Early and late results of descending thoracic and thoracoabdominal aortic aneurysm open repair with deep hypothermia and circulatory arrest

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Objective: Open repair of descending thoracic aortic and thoracoabdominal aortic aneurysms may carry low morbidity and mortality, depending on experience of the surgeon and operative technique used. Although thoracic endovascular aortic repair is less invasive, its limitations include anatomy and pathology of the aorta, proximity of major branches, and significant complication and reintervention rates. We retrospectively reviewed a 2-surgeon experience (J.W.F. and J.S.C.) with deep hypothermic circulatory arrest to repair descending thoracic aortic and thoracoabdominal aortic aneurysms.

Methods: All patients (n = 343) who underwent surgical replacement of descending thoracic aortic or thoracoabdominal aortic aneurysm with deep hypothermic circulatory arrest from 1995 to 2009 were included. Segmental arteries between T8 and the celiac artery were aggressively reimplanted as indicated. Visceral and renal artery bypasses were performed for significant stenosis. Concomitant coronary artery bypass grafting was performed if targets were anterior or lateral wall vessels. Lumbar drains were not routinely used but placed postoperatively on clinical evidence of spinal cord ischemia.

Results: Of 343 patients, 98 had descending thoracic aortic aneurysms, 69 had Crawford type I thoracoabdominal aortic aneurysms, 111 had type II, 32 had type III, and 33 had type IV. Emergency or urgent operations comprised 13% of repairs. Hospital mortalities were 5.0% for all cases, 3.7% for elective cases, and 13.3% for urgent or emergency cases. Overall incidences were 4.4% for stroke, 3.2% for paraplegia or paraparesis, 1.5% for renal failure requiring dialysis, and 3.5% for tracheostomy. The 1-, 3-, 5-, and 10-year survival rates were 90%, 79%, 69%, and 54%, respectively.

Conclusions: Surgical repair of descending thoracic aortic and thoracoabdominal aortic aneurysms with deep hypothermic circulatory arrest carries low operative morbidity and mortality and excellent early and late survival rates. These results can be used as a benchmark for future techniques and technologies. (*J Thorac Cardiovasc Surg* 2010;140:S154-60)

Open repair of descending thoracic aneurysms (DTAs) and thoracoabdominal aortic aneurysms (TAAAs) continues to be a challenge for cardiothoracic and vascular surgeons. As a result of the complexity and significant mortality and morbidity of the operation, a major shift favoring endovascular repair has been undertaken by many cardiothoracic and vascular surgeons.¹⁻⁵ Multiple centers have published good to excellent results with open DTA and TAAA repair. With the diversity of open repair techniques and

the inclusion of different repair techniques in most studies, however, it is difficult to determine whether any single technique carries the least mortality and morbidity, as well as the best long-term results.⁶⁻¹¹

Deep hypothermic cardiopulmonary bypass with periods of circulatory arrest (DHCA) has been used by a limited number of surgeons as the only technique for replacement of the descending thoracic and thoracoabdominal aorta and by others for the more complex aneurysms.¹²⁻¹⁸ We have used this technique as the singular therapy for DTAs and TAAAs for the past 15 years, excluding patients with traumatic distal arch and descending thoracic aortic injuries, those with selected acute complicated type III aortic dissections amenable to endovascular repair, and patients at very high risk with thoracic aneurysms that are amenable to endovascular repair.

The minimally invasive nature and early results of thoracic endovascular aortic repair have highlighted the importance of studying the long-term survival and durability of open DTA and TAAA repairs. In this study, we show that

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Abbreviations and Acronyms

DHCA = deep hypothermic cardiopulmonary
bypass with periods of circulatory arrest
DTA = descending thoracic aneurysm
SMA = superior mesenteric artery
TAAA = thoracoabdominal aortic aneurysm

DHCA provides optimal end-organ protection during the operation and has excellent early and late results for complex repairs of DTAs and TAAAs.

MATERIALS AND METHODS

This retrospective study was approved by the institutional review board of Indiana University–Purdue University and Methodist Hospital, Indianapolis, Ind. Because of the retrospective nature of the study, informed consent was waived. All patients (n = 343) from January 1, 1995, to December 31, 2009, who underwent descending thoracic aortic replacement or thoracoabdominal aortic replacement by either of 2 surgeons (J.W.F. or J.S.C.) with DHCA were included in the study. Patients who underwent replacement of the descending thoracic or thoracoabdominal aorta with left heart bypass or full cardiopulmonary bypass without hypothermia or without the use of cardiopulmonary bypass were excluded. Patients who underwent thoracic endovascular aortic repairs were also excluded. Long-term survival data were obtained by querying the Social Security Death Index and by referencing the computerized medical records system at Methodist Hospital.

Statistical Analysis

All data were summarized with descriptive statistics (mean $\pm$ SD for continuous measures and counts with percentages for categorical measures). Survival estimates were calculated with the Kaplan–Meier method. Observations for patients who were unavailable for follow-up or who were still alive as of December 31, 2009, were considered to be censored.

Indications for Operation

Elective DTA and TAAA repairs were performed when the thoracic component of the aneurysm was larger than 5.5 cm or had a growth rate of greater than 0.5 cm per year. TAAAs were also repaired if the abdominal component was larger than 5.0 cm. Chronic dissections involving the thoracic or thoracoabdominal aorta were repaired if the aneurysmal component of the dissected aorta measured 5.0 to 5.5 cm.

Indications for urgent or emergency repair included acute, complicated type III aortic dissection, malperfusion syndrome, persistent pain despite adequate blood pressure control, aortic rupture, and aortobronchial or aortoesophageal fistula.

Preoperative Considerations

All elective patients underwent preoperative coronary catheterization. Hemodynamically significant left anterior descending or circumflex distribution coronary arteries were bypassed at the time of surgery for DTA or type I or II TAAA repairs. In the case of type III or IV TAAA, significant left-sided lesions were treated with percutaneous coronary intervention. Hemodynamically significant lesions in the right coronary distribution were treated with percutaneous coronary intervention if amenable. In the event of severe 3-vessel coronary artery disease, a coronary artery bypass operation through a sternotomy was completed before the aneurysm repair. All patients with worse than moderate aortic insufficiency underwent

aortic valve replacement before the aneurysm repair. Severe chronic obstructive pulmonary disease and home oxygen therapy were not contraindications for surgery. Severe bronchiectasis or the production of large amounts of dirty sputum were relative contraindications. Spinal drainage was not used routinely but was placed only when motor-evoked potentials did not return to baseline after completion of the operation or when there were changes in the lower extremity neurologic function or with delayed paraparesis.

Operative Technique

All 343 patients underwent descending thoracic or thoracoabdominal aortic replacement with DHCA. The details of this technique are very important and have been previously published.¹² Important technical considerations included the following: (1) hypothermia for organ protection with minimization of circulatory arrest time to any given vascular bed or end organ, including the spinal cord; (2) avoidance of placing a proximal aortic crossclamp unless the inside of the aorta has been visually inspected during the period of circulatory arrest; (3) aggressive use of bypasses to stenotic visceral or renal arteries; (4) placement of saphenous vein bypass grafts to significantly diseased coronary arteries in the left anterior descending or circumflex distributions; (5) aggressive preservation of important intercostal artery pairs by reimplantation into the side of the graft or incorporation with proximal or distal anastomoses; (6) avoidance of air and particulate emboli during the periods of cardiopulmonary bypass and circulatory arrest; and (7) cautious manipulation of the left lung during the period of anticoagulation and adequate decompression of the left ventricle during hypothermic bypass to avoid left lung parenchymal hemorrhage.

A total arch replacement was defined as resection of the entire transverse arch with a proximal anastomosis to the ascending aorta or previous ascending aortic graft. Arch vessels were reimplanted as an island or individually bypassed with a branched graft (Hemashield; Maquet, Inc, Wayne, NJ; and Vascutek; Terumo Medical Corporation, Somerset, NJ). A partial arch replacement involved resection of the arch proximal to the ligamentum arteriosum with or without a bypass to the left subclavian artery. A bypass to the celiac artery, superior mesenteric artery (SMA), or renal artery was defined as the use of a polytetrafluoroethylene interposition graft (W. L. Gore & Associates, Inc, Flagstaff, Ariz) to reach proximal to an arterial stenosis. Simple reimplantation of a vessel with an aortic button was not considered to be a bypass. Coronary artery bypass with saphenous vein was performed in descending thoracic and type I or II thoracoabdominal aortic replacements when appropriate left anterior descending or circumflex targets had significant disease.

RESULTS

The patient characteristics are listed in Table 1. The mean age was 66.0 ± 12.3 years. Men comprised 63.6% of the patient population. Previous abdominal aortic replacement had occurred in 24.5% of patients, and previous thoracic aortic replacement had occurred in 24.8%. Chronic renal insufficiency was seen in 15.5% of patients, with overt renal failure in 7.3%. The aortic pathologic indications included atherosclerotic aneurysm in 61.5%, chronic dissection with aneurysmal degeneration in 27.1%, and acute, complicated type III dissection in 3.8%. Emergency or urgent operations were performed in 13.1% for acute complicated type III dissection, rupture or impending rupture of DTAs or TAAAs, or acute aortic thrombosis.

The operative characteristics are listed in Table 2. Of the 343 operations, replacement of the descending thoracic aorta

TABLE 1. Patient characteristics (n = 343)

Age (y, mean $\pm$ SD)	66.0 $\pm$ 12.3
Male	218 (63.6%)
Previous myocardial infarction	45 (13.1%)
Previous percutaneous coronary intervention	32 (9.3%)
Previous coronary artery bypass grafting	60 (17.5%)
Hypertension	311 (90.7%)
Chronic obstructive pulmonary disease	90 (26.2%)
Previous or current tobacco use	148 (43.1%)
Hyperlipidemia	137 (39.9%)
Diabetes mellitus	42 (12.2%)
Previous abdominal aortic surgery	84 (24.5%)
Previous thoracic aortic surgery	85 (24.8%)
Chronic renal insufficiency	53 (15.5%)
Previous renal failure	25 (7.3%)
Preoperative mesenteric ischemia	9 (2.6%)
Preoperative paraplegia	5 (1.5%)
Chronic dissection (type I or III)	93 (27.1%)
Acute type III dissection	13 (3.8%)
Degenerative aneurysm	211 (61.5%)
Pseudoaneurysm	18 (5.2%)
Infected aortic graft	10 (2.9%)
Coarctation	7 (2.0%)
Emergency or urgent operation	45 (13.1%)

Data represent numbers and percentages of patients except as marked.

was involved in 28.6%, Crawford type I TAAA in 20.1%, type II in 32.4%, type III in 9.3%, and type IV in 9.6%. Total arch replacement was performed in 5.5% of all patients and in 15.3% of DTA cases, 4.3% of type I TAAA cases, and 0.9% of type II TAAA cases. Partial arch replacement was performed in 23.6% of all patients and 60.2% of DTA

TABLE 2. Operative characteristics (n = 343)

Extent of aortic replacement	
Descending thoracic aorta	98 (28.6%)
Type I thoracic aortic aneurysm	69 (20.1%)
Type II thoracic aortic aneurysm	111 (32.4%)
Type III thoracic aortic aneurysm	32 (9.3%)
Type IV thoracic aortic aneurysm	33 (9.6%)
Total arch	19 (5.5%)
Partial arch	81 (23.6%)
Other procedures	
Celiac bypass	10 (2.9%)
Superior mesenteric artery bypass	6 (1.7%)
Celiac and superior mesenteric artery bypasses	15 (4.4%)
Left renal artery bypass	33 (9.6%)
Right renal artery bypass	19 (5.5%)
Left and right renal artery bypasses	22 (6.4%)
Coronary artery bypass	15 (4.4%)
Reimplantation of intercostal arteries	117 (34.1%)
Femoral cannulation	285 (83.1%)
Circulatory arrest time (min, mean $\pm$ SD)	27.5 $\pm$ 13.1
Cardiopulmonary bypass time (min, mean $\pm$ SD)	242.6 $\pm$ 80.3

Data represent numbers and percentages of patients except as marked.

cases, 14.5% of type I cases, and 10.8% of type II cases (see Table 3).

Of the patients with type II TAAA, 18 (16.2%) had a celiac or SMA bypass or both and 50 (45.0%) had at least 1 renal artery bypass. Of the patients with type III TAAA, 7 (21.9%) had a celiac or SMA bypass or both and 12 (37.5%) had at least 1 renal artery bypass. Of the patients with type IV TAAA, 5 (15.2%) had a celiac or SMA bypass or both and 12 (36.4%) had at least 1 renal artery bypass. Coronary artery bypass grafting with saphenous vein grafts was performed in 7 DTA cases (7.1%), 5 type I TAAA cases (7.2%), 2 type II cases (1.8%), and 1 type III case (3.1%).

Circulatory arrest time to the brain and heart was 27.5 $\pm$ 13.1 minutes. Total cardiopulmonary bypass time was 242.6 $\pm$ 80.3 minutes.

In-hospital mortality was 5.0% for all patients. Permanent paraplegia or paresis occurred in 3.2%. Permanent cerebrovascular accident occurred in 4.4%. Dialysis-dependent renal failure occurred in 1.5% (Table 4). Major morbidities and mortalities by extent of aortic replacement are listed in Table 3. Not surprisingly, type II TAAA operations carried the highest morbidity and mortality, with an operative mortality of 9.0%, a permanent stroke rate of 6.3%, a permanent paraplegia or paresis rate of 5.4%, and a dialysis-dependent renal failure rate of 1.8%. Emergency and urgent operations also carried significant morbidity and mortality, with an operative mortality of 13.3% and permanent spinal cord ischemia in 4.4%, permanent stroke in 8.9%, and renal failure requiring dialysis in 2.2%. Elective operations carried less major morbidity and mortality, with an operative mortality of 3.7% and permanent stroke in 3.7%, permanent spinal cord ischemia in 3.0%, and dialysis-dependent renal failure in 1.3%.

Kaplan–Meier survival data are shown in Table 5 and graphically depicted in Figure 1. Overall 1-, 5- and 10-year survivals were 90.1%, 69.3%, and 53.5%, respectively. For patients who underwent elective DTA or TAAA repair, 1-, 5-, and 10-year survivals were 91.6%, 70.7%, and 54.3%, respectively. For patients who underwent emergency or urgent repair, 1- and 5-year survivals were 79.6% and 55.7%, respectively. Long-term survival appeared to be greatest among those patients with isolated DTA, with or without arch aneurysm (74.9% at 10 years).

Operative mortality and Kaplan–Meier survival data for patients according to decade of age at the time of surgery are shown in Table 6. For patients younger than 50 years, operative mortality was 0%, and 10-year survival was 97.3%. For patients 80 years old and older (n = 31), operative mortality was 16.1%; however, there are 2 octogenarians who have survived at least 10 years after their aneurysm repair.

The rate of reexploration for postoperative bleeding was 5.0% for all patients. Prolonged intubation was a complication in 11.4% of all patients. Tracheostomy was necessary

TABLE 3. Major morbidity and mortality by extent of repair and acuity of operation

	DTA	Type I TAAA	Type II TAAA	Type III TAAA	Type IV TAAA	DTA + Type I TAAA	Elective	Emergency or urgent
No.	98	69	111	32	33	167	298	45
Arch replacement								
Total	15 (15.3%)	3 (4.3%)	1 (0.9%)	0 (0%)	0 (0%)	18 (10.8%)	17 (5.7%)	2 (4.4%)
Partial	59 (60.2%)	10 (14.5%)	12 (10.8%)	0 (0%)	0 (0%)	69 (41.3%)	69 (23.2%)	12 (26.7%)
Operative mortality	3 (3.1%)	1 (1.4%)	10 (9.0%)	2 (6.3%)	1 (3.0%)	4 (2.4%)	11 (3.7%)	6 (13.3%)
Dialysis-dependent renal failure	0 (0%)	1 (1.4%)	2 (1.8%)	1 (3.1%)	1 (3.0%)	1 (0.6%)	4 (1.3%)	1 (2.2%)
Permanent paralysis or paresis	1 (1.0%)	3 (4.3%)	6 (5.4%)	1 (3.1%)	0 (0%)	4 (2.4%)	9 (3.0%)	2 (4.4%)
Permanent cerebrovascular accident	4 (4.1%)	2 (2.9%)	7 (6.3%)	1 (3.1%)	1 (3.0%)	6 (3.6%)	11 (3.7%)	4 (8.9%)
Tracheostomy	5 (5.1%)	2 (2.9%)	5 (4.5%)	0 (0%)	0 (0%)	7 (4.2%)	10 (3.4%)	2 (4.4%)

Data represent numbers and percentages of patients except as marked. DTA, Descending thoracic aneurysm; TAAA, thoracoabdominal aneurysm.

in 3.5% of patients. Mean postoperative stay was 11.8 ± 9.8 days, with a median of 9 days.

DISCUSSION

Despite the mortality risk with the surgical repair of DTAs and TAAAs, repair remains beneficial relative to the natural history of untreated aneurysms. Left untreated, these aneurysms carry an estimated 5-year survival of only 18% to 46%.^{19,20}

Hypothermic cardiopulmonary bypass for DTA and TAAA repair requires a strong command of pump management techniques and is used by other centers, especially in the repair of extensive or complex TAAAs.¹²⁻¹⁸ Soukiasian and colleagues¹⁵ and Okita and associates¹⁷ achieved improved results by adopting DHCA as the sole technique of TAAA repair. Although their results were surprising to Etz and coworkers,¹⁸ we have found, as they did, that hypothermia and circulatory arrest are not only useful in reoperative thoracic and thoracoabdominal procedures but central to achieving excellent results in this difficult patient population.¹⁸ One luxury of circulatory arrest is the avoidance of the difficult exposures that would be necessary if one were to place clamps while using other techniques, such as left heart bypass or “clamp and sew.” The ability to visualize the inside of the arch during the period of circulatory arrest gives the surgeon the ability to avoid or remove severely atherosclerotic segments, perform endarterectomy of very calcified segments, and assess the need for arch branch bypasses or total arch replacement. In the combined group of DTA, type I, and type II repairs, 29.1% required a partial arch replacement, 6.8% a total arch replacement, and 11.1% a left subclavian artery bypass. DHCA affords the time and cerebral protection needed to accomplish these proximally extended repairs safely.

Other authors are cautious about the routine use of DHCA in DTA and TAAA repairs because of their own experience and results.²¹⁻²³ Safi and colleagues²¹ used this technique when a proximal clamp could not be placed or when “catastrophic bleeding” complicated the procedure.

That group reported a 29% mortality with DHCA and a 67% rate of pulmonary complications, including a 10% rate of left pneumonectomy for uncontrolled pulmonary hemorrhage, and a 32% rate of neurologic injury. In that series, 6 of 21 cases were emergency operations, with a 50% mortality in that subset of patients. Coselli and coworkers²² reported a 28% mortality and morbidity rates of 9% for stroke, 15% for renal failure, and 22% for tracheostomy in a series of 111 patients, 102 of whom required emergency or urgent operation. Certainly, emergency or urgent operations overall carry significant morbidity and mortality, regardless of the operative technique. We have found that uncontained aortic rupture is a situation in which DHCA is not advantageous unless the bleeding is controlled and the entire body is sufficiently perfused and cooled. In addition, we have avoided major pulmonary hemorrhage

TABLE 4. Operative results (n = 343)

In-hospital mortality	17 (5.0%)
Mortality within 30 d	15 (4.4%)
Permanent cerebrovascular accident	15 (4.4%)
Transient cerebrovascular accident	10 (2.9%)
Permanent paraplegia or paresis	11 (3.2%)
Transient spinal cord ischemia	13 (3.8%)
Postoperative lumbar drain	17 (5.0%)
Acute renal failure	17 (5.0%)
Dialysis-dependent renal failure	5 (1.5%)
Myocardial infarction	4 (1.2%)
Gastrointestinal complications	12 (3.5%)
Tracheostomy	12 (3.5%)
Prolonged intubation	39 (11.4%)
Reintubation	40 (11.7%)
Reexploration for bleeding	17 (5.0%)
Transfusion (units, mean $\pm$ SD)	
Packed red blood cells	4.7 $\pm$ 5.2
Fresh-frozen plasma	4.6 $\pm$ 3.9
Platelet pheresis	1.9 $\pm$ 2.4
Cryoprecipitate (10 units)	10.4 $\pm$ 7.0
Postoperative stay (d, mean $\pm$ SD)	11.8 $\pm$ 9.8

Data represent numbers and percentages of patients except as marked.

TABLE 5. Kaplan–Meier survival estimates by extent of repair and acuity of operation

	All	DTA	Type I TAAA	Type II TAAA	Type III TAAA	Type IV TAAA	Elective	Emergency or urgent
No.	343	98	69	111	32	33	298	45
Survival (%)								
1 y	90.1%	94.8%	92.5%	83.2%	90.5%	93.7%	91.6%	79.6%
3 y	79.4%	87.6%	87.0%	69.6%	79.8%	73.5%	80.2%	75.2%
5 y	69.3%	80.2%	73.4%	59.2%	65.4%	73.5%	70.7%	55.7%
7 y	62.9%	74.9%	64.0%	54.4%	58.9%	66.2%	63.9%	55.7%
10 y	53.5%	74.9%	53.3%	43.0%	44.2%	49.6%	54.3%	55.7%

DTA, Descending thoracic aneurysm; TAAA, thoracoabdominal aneurysm.

through adequate decompression of the left ventricle, usually by direct drainage, and careful manipulation of the lung during the period of hypothermia and anticoagulation.

Our results with type II TAAA repair compare favorably with published studies from specialized aortic centers that use many techniques.²⁴⁻²⁷ Operative mortality for type II repair in our series was 9.0%, which compares favorably with other published studies, which have a range from 10% to 22%. Permanent spinal cord injury in our series was 5.4% without the routine use of lumbar drains. Other studies have reported paraplegia or paraparesis rates from 7% to 22%. The greatest difference in outcome between our series with DHCA and others was in renal failure and renal failure requiring dialysis. Our incidence of renal failure in type II TAAA repair was 7.2%, with 1.8% requiring dialysis. Other studies have shown renal failure rates from 16% to 22%, with postoperative dialysis rates of 8.5% to 21%. We believe that end-organ protection is imperative in extensive type II aortic repairs. Deep hypothermic cardiopulmonary bypass protects the spinal cord and kidneys and allows adequate time for complex and extensive repairs.

We also use DHCA in the repair of Crawford type IV TAAAs. Other series have reported operative mortalities of 6% to 13%, with rates of acute renal failure requiring dialysis of 6% to 12% and of paraplegia of 2% to 5%, predominantly with the clamp and sew method.²⁸⁻³⁰ In our series, isolated Crawford type IV TAAAs carried an operative mortality of 3%, a dialysis-dependent renal failure rate of 3%, a stroke rate of 3%, and a paraplegia rate of 0%. Of these patients, 6% had SMA bypass, 9% had both celiac and SMA bypasses, 12% had left renal artery bypass, 6% had right renal artery bypass, and 18% had bilateral renal artery bypasses. Deep hypothermia protects end organs, as well as affording the surgeon time to perform bypasses of stenotic visceral or renal vessels. The ability to achieve uncompromised revascularization of the viscera and kidneys with limited ischemic damage is one of the strengths of this technique.

Thoracic endograft repair, although much less invasive and often an enticing option in this patient population, still carries significant neurologic morbidity and mortality, with no long-term data available regarding survival or durability of the repair.³¹⁻³³ Visceral debranching followed by thoracoabdominal endograft exclusion carries significantly high morbidity and mortality and has been largely abandoned as a first option for TAAA repair.^{2,34} Custom-made branched endografts have promise, but they are not commercially available in the United States, have significant rates of reintervention, and do not have long-term follow up.^{35,36} In our combined Crawford type II, III, and IV TAAA groups, which had aortic disease comparable to that in the hybrid and branched endograft candidates, mortality was 7.4%, permanent stroke rate was 4.5%, paraplegia rate was 4.0%, and new dialysis renal failure rate was 2.3%. The rate of reintervention in these open surgical cases was 3.9%, with reintervention typically needed for pseudoaneurysm formation or replacement of an infected graft. Our results are comparable to the early results of branched endograft procedures, are superior to the results of hybrid endograft repairs, and have significantly lower rates of reintervention.^{2,34-36}

FIGURE 1. Kaplan–Meier survival curve for all patients (n = 343).

TABLE 6. Operative mortality and Kaplan–Meier survival estimates by decade of age at the time of operation

	All	<50 y	50–59 y	60–69 y	70–79 y	80–89 y
Mean age (y, mean $\pm$ SD)	66.0 $\pm$ 12.3	40.4 $\pm$ 6.7	55.2 $\pm$ 2.9	64.5 $\pm$ 2.7	74.4 $\pm$ 2.9	82.2 $\pm$ 2.0
No.	343	38	46	95	133	31
In-hospital mortality (%)	5.0%	0%	4.3%	4.2%	4.5%	16.1%
Survival (%)						
1y	90.1%	97.3%	91.3%	87.3%	91.5%	80.4%
3 y	79.4%	97.3%	88.3%	74.6%	77.3%	68.6%
5 y	69.3%	97.3%	80.9%	61.9%	64.5%	61.7%
7 y	62.9%	97.3%	80.9%	56.0%	52.9%	61.7%
10 y	53.5%	97.3%	64.8%	41.5%	43.0%	61.7%

Surgeons have used “chimney” or “snorkel” stents to extend the application of thoracic endovascular aortic repair to patients with aortic anatomy that is not suitable with regard to the landing zones. The placement of chimney stents into the supra-aortic arch branches, visceral, and renal arteries to gain landing zone length does not yet have long-term efficacy or long-term survival data.^{37,38} Regardless of the complexity of thoracic endograft procedures, they will always have inherent anatomic limitations regarding the length and quality of the landing zones and the patency or proximity of aortic branches. These limitations are not an issue in open repair, especially with DHCA.

Although it is a common practice to place endografts in chronic aortic dissections, long-term efficacy has not been reported. Furthermore, the use of thoracic endografts in chronic aortic dissections may not reduce the risk of aortic rupture or improve survival.³⁹ It is difficult to conceive how an endoluminal graft of a lesser length will be able to adequately and consistently treat an extensive aortic dissection with multiple points of reentry distal to the repair. We have chosen to repair all chronic dissections with our open technique. In 49 patients with chronic dissections who underwent DTA or type I TAAA repair, our mortality was 2.0%, our paraplegia rate was 0%, our stroke rate was 0%, our rate of renal failure requiring dialysis was 0%, and our reintervention rate was 2.0%. Because of the success of open repair with DHCA in this particular subset of patients and the uncertainty of endoluminal repair for this aortic pathology, we will continue to repair chronic dissections with our open technique.

Pulmonary complications are still the most common postoperative complications of DTA and TAAA repair; however, most are temporary. Prolonged intubation affected 7.1% of patients with DTA repairs and 13.1% of patients with TAAA repairs. In our series, only a few patients required tracheostomies, none of which were permanent in the operative survivors. Significant pulmonary hemorrhage related to coagulopathy can be a major morbidity but has been an infrequent and reversible problem in our series. No patients required lung resection for intractable intraparenchymal pulmonary hemorrhage.

Our 5-year survival of 69% for our surgically treated patients is clearly better than the 13% 5-year survival of all patients with untreated thoracic aneurysms reported by Bickerstaff and associates.⁴⁰ The general population in that study had a 5-year survival of 75%. Coady and colleagues⁴¹ found that 5-year survival of a more contemporary population of patients with DTAs was 39%, whether or not they were surgically treated. The 5-year survival in an age and sex-matched population was 80%. Repair of DTA and TAAA with DHCA provides survival at 5 years similar to that of the general population and superior to that of patients with nonoperative aneurysm management.

Our 10-year survival of 54% overall compares favorably with those of other surgical series showing 10-year survivals of 29% to 38%.^{7,8,10,42} We attribute the excellent long-term survival to the intensive preoperative cardiac screening, including coronary catheterization in all patients and insistence on coronary revascularization either preoperatively or intraoperatively as part of the aneurysm repair. Our patients undergoing DTA repair had the greatest long-term survival of 75% at 10 years. Additionally, we had a low rate of reintervention (2.9%) for pseudoaneurysm or graft infection. It is our practice to follow up with serial computed tomographic scans for several years after repair to assess the need for reoperation on repaired aortic segments or for extension of the repair for continued aneurysmal degeneration of adjacent aortic segments.

Our study has the inherent limitations of a high-volume, single-institution, 2-surgeon, retrospective study. Our survival data are based in part on the completeness of the Social Security death index. Although we acknowledge that we may have lost some patients to follow-up, most patients who continue to reside in Indiana are referred back to our institution for new problems or continuing follow-up of the thoracoabdominal aorta.

In summary, the use of open repair with DHCA, although a complex technique, can provide low mortality and morbidity in the repair of descending thoracic and TAAAs. We believe that this technique can be safely used by more surgeons in the future and become a benchmark for development of new techniques and technologies.

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