cobe Cardiovascular, Arvada, CO) was used in all cases. A common femoral artery was used for arterial return in 26 patients, and the right axillary artery was used in the remaining 25. The mean durations of cooling, circulatory arrest, hypothermic arch perfusion, spinal cord and lower body ischemia, myocardial ischemia, rewarming, and cardiopulmonary bypass are reported in Table 3. Among the 26 patients in whom a cuff of aorta was used to attach the brachiocephalic arteries to the aortic graft, the mean duration of circulatory arrest was 41 ± 8 minutes, exceeded 50 minutes in 4 patients, and did not exceed 60 minutes in any patient. Among the 25 patients in whom axillary artery perfusion and a branched aortic graft were used, the mean duration of circulatory arrest of the brain was 12 ± 7 minutes, and exceeded 30 minutes in only 1 patient (38 minutes). The brief interval of arrest was followed by an interval of hypothermic (20° to 22°C) perfusion of the brain from the right vertebral and right carotid arteries that averaged 38 ± 9 minutes.

*Statistical Analyses*

Standard descriptive statistical analyses were used. Values are expressed as mean ± standard deviation. The product limit method was used to determine survival and time-related freedom from reoperation. The χ<sup>2</sup> test was used to determine differences among variables.

**Results**

*Early Mortality*

Two early deaths occurred, for a 30-day and hospital mortality rate of 3.9% (70% confidence limits, 0.7% to 4.7%). A 71-year-old woman with an expanding chronic type A dissection and severe aortic regurgitation after a

CABG procedure died in the operating room of biventricular failure. A 47-year-old man died on postoperative day 8 after a cardiac arrest. He underwent operation for acute type A aortic dissection 9 months previously and required reoperation for persisting severe aortic regurgitation and heart failure combined with progressive enlargement of the aortic arch and the descending thoracic aorta.

*In-Hospital Morbidity*

Reoperation for bleeding or for evacuation of clot from the left pleural space was required in 5 patients (10%). The intraoperative mean transfusion requirements were 8.9 ± 4.9 U of packed red cells, 7.2 ± 4.4 U of fresh frozen plasma, 5.5 ± 3.3 U of platelets, and 7.5 ± 11.9 U of cryoprecipitate.

Mechanical ventilatory support for more than 72 hours was required in 23 of the 50 operative survivors (46%), and 9 (18%) required tracheostomy. The mean duration of ventilatory support was 12 ± 20 days (median, 3; range, 1 to > 90 days). All but 2 patients were successfully weaned from mechanical support. Permanent left vocal cord paralysis occurred in 1 patient (2%).

Inotropic support with more than 5 µg /kg/min of dobutamine for more than 24 hours was required in 9 of the 50 operative survivors (18%). One patient required intraoperative insertion of a ventricular assist device for right ventricular failure. It was removed on the third postoperative day, and the patient made a full recovery.

Renal failure requiring ultrafiltration or hemodialysis occurred in 5 patients (10%). Three of these patients were successfully weaned, with return of serum urea and creatinine levels to baseline by the time of hospital discharge.

Permanent and transient neurologic dysfunction was evaluated according to the classification of Ergin and colleagues [20]. No strokes occurred. One patient sustained bilateral optic nerve injury resulting in blindness but without CT or MRI evidence for cerebral cortical infarction, and paraplegia also developed. Transient neu-

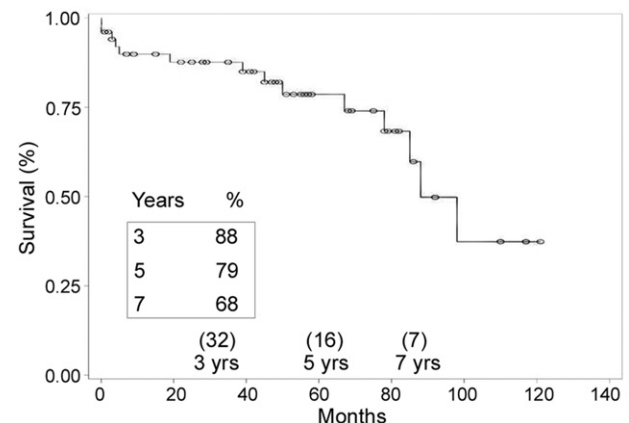


Fig 3. Product-limit estimate of survival after single-stage extensive replacement of the thoracic aorta. The number of patients at risk is indicated in the parenthesis.

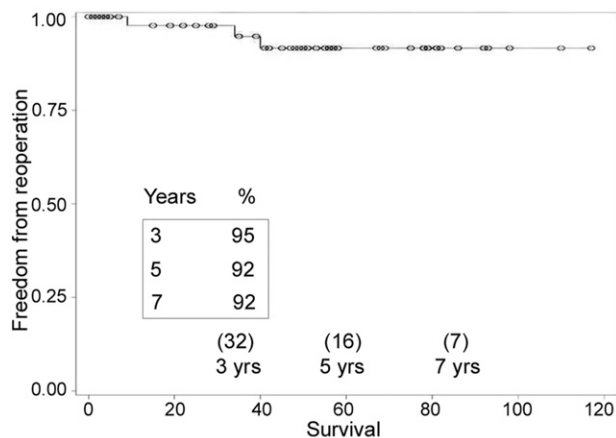


Fig 4. Product-limit estimate of freedom from reoperation on the thoracic or abdominal aorta after single-stage extensive replacement of the thoracic aorta. The number of patients at risk is indicated in the parenthesis.

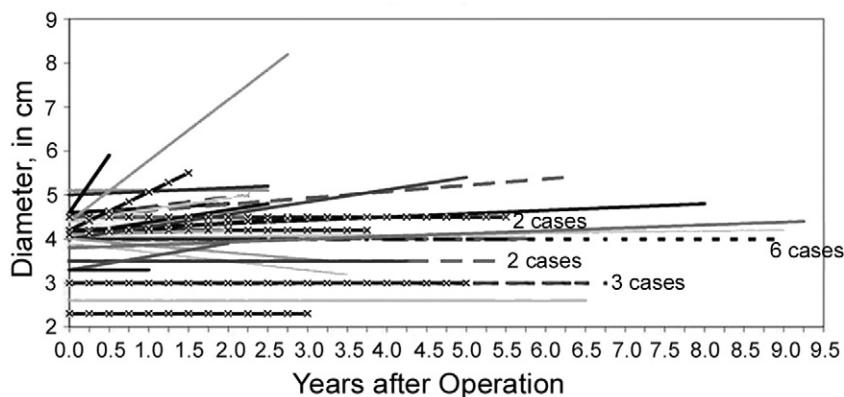
rologic dysfunction occurred in 7 of the 50 operative survivors (14%) and resolved completely in all of them.

There were no deep chest wound infections. One patient required a femorofemoral artery bypass graft for postoperative occlusion of the left external iliac artery. One patient required exploration of a groin incision for arterial bleeding and also a left thoracotomy to treat a persistent chylothorax. One patient with Marfan syndrome required laparotomy for intraperitoneal bleeding resulting from spontaneous rupture of a branch of the splenic artery. The mean duration of the postoperative hospital stay was 23 days (median, 12; range, 11 to 71 days).

**Late Mortality**

During the follow-up interval, which extends to 117 months, 12 late deaths occurred between 2.4 and 100 months. The modes of death are summarized in Table 4. The mean duration of follow-up was 47 months. Thirty-two patients have been followed up for more than 3 years, 16 for more than 5 years, and 7 for more than 7 years. The 1-, 3-, 5- and 7-year survival rates are 90%, 88%, 79%, and 68%, respectively (Fig 3).

Fig 5. Plot of diameters of the remaining distal thoracic or upper abdominal aorta at the hiatus determined by serial computed tomography imaging studies for 36 patients followed up for more than 1 year. The 2 patients with the greatest change in diameter underwent reoperation. Each line, unless labeled, represents a patient.



**Late Reoperations**

Three patients have undergone successful reoperations that involved the aortic graft in 1 patient and the remaining aorta in 2 patients:

- A 20-year-old woman with type I Ehlers-Danlos syndrome had successful repair of an acute type A aortic dissection. Four months later, because of rapid enlargement of the dissected aortic arch and descending thoracic aorta, she underwent replacement of the remaining ascending aorta, the arch, and the entire descending thoracic aorta to the level of the aortic hiatus. Subsequent CT studies demonstrated progressive dilatation of the contiguous abdominal aorta. At 9 months after the second procedure, she underwent replacement of the abdominal aorta, in which the celiac, superior mesenteric, and both renal arteries were attached to a branched graft. She recovered uneventfully, and subsequent testing confirmed the presence of Loays-Dietz syndrome.
- A second patient, who had repair of a chronic type B aortic dissection with proximal extension, required replacement of the remaining contiguous thoracic and the adjacent abdominal aorta for aneurysmal enlargement 34 months after the initial operation.
- The third patient was found to have a false aneurysm surrounding the descending thoracic segment of the aortic graft 40 months postoperatively. At reoperation, erosion of the graft resulting from compression against a rib was noted, and the involved segment of the graft was replaced.

The 1-, 3-, 5- and 7-year freedom from reoperation rates on the thoracic or abdominal aorta were 98%, 95%, 92%, and 92%, respectively (Fig 4).

Serial CT examinations available for analysis were performed in 44 of the 49 hospital survivors who have been followed up for more than 6 months. The rates of growth of the contiguous thoracic or abdominal aorta are shown in Fig 5. Minimal enlargement of the remaining dissected aorta has been observed among the patients

who have not required reoperation for up to 117 months postoperatively.

### Comment

After successful repair of acute type A aortic dissection, which includes graft replacement of the ascending aorta and part or all of the aortic arch, the false lumen remains patent in most patients, and this has been shown to be a risk factor for aneurysm formation in the residual dissected aorta [2, 5]. Yeh and colleagues [21] observed descending aneurysm formation (> 55 mm aortic diameter) in 54 of 144 patients (38%) who survived operation for acute type A dissection and who were followed up for a mean duration of 58 months. Logistic regression identified a patent false lumen and the initial diameter at the aortic isthmus to be significant predictors of aneurysm formation. Only 16 of the 54 patients with aneurysms underwent operations on the descending aorta.

Other studies have shown actuarial freedom from reoperation on the distal aorta at 10 years to be between 75% and 77% [3, 4, 6]. Younger age and the presence of Marfan syndrome are also associated with higher rates of reoperation [3, 6, 22]. In the series of Kazui and colleagues [4] and Shiono and colleagues [22], replacement of the entire aortic arch at the time of repair of the acute dissection was not associated with a lower incidence of reoperation on the distal aorta compared with less extensive resection. Freedom from reoperation on the distal aorta does not reflect the true frequency of aneurysm formation, because rupture of distal aneurysms has been noted in all published series. Lack of complete follow-up as well as the decision of some patients not to undergo reoperation are also factors that can affect the rate of reoperation [21].

Options besides a one-stage procedure for management of chronic dissecting aneurysms confined to the thoracic aorta that develop after successful initial repair, or after other surgical procedures, include a staged approach, commonly using the elephant trunk technique, and hybrid procedures [9-13, 23]. In four of the largest, recently reported series of elephant trunk procedures, which contain a substantial number of patients with chronic aortic dissection (31% to 39% of the total), the cumulative mortality for the two procedures and from deaths in the interval between the two procedures (commonly from aortic rupture) exceeded 20% [10, 11, 23, 24].

In the present study and in our previously reported series of single-stage procedures including other aortic pathology besides chronic dissection [14], the early mortality did not exceed that reported for the first stage of a two-stage procedure [10, 11, 23, 24]. In addition, the intraoperative transfusion requirements in our series were substantially less than those for the first-stage elephant trunk procedure reported by LeMaire and colleagues [11] and Safi and colleagues [25]. The prevalence of stroke, renal failure, and left recurrent laryngeal nerve injury did not exceed that reported for the first-stage procedure [10, 11, 23, 24].

Although our technique is not applicable in patients whose aneurysmal enlargement extends into the abdominal aorta, it represents a suitable alternative to staged procedures when the aneurysmal enlargement is confined to the thoracic aorta. Its use in the latter circumstance eliminates the risk of rupture of the remaining aneurysmal aorta in the interval between the first and second procedures, a common cause of death in this period, and the risks associated with a second procedure on the thoracic aorta [1, 10, 11, 23, 25].

The fate of the remaining chronically dissected descending thoracic aorta is of critical importance when the one-stage procedure we have described is used. Song and colleagues [26], using CT imaging, evaluated the long-term natural course of distal aortic dilatation in 51 patients who survived operation for acute DeBakey type I (type A) dissection. They followed up 27 of the 51 patients (53%) for more than 24 months, during which aneurysms (aortic diameter > 60 mm) developed in 8 patients (16%), and 3 died at 16, 21, and 71 months after onset of the acute dissection. In the follow-up interval, the incidence of aneurysmal change was 0% in the aortic arch, 15.7% at the upper descending thoracic aorta, 7.8% at the middle descending thoracic aorta, 2% at the lower descending thoracic aorta, and 2% at the abdominal aorta.

In our series, the upper descending thoracic aorta was replaced in all patients and the middle descending in 43 of the 51 patients (Table 2). Reoperation on the remaining dissected aorta was required in only 2 of the 49 hospital survivors in the follow-up interval, which extended to 117 months. Serial CT examinations have documented little or no increase in the diameter of the residual dissected aorta in the remaining patients. These findings, and the extremely low rate of aneurysm formation in the distal descending thoracic and abdominal aorta noted by Song and colleagues [26], suggest that more extensive replacement of these segments is unnecessary in most patients with chronic type A dissection. However, surveillance with serial imaging studies is essential and of particular importance in patients with Marfan syndrome and other genetically mediated conditions.

Stent grafting of the chronically dissected descending thoracic aorta at the time of reoperation on the ascending aorta and aortic arch (hybrid procedure) is another therapeutic alternative. To date, it has been used in only a small number of patients and follow-up is limited [12, 13, 27, 28]. Its role in the management of patients with chronic aortic dissection remains uncertain [29, 30]. Progressive thickening and stiffening of the septum between the true and false lumen and the presence of multiple fenestrations in the septum have brought into question the ability of stent grafts to induce complete thrombosis of the false lumen and remodeling in the descending thoracic aorta [30]. In the study of Shimono and colleagues [31], who used a transluminal stent graft placement technique for patients with acute and chronic aortic dissection, complete obliteration of the false lumen was observed in only 38.5% of patients with chronic dissection compared with 70% of those with acute dissection.

Because a higher incidence of spinal cord ischemic injury has been reported with extensive coverage of the descending thoracic aorta, several authors have recommended that the length of the stent graft be limited to the proximal 10 to 15 cm [10, 12, 27]. Stent graft collapse because of extremely small or stiff true lumens, endoleaks, torsion of the endograft, aorto-esophageal fistula, new intimal tears, aneurysm formation, and late rupture are other reported complications that are unique to stent grafts and mandate lifelong imaging follow-up [30, 32-35]. Thrombosis of the false lumen distal to the implanted endograft can result in loss of perfusion to vital organs. Cost of the endografts is another consideration. In the United States at present, the minimal added cost of an endograft to a single-stage procedure would be \$10,000.

In summary, our extended experience with the one-stage, arch-first technique for the management of chronic aortic dissection indicates that it is a safe and suitable alternative to the two-stage procedure and to current hybrid procedures based on currently available information. Our current and preferred technique for brain protection with axillary artery cannulation, a brief period of circulatory arrest, subsequent hypothermic brain perfusion, and use of a branched graft, has substantially reduced the duration of circulatory arrest of the brain. It obviates the need for direct cannulation of the brachiocephalic arteries and is safe, as evidenced by the absence of stroke and a low prevalence of temporary neurologic dysfunction. It has been associated with low hospital mortality, satisfactory long-term survival, and a low prevalence of reoperation on the distal aorta. It remains our treatment of choice for extensive chronic aortic dissection with aneurysmal dilatation confined to the thoracic aorta.

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## INVITED COMMENTARY

In this study, the authors [1] described a one-stage technique for extensive replacement of the thoracic aorta in a series of 51 patients with chronic aortic dissection. The series comprises mostly patients requiring reoperation after previous repairs of acute type A aortic dissection. The authors have used bilateral thoracotomy and arch-first technique in these patients with commendable clinical results. They claim that this one-stage procedure is superior to the conventional two-stage procedure and frozen elephant trunk technique (hybrid procedure) for extensive chronic aortic dissection confined to the thoracic aorta.

The results of the present study generally attest to the appropriateness of the use of a branched aortic graft and antegrade selective cerebral perfusion through the right axillary artery for total arch replacement procedure. Although the points raised by the authors are well taken, a few issues need to be clarified. First, the postoperative pulmonary dysfunction seems to be relatively high in this series, probably because of the bilateral thoracotomy and hypothermia. Are there any exclusion criteria for this extensive approach on the basis of the preoperative pulmonary function test? Second, one of the concerns with unilateral cerebral perfusion through the right axillary artery is possible hypoperfusion of the left cerebral hemisphere. How do the authors preoperatively and intraoperatively determine that the cerebral perfusion in

the left hemisphere is adequate? Third, how do the authors avoid injury to the patent left internal thoracic artery graft during the procedure?

Considering the fact that extensive reoperation on the distal aorta, remaining ascending aorta, aortic arch, and descending aorta is often required in the late postoperative period in some patients after limited ascending aortic replacement for acute type A aortic dissection (DeBakey type 1 aortic dissection), total aortic arch replacement with the elephant trunk technique could be justified in selected patients at the time of the initial surgery to avoid the extensive reoperation on the ascending and aortic arch.

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