Open thoracoabdominal aortic repair for chronic type B dissection

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Objectives: Advances in endovascular surgery have brought into question the role of open operative treatment of chronic thoracoabdominal aortic dissection. In this context, we evaluated our experience with open repair of this condition using a single operative technique.

Methods: From January 1986 to January 2014, 69 patients with chronic thoracoabdominal aortic dissection underwent open repair using total cardiopulmonary bypass (CPB) and hypothermic circulatory arrest (HCA). The degree of repair was as follows: Crawford extent I, 13 patients (19%), Crawford extent II, 41 patients (59%), and Crawford extent III, 15 patients (22%). Thirty patients (43%) had Marfan or Loeys-Dietz syndrome. Fifty-three patients (77%) had previous operations on the thoracic or abdominal aorta.

Results: The 30-day mortality rate was 5.8% (4 patients). Stroke occurred in 2 (3%) of 66 operative survivors, and spinal cord ischemic injury in 4 (6%). Temporary dialysis for new-onset renal failure was required in 4.5% of hospital survivors and tracheostomy in 10.6%. Survival after 1, 5, and 10 years was 87%, 65%, and 40%, respectively. Eighteen patients (26%) required a total of 20 subsequent operations on the thoracic or abdominal aorta of whom 15 had Marfan or Loeys-Dietz syndrome. Three of these procedures were for contiguous distal aortic disease and 10 were for patch aneurysms of the intercostal or visceral/renal arteries.

Conclusions: Open thoracoabdominal aortic repair for chronic dissection using CPB and HCA can be accomplished with mortality and morbidity rates that are comparable with those reported for endovascular or hybrid techniques. Open repair should remain a viable and primary option for the management of this condition until the long-term effectiveness of alternative methods of treatment is clearly established. (*J Thorac Cardiovasc Surg* 2015;149:S125-9)

As a result of improved management of acute aortic dissection with open or endovascular repair and medical treatment, the number of patients presenting with chronic dissection of the descending thoracic and thoracoabdominal aorta is increasing. The optimal management strategy for patients with chronic dissection of the thoracoabdominal aorta who require intervention is not clearly established. Until recently, open repair represented the only surgical option. However, endovascular and hybrid repair of chronic thoracoabdominal aortic dissection are being used with increasing frequency, bringing into question the role of open surgery as the method of choice. In this context, we reviewed our experience with open repair of chronic thoracoabdominal aortic dissection using total cardiopulmonary bypass (CPB) and hypothermic circulatory arrest (HCA).

MATERIALS AND METHODS

Patient Characteristics

Between January 1986 and January 2014, 274 patients underwent open surgical repair of the descending thoracic or thoracoabdominal aorta repair using total CPB and HCA. No other operative technique was used during this interval. Sixty-nine of these patients (15%) had chronic thoracoabdominal aortic dissection and constitute the study population. The clinical characteristics of the 69 patients are shown in Table 1. The mean age at the time of operation was 54 ± 16 years (range, 22-77 years), and 53 (77%) patients were male. Thirty patients (43%) had clinical manifestations of Marfan or Loeys-Dietz syndrome. Thirty-three patients (48%) had symptoms associated with their aortic disease. The remaining patients had aneurysms greater than 5.5 cm in maximum diameter or rates of growth of the dissected aorta greater than 4 to 5 mm per year. Fifty-four patients (78%) had undergone previous operations on the thoracic or abdominal aorta (Table 1). Seventeen patients had undergone 2 or more procedures.

The extent of aortic disease requiring replacement is shown in Table 1. Patients with Crawford extent IV disease, where the aneurysmal segment was confined to the abdominal aorta, were excluded from the analysis. The study was reviewed by the Institutional Review Board of the Missouri Baptist Medical Center and was exempted from the need for board approval.

Operative Technique

Our general technique using total CPB with an interval of HCA has been described previously.^{1,2} With increasing experience, several modifications have been introduced. Since September 2004, cerebral spinal fluid drainage (CSF) has been used routinely, if technically feasible. Because of concern for embolization of thrombus or atheroma into the cerebral circulation with the use of femoral artery perfusion during CPB, in 1997, we began inserting a dispersion arterial cannula (Edwards Lifesciences Inc, Midvale, Utah) into the descending thoracic aorta at a site free of thrombus or atheroma as determined by epiaortic ultrasonography. CPB is established with this

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Abbreviations and Acronyms

CPB = cardiopulmonary bypass
 CSF = cerebral spinal fluid
 HCA = hypothermic circulatory arrest
 SCII = spinal cord ischemic injury

arterial cannula and with femoral venous cannulation. Femoral artery perfusion is initiated only after the aorta distal to the segment to be replaced has been occluded with a clamp. Alternatively, an 8-mm collagen impregnated polyester graft is anastomosed to the left axillary artery through a small incision in the axilla, and CPB is initiated through this artery.

After adequate cooling is achieved, the proximal anastomosis of the aortic graft to the descending thoracic aorta is completed during an interval of HCA. Flow is then reestablished to the upper body. Patent intercostal and lumbar arteries below the sixth or seventh intercostal space are preserved, when technically feasible. A full-thickness cuff of aortic tissue containing the intercostal arteries is sutured to an opening in the aortic graft. The clamp present on the aortic graft is repositioned below the implanted intercostal/lumbar arteries and perfusion of these arteries is established.

Before 2003, the visceral and renal arteries were attached to the aortic graft as a Carrel patch by using a full-thickness cuff of aortic tissue surrounding these arteries. Often, the left renal artery was attached separately to the aortic graft using a 6-mm or 8-mm interposition graft. Because of the development of patch aneurysms, particularly in patients with Marfan or other connective tissue syndromes, we modified our technique. In the subsequent 29 patients, the celiac, superior mesenteric, and renal arteries were detached from the aorta and attached separately to the branches of a woven polyester branched aortic graft (Hemashield Platinum TAAA graft, MAQUET Cardiovascular LLC, Wayne, NJ).³ Anastomosis of the body of the branched graft to the aorta distal to the renal arteries was performed before attaching the renal and visceral arteries to the aortic graft, to permit perfusion of the lower body through the second arterial line in the femoral artery. This was done to minimize the duration of spinal cord ischemia. The cardiopulmonary perfusion data are shown in [Table 2](#).

Follow-up

After hospital discharge, patients were evaluated at 1 and 6 months postoperatively and subsequently at 12-month intervals. Computed tomography or magnetic resonance imaging studies were obtained before discharge, at 6 months postoperatively, and yearly thereafter. Follow-up was 100% complete. Mean duration of follow-up was 5.4 years (range, 1 month to 19.4 years). Twenty-nine patients were followed for more than 5 years.

Statistical Analysis

Data were analyzed using Intercooled Stata 9.2 software (StataCorp, College Station, Tex). Standard descriptive statistical analyses were used. Continuous data are presented as a mean $\pm$ standard deviation. Categorical data are presented as proportions and were compared between subgroups by using the Fisher exact test. Nonparametric estimates of freedom from all-cause death and reoperation were determined using the Kaplan-Meier method and are reported as mean $\pm$ standard errors.

RESULTS

Early Mortality

The 30-day mortality rate was 5.8% (4 patients). Three patients died in the immediate postoperative period: 2 patients died intraoperatively of myocardial failure, and the

third died early after arrival in the intensive care unit of tension pneumothorax resulting from perforation of the trachea. A fourth patient died of multiple organ system failure on the 18th postoperative day. Two additional patients died in the hospital of multiple organ system failure 83 days and 108 days postoperatively. The 1-year actuarial mortality rate was 13.4%. Mortality according to the extent of aorta replaced is summarized in [Table 3](#).

Neurologic Complications

Spinal cord ischemic injury (SCII) occurred in 4 (6.1%) of 66 operative survivors. All developed paraplegia SCII according to the extent of aorta replaced is shown in [Table 3](#). SCII occurred in 1 (2.4%) of 42 patients who had implantation of intercostal or lumbar arteries, and in 3 (12.5%) of 24 patients in whom no intercostal or lumbar arteries were implanted. The difference in the incidence of paraplegia was not statistically significant ($P = .13$). Two of 22 patients (9%) who underwent CSF drainage developed paraplegia and are alive 4.5 and 6 years later. Two of 44 patients (4.5%) who did not undergo CSF drainage developed paraplegia. They survived for 18 days and 4.5 years. This difference was not statistically significant ($P = .6$). Stroke occurred in 2 (3%) of the operative survivors. The incidence of stroke according to the extent of aorta replaced is summarized in [Table 3](#).

Other Morbidity

New-onset renal failure requiring dialysis developed in 3 (4.5%) patients. Ventilatory support was required for a mean of 6.6 ± 16.2 days (median, 1.5 days), and 15 patients (23%) required ventilatory support for longer than 72 hours. Tracheostomy was required in 7 (10.6%) patients. The mean duration of stay in the intensive care unit was 10.2 ± 19.6 days (median, 4 days). The average intraoperative transfusion requirements were 8.3 units of packed red cells, 6.7 units of fresh frozen plasma, 3.8 units of platelets, and 10.2 units of cryoprecipitate. Two patients (2.8%) required early reoperation for bleeding.

Long-Term Follow-up

During the follow-up period, which extended to 18 years, there were 31 late deaths. Two of the 21 patients whose cause of death was known, died of rupture. Five- and 10-year actuarial survival was 65% and 40%, respectively ([Figure 1](#)). Five- and 10-year actuarial rates of freedom from reoperation on the contiguous aorta were 97% and 83%, respectively ([Figure 2](#)). Actuarial rates of freedom from any operation on the aorta or the aortic graft at 5 and 10 years were 87% and 37%, respectively ([Figure 3](#)). The reoperative procedures performed are shown in [Table 4](#). Fifteen of the 18 patients in whom 20 reoperations were required had Marfan or Loeys-Dietz syndrome. The most common procedure was open or endovascular repair for

TABLE 1. Preoperative patient characteristics

Characteristics	No. (%) of patients (N = 69)
Comorbidities	
Marfan, Loeys-Dietz syndrome	30 (43)
Hypertension	49 (71)
Hyperlipidemia	22 (32)
Chronic obstructive pulmonary disease	17 (25)
Coronary artery disease	10 (15)
Diabetes	2 (3)
Peripheral vascular disease	22 (32)
Previous transient ischemic attack or stroke	13 (19)
History of smoking	29 (42)
Creatinine >1.5 mg/dL	9 (13)
Previous operations	
Ascending aortic repair	53
Aortic arch repair	21
Descending thoracic aortic repair	14
Abdominal aortic repair	8
Coronary artery bypass graft or percutaneous coronary intervention	8
Aortic valve procedure	44
Mitral valve replacement	3
Atrial septal defect	1
Saphenous vein graft to renal artery	1
Extent of thoracoabdominal aortic dissection	
Crawford extent I	13 (19)
Crawford extent II	41 (59)
Crawford extent III	15 (22)

patch aneurysms of the intercostal or visceral/renal arteries.⁴ Nine of the 10 patients who required these procedures had Marfan or Loeys-Dietz syndrome. No reoperations on the aortic graft or the renal or visceral arteries have been required among the patients who had implantation of a branched graft.

TABLE 2. Cardiopulmonary perfusion data

	Mean ± standard deviation	Range
Time (min)		
Cardiopulmonary bypass	197.1 ± 43.4	90-307
Cooling	40.6 ± 12.4	22-75
Circulatory arrest	30.8 ± 11.0	8-61
Low-flow hypothermic bypass	62.7 ± 28.9	16-160
Hypothermic ventricular fibrillation	128.6 ± 34.6	41-230
Spinal cord ischemia	78 ± 26.2	30-172
Left renal ischemia	111.1 ± 38.8	16-202
Right renal ischemia	108.3 ± 37.5	16-200
Celiac ischemia	119 ± 39.4	16-215
Superior mesenteric artery ischemia	111.7 ± 38.7	16-230
Rewarming	81.2 ± 22.7	49-154
Temperature (°C)		
Lowest nasopharyngeal	15 ± 2.4	11.8-24
Lowest bladder/rectal	18.9 ± 2.6	12.3-26.5

TABLE 3. Extent of repair and associated mortality and morbidity

Crawford extent of repair	30-d mortality, n (%)	Stroke, n (%)*	Spinal cord ischemic injury, n (%)*	New dialysis, n (%)*
Type I (n = 13)	0	0	0	0
Type II (n = 41)	3	1	1	2
Type III (n = 15)	1	1	3	1
Total (n = 69)	4 (5.8)	2 (3.0)	4 (6.1)	3 (4.5)

*Based on 66 operative survivors.

DISCUSSION

Our cumulative experience with CPB and HCA for the management of thoracic and thoracoabdominal aortic disease has confirmed the safety and efficacy of the technique.^{1,2} The present study demonstrates its effectiveness for the subset of patients with chronic thoracoabdominal aortic dissection. Corvera and Fehrenbacher⁵ have also reported satisfactory outcomes using this technique for patients with chronic thoracic and thoracoabdominal aortic dissection. Other groups, using differing techniques, have reported similar or higher early mortality rates and comparable rates of major morbidity for open repair of chronic descending aortic dissections.⁶⁻⁸ However, these series included patients with both thoracic and thoracoabdominal procedures, and the subgroups were not analyzed separately. Several of these reports have also noted the need for subsequent open and endovascular vascular procedures. Pujara and colleagues⁷ reported a 79% rate of freedom from reoperation at 5 years among patients treated with open repair. They observed, as we did, that these procedures involved the aorta both proximal and distal to the operated segment, as well as the operated segment.

Early in our experience with Crawford extent II and III disease, the renal and visceral arteries were attached to the aortic graft with a full-thickness cuff of aortic tissue. Patch aneurysms and false aneurysms requiring reoperation

FIGURE 1. Long-term survival after repair of chronic thoracoabdominal aortic dissection.

FIGURE 2. Freedom from reoperation on the contiguous proximal or distal aorta after repair of chronic or chronic thoracoabdominal aortic dissection.

developed in some of these patients. Since adopting the use of branched grafts to restore flow to the visceral and renal arteries, these complications have been eliminated, and patency of the branch grafts has been excellent.⁴ Intercostal and lumbar arteries that were preserved were also attached to the aortic graft with a cuff of aortic tissue. A substantial percentage of these patients, particularly those with Marfan or Loeys-Dietz syndrome, developed patch aneurysms that required open or endovascular repair from 7 months to 14.4 years after the initial procedure (Table 4). All patients survived the reoperative procedure. We continue to attach patent lumbar and lower intercostal arteries with a cuff of aortic tissue, when technically feasible, to maintain flow to the spinal cord, particularly in younger patients who may not have developed adequate collateral pathways to supply the spinal cord. However, because of the propensity for development of patch aneurysms, continued surveillance with imaging is essential. Although interposition grafts have been used as an alternative method to preserve patent intercostal arteries, Omura and colleagues⁹ reported

FIGURE 3. Freedom from any operation on the aorta or the aortic graft after repair of chronic thoracoabdominal aortic dissection.

TABLE 4. Subsequent aortic procedures in 18 patients*

Aortic segment	No. (%) of reoperations (N = 20)
Aortic root	3 (4.3)
Proximal contiguous aorta	3 (4.3)
Aortic graft patch or other false aneurysm†	10 (14.5)
Distal contiguous aorta	3 (4.3)
Abdominal aorta	1 (1.5)
Total	20 (29)

*15 of the 18 patients had Marfan or Loeys-Dietz syndrome. †9 of the 10 patients had Marfan or Loeys-Dietz syndrome.

a significantly higher patency rate with the intercostal patch technique, 90.8% (109 of 120 arteries) compared with 74.2% (256 of 345 arteries) with the graft interposition technique ($P < .01$).

Uncertainty remains regarding the role of endovascular stent grafting and hybrid techniques for the management of chronic thoracoabdominal aortic dissection, and the results to date have been variable. A meta-analysis of outcomes from 39 studies of distal aortic dissection involving 197 patients treated with endovascular grafts reported a 30-day mortality of 3.2% and 2-year survival of 91%.¹⁰ The rates of overall, major, and procedure-related complications (including retrograde aortic dissection) were 9.1%, 7.9% and 8.3%, respectively. In a subsequent systematic review of midterm outcomes after endovascular repair that involved 17 studies of 567 patients, the midterm mortality was 9.2%.¹¹ Reintervention rates ranged from 0% to 60% in those studies with a median follow-up of 31 months. Distal aneurysm formation or continued false aneurysm perfusion with aneurysmal dilatation developed in 7.8% of patients. In a series of 76 patients reported from the Cleveland Clinic, the 30-day mortality was 5% and the 3-year survival was 80%.¹² During a mean follow-up interval of 24 months, 19 reinterventions were required in 17 patients, more than half of which entailed aortic repairs distal to the endograft. Three patients sustained a retrograde aortic dissection, prosthetic collapse occurred in 2 patients, and most importantly, enlargement of the aorta distal to the stent occurred in 9 patients. The intervention-free rate was 73% at 3 years. Freedom from death or intervention at 3 years was 59%. These results suggest that endovascular repair may not be the optimal method of management for patients with extensive thoracoabdominal aortic dissection, particularly when the aneurysmal enlargement extends into the infradiaphragmatic segment of the aorta.

Hybrid procedures represent another alternative for repair of chronic thoracoabdominal aortic dissection. However, in a recently published meta-analysis of 19 studies of 660 patients who had hybrid repair of thoracoabdominal aortic aneurysms, only 7.8% of the procedures involved patients with aortic dissection, and the outcomes of this subset were not analyzed separately.¹³ Early mortality for the

entire cohort was 12.6%, and the overall rate of spinal cord ischemia was 3.4%. The overall rates of permanent renal failure, mesenteric ischemia, and severe cardiopulmonary complications were 10.4%, 4.6%, and 7.8%, respectively. The overall rate of renal and visceral artery graft patency during a mean follow-up of 26.2 months was 94.7%. Experience with fenestrated and branched endovascular aortic repair for chronic thoracoabdominal aortic dissections remains limited.¹⁴

Because of selection bias, differing operative techniques, and lack of long-term follow-up, particularly for the more recently implemented endovascular and hybrid techniques, uncertainty regarding the optimal method of management will persist until the results of randomized trials comparing well-matched patients in whom standardized open and endovascular techniques are used become available.

Limitations

The present study was observational in nature and involved retrospective review of prospectively collected data in a referral-based tertiary care center. Surgical techniques evolved during the 18 year time period of the study. However, long-term follow-up, including periodic imaging studies, was available for most patients.

CONCLUSIONS

Open repair of chronic thoracoabdominal aortic dissection using total hypothermic CPB and HCA can be accomplished with acceptable mortality and morbidity rates that are comparable with those reported for endovascular or hybrid techniques. Open repair should remain a viable and primary option for repair of this condition until the long-term effectiveness of the alternative methods of treatment is clearly established.

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