Hybrid proximal surgery plus adjunctive retrograde endovascular repair in acute DeBakey type I dissection: Superior outcomes to conventional surgical repair

Sophie C. Hofferberth, BSc, BmedSc,^a Andrew E. Newcomb, MBBS, FRACS,^b
Michael Y. Yui, MBBS, FRACS,^b Kelvin K. Yap, MBBS, FRANZCR,^c Raymond C. Boston, PhD,^d
Ian K. Nixon, MBBS, FRACS,^b and Peter J. Mossop, MBBS, FRACR^c

Objective: The present study compared the outcomes between conventional surgery and the hybrid approach of proximal surgery with adjunctive retrograde descending aortic endografting plus distal bare metal stenting in acute DeBakey type I dissection.

Methods: From 2003 to 2011, 61 patients underwent surgical management for acute type A aortic dissection at our institution. Of these, 37 were DeBakey type I dissections: 18 patients (group 1) received conventional surgical repair alone, and 19 (group 2) underwent conventional hybrid surgery with adjunctive retrograde descending aortic stent grafting plus distal bare metal stenting.

Results: The patients' baseline characteristics were comparable, including the incidence of preoperative malperfusion syndromes ($P = .23$). The intraoperative and postoperative characteristics were similar, except 4 (22%) patients in group 1 (vs 0 in group 2) had ongoing malperfusion postoperatively ($P = .04$). Overall, hospital mortality was 11% ($n = 2$) for group 1 versus 5% ($n = 1$) for group 2. At a mean follow-up of 50 months, 4 (25%) subjects in group 1 required secondary thoracoabdominal aortic reintervention versus none in group 2 ($P = .03$).

Conclusions: The use of adjunctive retrograde descending aortic endografting plus distal bare metal stenting during acute DeBakey type I dissection repair is a feasible method to enhance thoracoabdominal remodeling. This hybrid strategy improves perioperative outcomes and decreases late distal aortic complications compared with conventional surgical repair for acute DeBakey type I dissection. A prospective, multicenter study is warranted to definitively assess this promising new treatment paradigm. (*J Thorac Cardiovasc Surg* 2013;145:349-55)

Acute type A aortic dissection is a catastrophic condition with high mortality.¹⁻³ Surgical management consists of aortic root repair or replacement, ascending aortic resection, and variable aortic arch replacement.⁴ Although the primary tear usually originates in the ascending aorta, the dissection extends beyond the arch in most patients. The DeBakey classification characterizes this as a type I dissection. Proximal surgical repair fails to address the

distal aorta beyond the arch, leaving a risk of malperfusion sequelae, aneurysmal degeneration, rupture, and late distal reoperation.⁵⁻⁷

In the past decade, our group has pioneered a radical endovascular treatment strategy to achieve more complete anatomic reconstruction of aortic dissection.^{8,9} Our initial experience, using a combination of descending aortic endografting plus distal bare metal stenting (Staged Total Aortic and Branch Vessel Endovascular Reconstruction [STABLE]), has proved its feasibility in aortic dissection repair, with favorable distal aortic remodeling.^{8,10} The aim of the present study was to compare the outcomes between conventional proximal surgical repair alone and the radical hybrid technique of proximal surgery with adjunctive retrograde stent grafting plus distal bare metal stenting of the descending thoracoabdominal aorta in acute DeBakey type I dissection.

From the Department of Medicine,^a St. Vincent's Hospital Melbourne, University of Melbourne, Fitzroy, Victoria, Australia; Departments of Cardiac Surgery,^b and Medical Imaging,^c St. Vincent's Hospital Melbourne, Victoria, Australia; and Department of Clinical Studies,^d New Bolton Center, University of Pennsylvania School of Veterinary Medicine, Philadelphia, Pa.

Disclosures: Peter J. Mossop, MB, BS, FRACR, and Ian Nixon, MB, BS, FRACS, were involved in patenting the Zenith Dissection stent. Both receive a share of patent royalties from Cook, Inc. All other authors have nothing to disclose with regard to commercial support.

Read at the 38th Annual Meeting of The Western Thoracic Surgical Association, Maui, Hawaii, June 27-30, 2012.

Received for publication May 24, 2012; revisions received June 22, 2012; accepted for publication July 25, 2012; available ahead of print Nov 12, 2012.

Address for reprints: Sophie C. Hofferberth, BSc, BMedSc, Department of Medicine, St. Vincent's Hospital, Melbourne, Level 4, Clinical Sciences Bldg, Fitzroy, Victoria 3065, Australia (E-mail: s.hofferberth@ugrad.unimelb.edu.au).

0022-5223/\$36.00

Copyright © 2013 by The American Association for Thoracic Surgery

<http://dx.doi.org/10.1016/j.jtcvs.2012.07.032>

METHODS

Patient Population

A retrospective review of the cardiovascular surgical database at our institution was performed from January 2003 to December 2011. The medical records were reviewed for preoperative risk factors, operative strategy, intraoperative events, and postoperative course.

Abbreviations and Acronyms

CTA	= computed tomography angiography
STABLE	= Staged Total Aortic and Branch Vessel Endovascular Reconstruction
TEE	= transesophageal echocardiography

During the study period, 61 patients presented to our tertiary referral center with acute type A dissection. Of these patients, 37 were identified with DeBakey type I dissection. After an early promising experience treating type B dissections, 2 operators, a cardiothoracic surgeon and interventional radiologist, adopted the hybrid approach of classic surgery with adjunctive retrograde STABLE repair for all DeBakey type I dissections. The remaining surgeons continued to implement the standard technique. The patients were separated into group 1 (control group, $n = 18$), who underwent conventional surgery, and group 2 ($n = 19$), who underwent conventional surgery with adjunctive retrograde STABLE repair. The St. Vincent's Hospital research ethics committee approved the present retrospective study and waived the need for individual patient consent.

Surgical Technique

The patients were taken directly to the operating room as soon as the diagnosis of acute type A dissection was confirmed. After induction of endotracheal general anesthesia, transesophageal echocardiography (TEE) was performed to assess the reparability of the aortic valve and root.

Arterial cannulation for group 1 patients included the femoral in 14, axillary in 2, and central (dissected ascending aorta or arch) in 2 patients. In group 2, femoral cannulation was performed in 18 and central in 1.

Venous return was achieved by 2-stage cannulation of the right atrium, and cardiopulmonary bypass was instituted. Core cooling, to 18°C, was begun with placement of a left ventricular vent, which was placed by way of the right superior pulmonary vein. The aorta was crossclamped as soon as ventricular fibrillation ensued. Retrograde tepid blood cardioplegia was then administered and given intermittently throughout the case for myocardial protection and direct antegrade cardioplegia.

During cooling, the proximal ascending aorta was debrided down to the sinotubular junction. Repairs were performed whenever feasible and consisted of commissural resuspension by reconstitution of dissected layers of sinuses using Bioglue (Cryolife Inc, Kennesaw, Ga) and reinforcement with pledgeted 2-0 TiCron (Covidien, Mansfield, Mass) sutures. The proximal aorta was then sutured end-to-end to an appropriately sized Dacron graft (Vascutek Ltd, Renfrewshire, Scotland) using 4/0 polypropylene suture and additional Bioglue. Aortic root remodeling surgery was performed when the sinuses had to be replaced, and composite root replacement was initiated when the aortic valve could not be spared.

Once adequate core hypothermia was achieved, deep hypothermic circulatory arrest was initiated. In 3 patients (1 in group 1 and 2 in group 2), direct antegrade cerebral perfusion was used in cases in which a prolonged period of deep hypothermic circulatory arrest was anticipated. Retrograde cerebral perfusion was used in 4 patients (3 in group 1 and 1 in group 2). At the distal anastomosis, the layers were reconstituted with Bioglue, with suturing of the beveled Dacron graft into the aorta using continuous 4/0 polypropylene suture.

Adjunctive Endovascular Procedure

The proximal repair was completed in an identical manner for all STABLE patients. The percutaneous endovascular component of the procedure was initiated on sternal closure. In patients who underwent femoral artery cannulation, an introductory sheath was placed at cannula removal. Otherwise, common femoral artery dissection was undertaken, and a 5/0 polypropylene pursestring suture performed. A detailed description of the Zenith

Dissection Endovascular System (Cook Medical, Bloomington, Ind), implemented in the STABLE procedure has been previously described.^{9,10} In brief, fluoroscopy and TEE were used to guide placement of a Lunderquist Extra Stiff Double Curved Exchange Wire Guide (Cook Medical) over a pigtail catheter maneuvered in the true lumen. The proximal Zenith TX2 endograft was then advanced over the wire and deployed in the intended position. The delivery systems were exchanged, and the Zenith Dissection Endovascular Stent (46 mm) was then advanced and deployed, overlapping 1 stent body with the proximal stent graft. The length of the delaminated aorta determined the choice of dissection stent length. Combinations of 4 (82 mm), 6 (126 mm), and 8 (164 mm) body length stents were used to approximate the extent of dissection and overlapped by 1 stent body.

Distal adjunctive procedures were undertaken if secondary entry tears were identified. The endovascular techniques used included aortic endografting, branch vessel-covered stenting, or embolization using coils or glue.

Follow-up Imaging

Serial computed tomography angiography (CTA) was performed at baseline, immediately and 3 months after the procedure, and annually thereafter. The latest follow-up CTA scan was reviewed to assess distal aortic remodeling, including the true lumen size, aortic diameters, and false lumen patency.

Statistical Analysis

Statistical analysis, using SPSS software, version 20.0 (SPSS Inc, Chicago, Ill), was used to compare the preoperative and postoperative characteristics. Fisher's exact test and Student *t* test were performed for the categorical and numeric variables, respectively. The time-to-event curves were calculated using the Kaplan-Meier method and compared using the log-rank test.

RESULTS

The patients' risk factors and presentation were similar for both groups (Table 1). Aortic valve resuspension was performed in 15 group 1 and 13 group 2 patients. Aortic root remodeling was performed in 2 patients in group 1 and 2 in group 2. Composite root replacement was performed in 1 patient in group 1 and 4 patients in group 2. Total arch, hemiarch, or isolated ascending aortic replacement was performed in 2, 9, and 7 patients in group 1 and 2, 8, and 9 patients in group 2, respectively. The extent of distal bare metal stent coverage was to the suprarenal aorta in 9 (47%) and infrarenal aorta in 10 (53%) patients in group 2.

Adjunctive Procedures

Seven patients (37%) in group 2 underwent 1 or more adjunctive procedures at primary intervention to address secondary re-entry tears. Distal re-entries were treated by way of renal ($n = 4$), mesenteric ($n = 1$), celiac ($n = 1$), or common iliac ($n = 1$) artery stenting, and percutaneous embolization using coils or glue in 2 patients. In 3 patients, arch vessel re-entries were treated; 1 received coil embolization of the innominate artery plus fenestrated cover stent grafting of the common carotid artery, and 2 received right internal carotid artery covered stent grafting. In all 3 patients, the arch re-entry tears were successfully excluded, with no associated morbidity.

TABLE 1. Preoperative characteristics

Variable	Conventional (n = 18)	Hybrid (n = 19)	P value
Age (y)	59 ± 13	54 ± 12	.16
Men	13 (72)	16 (84)	.45
Marfan syndrome	0	2 (11)	.49
Hypertension	16 (89)	15 (79)	.66
Diabetes mellitus	1 (6)	1 (5)	1
Peripheral vascular disease	0	1 (5)	1
Current smoker	7 (39)	3 (16)	.15
Previous CVA	2 (5)	1 (5)	.60
Previous cardiovascular surgery	2 (12)	2 (11)	1
Chronic renal insufficiency	2 (12)	0	.23
Hemodynamic compromise	5 (28)	4 (21)	.71
Cardiopulmonary resuscitation	1 (6)	0	.48
Cardiac tamponade	2 (12)	3 (16)	1
Inotropic support	4 (24)	4 (21)	1
AV regurgitation second degree or greater	6 (33)	7 (37)	1
Malperfusion	9 (50)	8 (42)	.23
Cardiac	2 (12)	2 (11)	1
Cerebral	2 (12)	3 (16)	1
Visceral (celiac, mesenteric, renal)	5 (28)	6 (32)	1
Iliofemoral	1 (6)	3 (16)	.60

Data presented as mean ± standard deviation or n (%). AV, Aortic valve; CVA, cerebrovascular accident.

Hospital Outcomes

The 30-day mortality was similar for both groups (Table 2). The postoperative complications were comparable, except that the incidence of malperfusion syndromes was significantly greater in group 1 (Table 2). In group 1, 1 patient developed lower limb weakness secondary to spinal cord infarction, necessitating a lengthy period of spinal

TABLE 2. Postoperative outcomes

Variable	Conventional (n = 18)	Hybrid (n = 19)	P value
Re-exploration for bleeding	1 (3)	2 (11)	1
Stroke	3 (18)	2 (11)	.65
Malperfusion syndrome	4 (22)	0	.04
Permanent spinal cord ischemia	1 (6)	0	.49
Visceral malperfusion	3 (17)	0	.10
Postoperative renal failure	6 (33)	5 (27)	.51
Requiring hemodialysis	2 (12)	2 (11)	1
Requiring permanent dialysis	0	0	1
Pleural effusion	10 (56)	5 (27)	.10
Chest infection	6 (33)	2 (11)	.12
Myocardial infarction	0	1 (5)	1
CPB time (min)	237 ± 67	213 ± 82	.36
Crossclamp time (min)	130 ± 42	104 ± 49	.11
DHCA (min)	37 ± 23	32 ± 8	.52
ICU stay (d)	7 ± 6	6 ± 6	.54
Hospital stay (d)	19 ± 15	21 ± 13	.69
30-d/In-hospital mortality	2 (12)	1 (5)	.60

Data presented as mean ± standard deviation or n (%). CPB, Cardiopulmonary bypass; DHCA, deep hypothermic circulatory arrest; ICU, intensive care unit.

rehabilitation after discharge. In 3 patients, visceral malperfusion remained postoperatively (Table 2). Two of these patients died. One was a young man, who had been successfully resuscitated in the preoperative phase. Poor ventricular contractility was noted at surgery. He was stable at completion of surgery; however, he required high-dose inotropic support and subsequently died 24 hours later. The other death was an 81-year-old woman, who had ongoing visceral and renal malperfusion postoperatively and died of multiorgan failure. The third patient presented in cardiogenic shock and received inotrope support before surgery. He developed coagulopathy and acidosis in the immediate postoperative period and had a prolonged intensive care unit stay.

Aortic Remodeling

Follow-up CTA beyond 6 months was available for 15 of 18 group 2 survivors (Figure 1). The maximal diameters were stable in the thoracic (34.8 ± 5.3 mm to 36.9 ± 6.9 mm, $P = .77$) and abdominal (26.6 ± 3.8 mm to 28.5 ± 5.7 mm, $P = .34$) aorta. The true lumen index (true lumen diameter/total aortic diameter) increased significantly in the thoracic (0.40 ± 0.2 to 0.78 ± 0.2 mm, $P = <.001$) and abdominal (0.46 ± 0.1 to 0.63 ± 0.3 mm, $P = .04$) aorta. Complete false lumen thrombosis of the thoracic aorta was achieved in 12 (80%) patients, with 9 (60%) throughout the abdominal aorta. Also, 6 (40%) had complete thoracoabdominal false lumen thrombosis (Figure 1).

In group 1, only 11 of 16 hospital survivors had follow-up CTA scanning available beyond 6 months. The thoracic (32.4 ± 3.6 mm to 44.5 ± 14.5 mm, $P = .01$) and abdominal (24.0 ± 4.1 to 29.1 ± 6 mm, $P = .04$) aorta grew significantly, with no significant increase in the true lumen index within the thoracic (0.44 ± 0.1 to 0.41 ± 0.1 mm, $P = .3$) or abdominal (0.44 ± 0.3 to 0.50 ± 0.2 mm, $P = .5$) aorta. One (9%) patient achieved complete false lumen thrombosis.

Clinical Outcomes

Late mortality was 1 of 16 for group 1 versus 1 of 18 for group 2 (Table 3). At a mean follow-up of 50 months, the overall actuarial survival was 80% in group 1 versus 87% in group 2 (log rank test, $P = .25$). The 1 death in group 1 was a 55-year-old man who died secondary to bronchial carcinoma 4 years after the procedure. The single late death in the group 2 hospital survivors was from disseminated carcinoma.

At latest follow-up, 6 (38%) group 1 versus 2 (10%) group 2 patients required an unplanned secondary reintervention (Table 3). Two group 1 patients required secondary proximal surgical reintervention; 1 received an aortic root replacement to treat aortic regurgitation caused by noncoronary cusp necrosis, the other underwent redo ascending aortic replacement for proximal ascending aortic saccular aneurysm. Four patients (25%) in group 1 required

FIGURE 1. A, Preoperative coronal computed tomography angiogram of acute DeBakey 1 dissection extending from aortic root to common iliac arteries. False lumen is to the right within the abdominal aorta involving renal and celiac arteries. B, Postoperative digital subtraction angiogram after deployment of thoracic TX2 endograft and Zenith dissection stents. C, Coronal computed tomography angiogram at 3 years demonstrating aortic stability and complete false lumen obliteration throughout treated thoracoabdominal aorta.

secondary distal aortic endovascular reintervention (Table 3). One received endovascular therapy to treat renal malperfusion at 7 months postoperatively. The other 3 required reintervention to treat thoracoabdominal aortic aneurysms. The extent of aortic growth from the initial surgery to reintervention was 12 mm, 21 mm, and 23 mm in the descending thoracic aorta, leading to reintervention at 1, 2, and 5 years, respectively. A fourth patient was found to have a 50-mm infrarenal aortic aneurysm at 3 years after surgical repair. He was admitted for endovascular repair; however, treatment has been delayed because of significant comorbidities. These 4 patients (25%) compare with no patients in group 2 developing thoracoabdominal aortic aneurysms. In group 2, unplanned secondary endovascular reintervention was required in 2 patients (Table 3). One presented at 4 months with proximal stent migration causing left subclavian artery dissection. A stent graft extension

was successfully deployed, and recovery was uneventful. The other had developed a type I endoleak that was treated with an overlapping proximal stent graft.

DISCUSSION

The natural history of acute type A dissection mandates emergent surgical intervention to avoid the potentially fatal complications.¹¹ Although the past decade has seen improvements in the safety and efficacy of surgical treatment,¹² hospital mortality has remained about 20%.^{3,13} Standard surgery for type A dissection has remained largely unchanged for decades and consists of proximal repair or replacement of the aortic root, with ascending aortic and variable arch replacement.⁴ Many surgeons also perform this type of repair in patients with the more extensive form of type A dissection, DeBakey 1 type. The problem with this approach is that most of these patients are left with residual “type B” dissection. The consequence of leaving a residually patent false lumen in the descending aorta is that a substantial subset of these patients are left at risk of developing acute and remote phase complications, including malperfusion sequelae, false lumen aneurysms, and rupture and requiring distal reoperation.⁵⁻⁷ Furthermore, standard open thoracoabdominal aortic aneurysm repair represents its own surgical challenges, with considerable perioperative morbidity and mortality.^{2,14}

The past decade has seen the evolution of hybrid open surgical techniques to address the residually diseased descending aorta in DeBakey type 1 dissection. Introduced

TABLE 3. Long-term survival and secondary interventions

Variable	Conventional (n = 16)	Hybrid (n = 18)	P value
Follow-up (mo)	41 ± 25	59 ± 34	.11
Secondary reinterventions	6 (38)	2 (11)	.07
Surgical	2 (13)	0	.21
Endovascular	4 (25)	2 (11)	.38
Distal aortic reintervention	4 (25)	0	.03
Thoracoabdominal aneurysm	3 (19)	0	.09
Branch vessel malperfusion	1 (6)	0	.47
Mortality	1 (6)	1 (5)	1

Data presented as mean ± standard deviation or n (%).

by Kato and colleagues,¹⁵ combined approaches of proximal surgical repair with antegrade descending aortic stent grafting have been reported.¹⁶⁻¹⁹ Initial studies had short-term outcomes similar to those of conventional surgical repair,¹⁶⁻¹⁹ with significantly improved remodeling of the descending thoracic aorta.^{17,18} However, complete thoracoabdominal false lumen thrombosis was achieved in just 17% of survivors.¹⁸ Longer follow-up is required to demonstrate whether this approach reduces late distal aortic complications.^{17,18}

The present study investigated the feasibility of more complete endovascular repair of the residually dissected aorta to prevent the clinical sequelae resulting from distal true lumen collapse, ongoing false lumen patency, and late aneurysmal degeneration. Early case reports using bare metal Z stents to successfully treat visceral malperfusion demonstrated its potential utility in dissection therapy.²⁰ Using the STABLE technique, the combined use of proximal endografting and distal bare metal stenting has achieved more complete reconstruction of the dissected aorta and its branches.^{8,9} Our initial case series demonstrated acceptable periprocedural morbidity and mortality rates, with favorable distal aortic remodeling at midterm.¹⁰ Others have reported similarly encouraging short-term clinical and anatomic outcomes using adjunctive bare metal stents in selected patients with type B dissection.²¹⁻²³ Nonetheless, we acknowledge the potential risk of procedural and remote complications associated with the use of adjunctive endovascular therapy in DeBakey type 1 dissection. Placement of covered stents and embolic materials in arch vessels invites the risk of stroke and arch redissection. Although these complications were not seen in the present series, we are seeking to evolve our proximal repair strategy to address the issue of residual arch dissection.

The present contemporary analysis has demonstrated that adjunctive retrograde STABLE repair significantly reduces the rate of distal aortic complications in DeBakey type I dissection compared with conventional surgical management. Our rationale for initiating the STABLE procedure at open surgical repair is to support and immediately expand the aortic true lumen, thereby enhancing distal branch vessel flow and preventing malperfusion.^{8,20} The reduced incidence of ongoing malperfusion in the STABLE cohort compared with those undergoing conventional surgical repair ($n = 4$ vs $n = 0$, $P = .04$) provides some evidence to support this hypothesis. However, we recognize these results do not definitively address the question of whether the residually dissected descending aorta contributed to all cases of malperfusion in group 1. It is, therefore, not possible to conclude that use of adjunctive STABLE repair would have prevented the malperfusion seen in those undergoing conventional surgery alone.

The adjunctive endovascular component of the primary operation did not increase the incidence of postoperative

renal failure and only minimally increased the total operative time because graft and stent implantation was performed during the rewarming of the patient and the establishment of antegrade flow. This enabled the use of TEE and limited angiography to assess true and false lumen flow and branch vessel perfusion. The extent of true lumen collapse was evaluated to optimize the size and extent of the endograft and bare stents and evaluate any necessity for specific branch vessel intervention. Antegrade stenting was not undertaken, because it is difficult to ascertain whether the stent has been placed in the true lumen when it is deployed in the bloodless open aorta during circulatory arrest. We found that retrograde passage of a wire using intervention techniques with catheters and contrast enabled accurate placement in the abdominal and thoracic true lumen, with confirmation of thoracic true lumen placement using TEE. In addition, retrograde stenting allows for a more direct approach to device delivery, and it is in accordance with device design, particularly in relationship to graft positioning and proximal device fixation methods.

The late distal aortic complications seen in DeBakey type 1 dissection are primarily caused by aneurysmal degeneration of the thoracoabdominal aorta owing to ongoing false lumen patency.^{5,7,24} We have shown adjunctive STABLE repair is associated with improved aortic remodeling and greater rates of false lumen thrombosis compared with conventional surgical repair in acute DeBakey type 1 dissection. Of those who received proximal surgery alone, 25% of survivors had developed thoracoabdominal aortic aneurysms at latest follow-up, with 3 (19%) requiring reintervention. Comparatively, none of the STABLE survivors required thoracoabdominal aortic reintervention. Although the CTA analysis was incomplete, the significantly greater rate of thoracic false lumen thrombosis in the STABLE patients was similar to that of other studies describing hybrid open surgical techniques for DeBakey type I dissection.^{17,18} Most STABLE patients (including the 2 requiring late reintervention) with available CTA follow-up did exhibit some degree of false lumen perfusion in the thoracoabdominal aorta. However, in contrast to those who received proximal surgical repair alone, the presence of ongoing false lumen perfusion was not associated with aortic growth or true lumen compression. We interpret these findings as evidence that the deployment of the bare metal stents in the distal aorta provides a form of supportive scaffolding that protects against aneurysmal degeneration. Furthermore, true lumen re-expansion using bare metal stenting might enable more limited endograft coverage in the descending thoracic aorta.

Study Limitations

The present study had several limitations. It was a single-center, retrospective, nonrandomized study. Incomplete radiologic follow-up was an additional weakness of our study.

Nonetheless, we are unaware of any other contemporary comparisons of proximal surgery plus adjunctive STABLE repair versus standard surgical repair for DeBakey type I dissection.

CONCLUSIONS

This novel approach represents a potential advancement of the existing treatment paradigm for acute DeBakey type I dissection. Although it remains a work in progress, hybrid surgery plus STABLE repair provides favorable short-term outcomes and decreases late distal aortic complications compared with conventional surgical repair. We have demonstrated a novel approach to coping with a complex surgical problem, with encouraging results. The results provide additional evidence to incorporate the STABLE treatment paradigm in the existing surgical armamentarium for aortic dissection. We would support additional prospective investigation to definitively assess this promising new treatment paradigm for acute DeBakey type I dissection.

References

- Crawford ES, Svensson LG, Coselli JS, Safi HJ, Hess KR. Surgical treatment of aneurysm and/or dissection of the ascending aorta, transverse aortic arch, and ascending aorta and transverse aortic arch: factors influencing survival in 717 patients. *J Thorac Cardiovasc Surg.* 1989;98:659-74.
- Elefteriades JA. Natural history of thoracic aortic aneurysms: indications for surgery, and surgical versus nonsurgical risks. *Ann Thorac Surg.* 2002;74:S1877-80. S92-8.
- Hagan PG, Nienaber CA, Isselbacher EM, Bruckman D, Karavite DJ, Russman PL, et al. The International Registry of Acute Aortic Dissection (IRAD): new insights into an old disease. *JAMA.* 2000;283:897-903.
- Bavaria JE, Pochettino A, Brinster DR, Gorman RC, McGarvey ML, Gorman JH, et al. New paradigms and improved results for the surgical treatment of acute type A dissection. *Ann Surg.* 2001;234:336-43.
- Ergin MA, Phillips RA, Galla JD, Lansman SL, Mendelson DS, Quintana CS, et al. Significance of distal false lumen after type A dissection repair. *Ann Thorac Surg.* 1994;57:820-5.
- Halstead JC, Meier M, Etz C, Spielvogel D, Bodian C, Wurm M, et al. The fate of the distal aorta after repair of acute type A aortic dissection. *J Thorac Cardiovasc Surg.* 2007;133:127-35.
- Kirsch M, Soustelle C, Houel R, Hillion ML, Loisanse D. Risk factor analysis for proximal and distal reoperations after surgery for acute type A aortic dissection. *J Thorac Cardiovasc Surg.* 2002;123:318-25.
- Mossop P, Nixon I, Oakes J, Devine TJ, McLachlan CS. Immediate "total" aortic true lumen expansion in type A and B acute aortic dissection after endovascular aortic endografting and GZSD bare stenting. *J Thorac Cardiovasc Surg.* 2007;134:1360-2.
- Mossop PJ, McLachlan CS, Amukotuwa SA, Nixon IK. Staged endovascular treatment for complicated type B aortic dissection. *Nat Clin Pract Cardiovasc Med.* 2005;2:316-22.
- Hofferberth SC, Foley PT, Newcomb AE, Yap KK, Yui MY, Nixon IK, et al. Combined proximal endografting with distal bare-metal stenting for management of aortic dissection. *Ann Thorac Surg.* 2012;93:95-102.
- Miller DC, Stinson EB, Oyer PE, Rossiter SJ, Reitz BA, Griep RB, et al. Operative treatment of aortic dissections: experience with 125 patients over a sixteen-year period. *J Thorac Cardiovasc Surg.* 1979;78:365-82.
- Tsai TT, Evangelista A, Nienaber CA, Trimarchi S, Sechtem U, Fattori R, et al. Long-term survival in patients presenting with type A acute aortic dissection: insights from the International Registry of Acute Aortic Dissection (IRAD). *Circulation.* 2006;114(1 Suppl):I350-6.
- Olsson C, Hillebrant CG, Liska J, Lockowandt U, Eriksson P, Franco-Cereceda A. Mortality in acute type A aortic dissection: validation of the Penn classification. *Ann Thorac Surg.* 2011;92:1376-82.
- Kouchoukos NT, Mauney MC, Masetti P, Castner CF. Single-stage repair of extensive thoracic aortic aneurysms: experience with the arch-first technique and bilateral anterior thoracotomy. *J Thorac Cardiovasc Surg.* 2004;128:669-76.
- Kato M, Ohnishi K, Kaneko M, Ueda T, Kishi D, Mizushima T, et al. New graft-implanting method for thoracic aortic aneurysm or dissection with a stented graft. *Circulation.* 1996;94(9 Suppl):III88-93.
- Chen X, Huang F, Xu M, Wang L, Jiang Y, Xiao L, et al. The stented elephant trunk procedure combined total arch replacement for DeBakey I aortic dissection: operative result and follow-up. *Inter Cardiovasc Thorac Surg.* 2010;11:594-8.
- Jakob H, Tsagakis K, Tossios P, Massoudy P, Thielmann M, Buck T, et al. Combining classic surgery with descending stent grafting for acute DeBakey type I dissection. *Ann Thorac Surg.* 2008;86:95-101.
- Pochettino A, Brinkman WT, Moeller P, Szeto WY, Moser W, Cornelius K, et al. Antegrade thoracic stent grafting during repair of acute DeBakey I dissection prevents development of thoracoabdominal aortic aneurysms. *Ann Thorac Surg.* 2009;88:482-90.
- Uchida N, Ishihara H, Shibamura H, Kyo Y, Ozawa M. Midterm results of extensive primary repair of the thoracic aorta by means of total arch replacement with open stent graft placement for an acute type A aortic dissection. *J Thorac Cardiovasc Surg.* 2006;131:862-7.
- Ito N, Tsunoda T, Nakamura M, Iijima R, Matsuda K, Suzuki T, et al. Percutaneous bare Z-stent implantation as an alternative to surgery for acute aortic dissection with visceral ischemia. *Catheter Cardiovasc Interv.* 2003;58:95-100.
- Lombardi JV, Cambria RP, Nienaber CA, Chiesa R, Teekken O, Lee A, et al. Prospective multicenter clinical trial (STABLE) on the endovascular treatment of complicated type B aortic dissection using a composite device design. *J Vasc Surg.* 2012;55:629-40. e2.
- Melissano G, Bertoglio L, Kahlberg A, Baccellieri D, Marrocco-Trischitta MM, Calliari F, et al. Evaluation of a new disease-specific endovascular device for type B aortic dissection. *J Thorac Cardiovasc Surg.* 2008;136:1012-8.
- Nienaber CA, Kische S, Zeller T, Rehders TC, Schneider H, Lorenzen B, et al. Provisional extension to induce complete attachment after stent-graft placement in type B aortic dissection: the PETTICOAT concept. *J Endovasc Ther.* 2006;13:738-46.
- Geirsson A, Bavaria JE, Swarr D, Keane MG, Woo YJ, Szeto WY, et al. Fate of the residual distal and proximal aorta after acute type A dissection repair using a contemporary surgical reconstruction algorithm. *Ann Thorac Surg.* 2007;84:1955-64.

Discussion

Dr R. Scott Mitchell (Stanford, Calif). Ms Hofferberth, first congratulations on a superb prescription. It was a great opening paper and very provocative. I additionally would like to thank you for getting me the manuscript long in advance.

I do have several questions. I think the major question is for whom does this confer the greatest advantage. In your study, you noted that you had almost 30% of patients who required distal re-intervention, and yet, in a large study, just recently out of Stockholm of more than 300 acute type A's, they required reintervention in only 8% of their patients at 10 years. That is a pretty significant difference. What I wonder is, what is your indication to do an endovascular repair for the distal aortic dilation? At what size do you recommend doing something?

Ms Hofferberth. Thank you for your question. Certainly, one of the limitations of this report is that the treated group is very much a heterogeneous population of patients. There were no uniform indications for reintervention. Three patients underwent reintervention; the first received endovascular treatment for thoracic aneurysm formation, after rapid expansion of 12 mm was observed at 3 months after the procedure. At this point, the treating surgeon intervened preemptively. The 2 remaining patients who were treated for thoracoabdominal aneurysms underwent reintervention after being observed to have ongoing aneurysmal expansion, and

both were treated when the thoracic aorta had reached a size of 60 mm.

Dr Mitchell. Thank you. Second, how do you size your proximal graft? I think a lot of us are pretty nervous about putting a stent graft, especially a stent graft with barbs on it, into that freshly dissected proximal descending thoracic aorta. How do you size that, and have you had any problems with those barbs?

Ms Hofferberth. Thank you. We have not observed any major adverse events related to proximal fixation method used in TX2 graft implantation. The proximal graft was sized according to the overall total lumen size.

Dr Mitchell. So all your repair occurs after bypass with administration of contrast. Would you agree that an alternative might be an antegrade insertion of the device through the open arch, which would not require radiographic control?

Ms Hofferberth. Thank you for your comment. We have used the retrograde approach for a couple of reasons. First, we believed that if an antegrade graft were deployed at circulatory arrest, it would be difficult to assess with a high degree of certainty whether one remained in the true lumen in both the thoracic and the abdominal aorta. This is more tightly controlled when one accesses the true lumen using the retrograde approach and the catheter techniques. Second, the devices used in all these cases were designed specifically for retrograde delivery. This is particularly relevant for proximal graft fixation and adjustment of the graft to the distal arch, which was designed specifically from a retrograde approach.

Dr Mitchell. Finally, I noted that 2 of your patients were indeed patients with Marfan syndrome. I am very curious as to how this graft performed in those patients and would you finally recommend this procedure for all patients undergoing acute type A's, the DeBakey type I extent.

Thank you and, again, congratulations.

Ms Hofferberth. Thank you for your comments. Although the results we have presented here are very encouraging, we are not, at this stage, in a position to recommend applying this treatment technique in all patients with DeBakey type I dissection, because we simply do not have the data to support this. However, in treating all-comers, the 2 operators have demonstrated that you can have good results in all patients, including those with connective tissue disorders, but we would certainly not be able to provide any sort of overriding recommendations just based on our data. Although we

cannot make any definite recommendations from our study, we do believe that these results warrant future prospective investigation of this promising adjunctive treatment strategy in patients with DeBakey type I dissection.

Dr John Ikonmidis (*Charleston, SC*). Thank you. Sophie, it was a fantastic presentation, and I join Dr Mitchell in congratulating you for this very interesting and provocative work.

I have a terminology question for you. Looking at your patient demographics, you said that you studied 61 consecutive patients with acute type A, of which 37 were DeBakey type I's. That implies that one half of the patients in the original 61 had ascending aortic dissections that were confined to just the ascending aorta, that were just type II's. Is that true?

Ms Hofferberth. Yes, that is correct.

Dr Ikonmidis. That strikes me as being quite unusual. Type II aortic dissections tend to be fairly uncommon relative to other types of aortic dissection. I was wondering if you could comment on the high incidence of type II dissection in this group.

Ms Hofferberth. Sorry, I would not be able to make a comment as to why there would be a discrepancy in the incidence of type II dissections. We only included patients who were demonstrated to have dissection that extended beyond the left subclavian artery.

Moderator. The water goes down the drain differently down there you know, something like that.

Dr Eric Roselli (*Cleveland, Ohio*). Sophie, again, congratulations. You have demonstrated that you can perform a more extensive repair safely for patients with type I extent dissections. It seems that the real advantage of these more extensive techniques is to promote remodeling of the aorta. My question is about how you assess that. You described the false lumen as being partially or completely thrombosed. I think an important point to understand in these patients is that the flow into the false lumen is diverted into other entry or re-entry tears. When you did your computed tomography analysis of these patients, did they undergo computed tomography scans with arterial contrast and also a delayed venous phase imaging study to really assess the perfusion and pressurization of that false lumen? I think it is an important detail. Thank you.

Ms Hofferberth. Thank you for your question. That is correct. In each patient, computed tomography angiography was performed using arterial contrast and delayed venous phase imaging to assess the false lumen perfusion rates.