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Cohort-Comparison of Thoracic Endovascular Aortic Repair with Open Thoracic Aortic Repair Using Modern End-Organ Preservation Strategies

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Abstract

Introduction—Pivotal trials showed that thoracic endovascular aortic repair (TEVAR) has improved outcomes compared to open surgery for treating descending thoracic aortic aneurysms. However, those trials included historical open controls in which modern end-organ preservation strategies were not routinely employed. To create a more level assessment, we compared our outcomes of elective TEVAR to modern open thoracic aortic repair (OTAR) controls.

Materials and Methods—A retrospective review of thoracic aortic aneurysm patients undergoing TEVAR was compared to a contemporaneous cohort of OTAR patients. Partial bypass or hypothermic circulatory arrest (HCA) was used in all OTAR patients. Cerebrospinal fluid (CSF) drain placement was attempted in all patients. Preoperative characteristics, operative variables, and outcomes were recorded, and the Kaplan-Meier method was used for survival estimates.

Results—The main outcome was mortality. Secondary outcomes included postoperative spinal cord ischemia (SCI) or stroke, and any persistent neurologic deficit 30 days following the operation. During the study period, 62 patients underwent TEVAR and 56 underwent OTAR with median follow-up of 23.7 months and 36.4 months, respectively. No difference existed between the TEVAR and OTAR with respect to overall neurologic complications (8.1% vs 12.5%; $P=.55$) as well as any residual neurologic deficit at 30 days (0% vs 5.4%, $P=.10$). TEVAR patients had fewer complications including pneumonia ($P=.02$), rebleeding ($P=.02$), and acute kidney injury ($P=.001$). There was no difference in 30-day mortality (1.6% vs 8.9%, $P=.10$), 1-year mortality (12.2% vs 14%, $P=.80$), or 5-year mortality (53.9% vs 44%, $P=.48$) between TEVAR and OTAR, respectively.

Conclusions—TEVAR continues to show improved perioperative outcomes with a trend towards decreased 30-day mortality and fewer major adverse events compared to OTAR. However,

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with the routine use of end-organ preservation strategies during OTAR, neurologic deficits, particularly SCI, can be safely reduced to comparable levels with those of TEVAR and 1-year all-cause mortality rates are similar between the groups. These OTAR results may serve as a benchmark as TEVAR is increasingly applied for other aortic pathologies, such as chronic dissection, wherein long-term efficacy is not proven.

Keywords

Thoracic Aneurysm Repair; TEVAR; Cardiac Bypass; CSF drain; RIFLE

Introduction

Traditional open thoracic aortic repair (OTAR) for descending thoracic aortic aneurysms (DTAA) carries substantial morbidity including neurologic, pulmonary, renal, and bleeding complications. Mortality rates following open repair have only recently improved and now approach 10%, particularly at high-volume centers of excellence.^{1, 2, 3, 4} Much of the improvement is related to refined strategies that minimize the frequency and severity of end-organ injury and spinal cord ischemia (SCI). These techniques aim to increase visceral and spinal cord blood flow, often via partial left heart bypass (LHB), cerebrospinal fluid (CSF) drainage, and reimplantation of intercostal arteries. Neuroprotective strategies also minimize SCI through hypothermia and epidural cooling.^{5, 6}

Thoracic endovascular aortic repair (TEVAR) has been increasingly applied to a variety of thoracic aortic pathology.⁷ Much of the support for TEVAR relates to the reported decrease in perioperative morbidity and mortality and improvement in quality of life compared to the traditional open repair.^{8, 9, 10} The original Food and Drug Administration Investigational Device Exemption (FDA IDE) studies that led to approval of the currently available thoracic aortic stent graft devices showed favorable results for TEVAR with marked reductions in mortality, stroke, and permanent paralysis.^{11, 12, 13}

However, these pivotal trials included historical open controls in which modern end-organ preservation strategies were not routinely employed. In an effort to create a more level and contemporary assessment, we compared our outcomes of elective TEVAR to modern open thoracic aortic repair (OTAR) controls.

Materials and Methods

Patient Data

We used a prospectively collected database to perform a retrospective review of DTAA patients undergoing TEVAR from March 2002 through February 2013. A contemporaneous cohort of OTAR patients from the same time period was included for comparison. Demographic variables including age, gender, and race as well as cardiovascular comorbidities were collected from the medical chart. Data on the patient's aortic pathology and presentation were recorded. All patients whose dissection or aneurysm extended to the abdominal aorta (zones 6–11) were excluded.¹⁴ Additional exclusion criteria included traumatic aortic pathology as well as ruptured presentation. For those undergoing OTAR,

operative records were reviewed to identify the bypass technique utilized (partial LHB, hypothermic circulatory arrest (HCA)), degree of hypothermia (moderate, circulatory arrest), number of intercostals reimplanted, the level of the proximal and distal anastomosis, and total length of aortic replacement. For those undergoing TEVAR, operative notes, intraoperative angiograms, and postoperative CT angiograms were evaluated to identify the number of devices deployed, stent graft distance from the left subclavian artery (LSA) and the celiac artery, and total length of aortic stent graft coverage. Adjunctive procedures, including CSF drainage and LSA bypass, were attempted in all patients except those patients in emergency settings.

Outcomes

The main outcome of the study was 1-year all-cause mortality. Secondary outcomes included 30-day mortality, 5-year mortality, and the presence of any neurologic complication, defined as postoperative SCI (paraparesis or paraplegia) or stroke. Neurologic complications were prospectively entered into a database. Additionally, we identified patients who had a persistent neurologic deficit, based on both objective and subjective strength and function scores, at 30 days following the operation. Postoperative complications including acute kidney injury (AKI), myocardial infarction (MI), pneumonia, bleeding, wound infection, and death were identified. Hospital length of stay (LOS), intensive care unit (ICU) LOS, and disposition to a rehabilitation facility were also recorded. The computerized medical record and the Social Security Death Index were queried to obtain long-term follow-up and survival status in order to calculate 1- and 5-year all-cause mortality.

Patients were classified as having AKI according to the RIFLE criteria based on the international consensus definition from the Acute Dialysis Quality Initiative Workgroup.¹⁵ We defined AKI to include any patient who met criteria for RIFLE-R, -I, or -F. eGFR was calculated using the Modification of Diet in Renal Disease formula.^{16, 17}

Technique for OTAR and Heart Bypass

The operative strategy for OTAR using partial LHB at Johns Hopkins Hospital has been described.⁵ The descending thoracic aorta is exposed through a posterolateral thoracotomy and the left inferior pulmonary vein is dissected and controlled. Simultaneously, the left common femoral artery is exposed and an 8-mm Dacron chimney is attached to the vessel in an end-to-side fashion. Proximal and distal control of the aorta is then obtained. Systemic heparin is administered (100 U/kg) and a venous cannula is placed into the left atrium via the pulmonary vein. An arterial cannula is advanced cephalad through the previously placed Dacron chimney along with an indwelling central line for distal perfusion pressure monitoring. The cannulas are connected to a centrifugal pump and flow rates of 3.5 to 4.5 L/min are usually required to maintain distal aortic perfusion pressure. The patient is cooled to 33.8°C and the aneurysm is then opened longitudinally after cross clamping of the aorta. After appropriate sizing of a 24- to 30-mm Dacron graft for aortic replacement, proximal and distal anastomoses are carried out in the standard fashion. Proximal intercostal arteries are oversewn; however, intercostals distal to T6 are often temporarily occluded and reimplanted into the Dacron graft. The patient is warmed, protamine is administered, cannulas

are removed, venotomy and arterial chimney sites are repaired, drains are positioned in the left chest, and the thoracotomy incision is closed.

For patients who had previous aortic arch surgery (ie., previous hemiarch repair) and presented with lesions involving the proximal descending thoracic aorta, mobilizing the aorta at the level of the left subclavian artery can be hazardous. In these situations, we selectively employ HCA for repair. Preparation, positioning, and incision are similar to LHB approach. Arterial and venous cannulas are placed in the left common femoral vessels under echocardiographic guidance and cardiopulmonary bypass is initiated after cannulating the left atrium. Profound hypothermia to 18°C is achieved by gradual cooling and circulation is arrested. After the distal aortic arch is cross-clamped, the aorta is opened and the proximal anastomosis is constructed as described above followed by restoration of cerebral circulation. The distal anastomosis is fashioned after flushing the native aorta and graft of air and debris and the intercostals are addressed as described above. The patient is warmed, cardiac activity returns, and cannulas are removed.

Endovascular Technique for TEVAR

The technique for TEVAR at Johns Hopkins has been previously described.¹⁸ All TEVAR procedures are performed using the Gore TAG (WL Gore & Associates, Flagstaff, Arizona) endovascular prosthesis. The right femoral artery is isolated through a groin incision and a 22F sheath is inserted after systemic heparinization. Percutaneous left transfemoral access is obtained and a 5F sheath is inserted. A wire is advanced into the abdominal aorta under fluoroscopy and pigtail catheter is positioned above the aortic bifurcation. Aortic dimensions are delineated by angiography prior to device deployment. Post-deployment angiograms are performed to document placement and absence of endoleak.

CSF Drainage and LSA Bypass

The approach for CSF drainage and LSA bypass at The Johns Hopkins Hospital has been recently published.¹⁸ At our institution, CSF drainage is attempted in all patients, except for those in emergent situations, since the catheter permits us to more safely, quickly, and effectively address any neurologic changes that may develop. For patients undergoing CSF drainage, 5F lumbar catheter (Codman, USA) was introduced into the subarachnoid space at the L3 or L4 intervertebral space typically on the day prior to surgery. On the day of TEVAR, the catheter was connected to a pressure transducer and a drainage bag for continuous monitoring. Drainage of CSF was initiated if the CSF pressure exceeded 10 cm H₂O, with the collection system leveled at the left earlobe. The drain was clamped on postoperative day 1 and removed on postoperative day 2 if the patient had a normal neurologic exam.

Currently, if coverage of the LSA is necessary due to anatomic constraints for proximal device deployment, a carotid-subclavian bypass using a 6- or 8-mm Dacron graft is routinely performed prior to TEVAR in a staged fashion. In our early experience, carotid-subclavian bypass was performed selectively for maintenance of LIMA to LAD coronary bypass.

Statistical Analysis

Continuous variables are presented with the mean $\pm$ standard deviation (SD) or with the median and interquartile range (IQR). Categorical variables are displayed as whole numbers and percentages. A comparative analysis of baseline characteristics and postoperative outcomes between TEVAR and OTAR groups was performed. When comparing continuous variables, Student's t-test and Wilcoxon test were used for parametric and nonparametric data, respectively. Fisher's exact test or Chi-square test was used for comparing categorical variables. A univariate analysis estimated predictors of mortality at 1-year. The Kaplan-Meier method was used to estimate survival. For statistical analyses, P-values less than .05 (two-tailed) were deemed significant. Hazard ratios (HR) are presented with 95% confidence intervals (CI). Statistical testing was conducted using STATA 12 software (StataCorp LP, College Station, TX).

Results

Demographics and Presentation

During the study period (2002–2013), 62 patients underwent TEVAR and 56 underwent OTAR. A relatively similar distribution of patients underwent TEVAR (n=30, 48%) or OTAR (n=23, 41%) during the first 6 years of the study. TEVAR patients were significantly older ($P<.001$), more likely to suffer from coronary artery disease ($P=.001$) and chronic obstructive pulmonary disease ($P=.017$), and had worse baseline renal function based on eGFR ($P=.024$) compared to OTAR patients. TEVAR patients were more likely to suffer degenerative aneurysmal disease while OTAR patients were more likely to present with chronic dissection. Additional preoperative characteristics are presented in Table I.

Operative Details

Operative data are shown in Table II. Of the 62 TEVAR patients, 13 (21%) underwent a staged LSA bypass procedure prior to the endovascular aortic repair due to anticipated coverage of the origin of the LSA. Forty-seven patients (76%) had a CSF drain placed preoperatively. Of the 56 OTAR patients, 51 patients (91%) had a CSF drain placed preoperatively. All OTAR patients underwent cardiac bypass with 50% of the cohort requiring HCA.

Outcomes

The median length of follow-up for the TEVAR and OTAR patients was 23.7 and 36.4 months, respectively. No difference existed between the TEVAR and OTAR with respect to overall neurologic complications (8.1% vs 12.5%; $P=.55$). Of the 5 patients in the TEVAR group who had a neurologic complication, 3 (4.8%) developed a stroke and 2 (3.2%) developed SCI. Of the 7 OTAR patients who sustained a neurologic complication, 3 (5.4%) had a stroke and 4 (7.1%) had signs consistent with SCI. Additional review of the patients with a neurologic complication was undertaken to identify whether they had a persistent neurologic deficit 30 days after the operation. None (0%) of the TEVAR patients had a residual neurologic deficit whereas 3 (5.4%) OTAR patients had a persistent deficit at 30 days; this difference, however, did not reach statistical significance ($P=.10$). Additional

outcomes between the groups, including wound infection, rebleeding, MI, and the development of AKI, are reported in Table III. There was no difference ($P=.80$) in the 1-year all-cause mortality rate between TEVAR (12.2%) and OTAR (14%). Although 30-day mortality was better in the TEVAR group (1.6%) compared to OTAR (8.9%), this finding did not reach statistical significance ($P=.10$).

Predictors of 1-year survival on univariate analysis included baseline eGFR ($P=.03$) and overall neurologic complications ($P=.01$) (Table IV). Surgical approach (TEVAR vs OTAR) did not significantly affect estimated 5-year survival ($P=.51$) (Figure I).

Discussion

Open repair of the descending thoracic aorta has been the traditional therapy for degenerative thoracic aortic aneurysms. However, this technique remains a surgical challenge as it is associated with substantial morbidity and mortality, even in centers of excellence. Initially, the “clamp and sew” technique was the mainstay approach and speed was paramount in order to minimize the profound homeostatic disturbances of simple aortic cross clamping and to prevent SCI. During the “clamp and sew” era of the 1970s and 1980s, the persistent SCI rates approached 10% and the cumulative morbidity exceeded 60%.^{19, 20, 21} Given these poor results, adjunctive procedure like partial LHB and CSF drains were introduced in order to preserve end-organ perfusion. These measures have improved outcomes; in most modern series, reported 30-day mortality rates generally approach 10% with 2% to 4% of patients suffering from paraplegia.^{1, 2, 3, 4, 20, 22} As such, we were compelled to examine our outcomes, particularly neurologic complications, in order to assess the efficacy of utilizing adjunctive end-organ strategies when performing TEVAR or OTAR.

The morbidity of open repair in conjunction with the advancement of endovascular therapy has led to the wide application of TEVAR. The original FDA IDE studies examining TEVAR showed improvements with 30-day mortality rates ranging from 1.9% to 2.1% and paraplegia rates ranging from 1.3% to 3% compared to the open controls whose mortality rates ranged from 5.7% to 11.7% and paraplegia rates ranged from 3.4% to 14%.^{11, 12, 13} Given these encouraging findings, the authors concluded that TEVAR is a safer and effective treatment for descending thoracic aortic aneurysms compared to traditional open repair. However, these pivotal trials included historical open controls in which modern end-organ preservation strategies were not routinely employed, and consequently motivated the examination of our outcomes in this endeavor. In the GORE TAG trial, only 78% of the open control patients had repairs undertaken on extracorporeal bypass and the CSF drain rate was variable and dependent on the participating institution.¹¹ The Medtronic Talent VALOR trial did not provide any details of the historical open controls used in the study.¹² In the Cook Zenith TX2 trial, 31.4% of the open control patients had distal aortic perfusion, 34.3% had some form of hypothermia, and 77.1% had a CSF drain placed.¹³ In contrast, modern end-organ preservation strategies were routinely employed in our study; 100% of the OTAR patients underwent cardiac bypass for distal perfusion and 91% had an adjunctive CSF drain placed.

A key finding of this study, in contrast to the pivotal trials, is that we found no difference in either overall or persistent neurologic outcomes, including both SCI and stroke, between TEVAR and OTAR. We surmise the adjunctive maneuvers routinely used to maximize spinal cord perfusion during open repair helped reduce our rate of persistent neurologic deficit at 30 days to only 5.4% (n=3). In fact, a residual neurologic deficit was attributable to SCI in only 1 (1.8%) of these 3 OTAR patients, a level comparable to that of TEVAR. We demonstrate that the dreaded neurologic sequelae of an open repair can be mitigated through the routine use of adjunctive measures. Thus, our study challenges the conventional wisdom that longer lengths of thoracic aortic coverage or graft replacement are explicit risk factors for paraplegia. Indeed, our strategy of employing end-organ preservation strategies may abrogate the excess physiologic stress of more extensive repairs regardless of surgical approach. To wit, the focus of intercostal preservation, in our view, may be over-emphasized; instead, by maintaining adjuncts and higher perfusion pressures, “length of coverage” concerns may be mitigated.

Similar to the reported data in the pivotal FDA IDE trials, our 30-day mortality rate for TEVAR (1.6%) was decreased compared to OTAR (8.9%), albeit this did not reach statistical significance in our study. However, an all-cause mortality analysis at 1-year demonstrated a more equal distribution of survivors between the TEVAR (12.2%) and OTAR (14%). Thus, our results do not contradict previous reports, as our study reaffirms the safety, limited morbidity, and short-term effectiveness of TEVAR. Furthermore, all-cause mortality at 5 years was similar between the groups suggesting the long-term efficacy of TEVAR.

Notably, half of the OTAR patients underwent cardiopulmonary bypass with HCA. HCA allows for safe construction of the proximal anastomosis but is likely a major driving factor for the 30-day mortality in our OTAR cohort given some disadvantages of HCA including coagulopathy causing difficulty in controlling bleeding, retraction injury to a heparinized lung, cold injury to the lung, and a profound inflammatory response from the bypass circuit.^{23, 24, 25} This is further reflected by the increased 30-day mortality rate comparing HCA (10.7%) with partial left heart bypass (7.1%). In fact, half of the OTAR mortalities in the series were directly related to complications of profound HCA (cardiac failure after rewarming and hemorrhagic stroke). We continue to employ HCA selectively for OTAR, typically in patients with a history of connective tissue disorder and/or prior hemiarch repair, as it allows for the safe construction of the proximal anastomosis in these situations; however, we have modified our practice over the years to minimize these complications. To address the risk of cardiac failure after rewarming, we now routinely use transesophageal echocardiography to observe the left ventricle during the bypass procedure to reduce its filling thereby minimizing the potential for subendocardial ischemia. To address hemorrhagic complications related to the increased fibrinolysis of deep hypothermia, we do not drain CSF while the patient is profoundly hypothermic in order to minimize the pressure and subsequent tearing of dural veins.

Similar to other reports, 21% of our overall study group developed AKI; this complication occurred more frequently and with more severity in our OTAR cohort compared to the TEVAR group. This finding is likely related to the physiologic effects of profound hypothermia in those undergoing HCA including increased systemic vascular resistance,

decreased cardiac output, and a left shift in the oxyhemoglobin saturation curve, all of which contribute to decreased oxygen delivery to tissues.³⁵ Despite starting with a lower baseline eGFR compared to OTAR patients, only 10% of the TEVAR cohort sustained AKI, which is lower than other reports.

This previous finding provides some guidance with respect to which patients we offer TEVAR as opposed to OTAR. Patients who present with renal insufficiency and/or chronic aortic dissection are likely better served by undergoing TEVAR as opposed to OTAR. Anatomically, we remain cautious in applying TEVAR to dissection patients as ongoing false lumen perfusion has been a longstanding concern. Furthermore, many chronic dissection patients in our series have connective tissue disorders, for which TEVAR has specific concern (ie., retrograde Type A dissection, stent-induced aortic tears, etc). As previously mentioned, patients with connective tissue disorders and/or prior hemiarch repair are best suited for OTAR under HCA in order to safely construct the proximal anastomosis. In addition, age has become a principal consideration for TEVAR given our clinical experience with the elderly and the prolonged convalescence associated with OTAR.

We believe future studies comparing TEVAR to OTAR should ensure that the OTAR cohort includes only those patients who undergo modern end-organ preservation strategies; otherwise, the comparison is arguably biased towards TEVAR outcomes. For example, Desai and colleagues reviewed their series of patients who had thoracic aortic aneurysms repaired by either TEVAR or OTAR.²⁶ Each of the 45 OTAR patients underwent either partial left heart bypass or HCA. The TEVAR cohort had a trend toward decreased 30-day mortality as well as decreased rates of neurologic complications; however, none of these findings reached statistical significance. On long-term follow-up, TEVAR versus open approach did not influence survival, which is similar to what we observed in our study. Consequently, clinical decision making for TEVAR and OTAR should not explicitly focus on paraplegia. Indeed, the management of chronic aortic dissection remains controversial. We believe many of these patients can be treated by either surgical approach with durable outcomes so long as end-organ preservation strategies are routinely utilized.

Limitations of the study include its retrospective design and lack of randomization, thereby subjecting the results to selection and measurement bias. Also, we must stress that the two cohorts are not identical, in that there are more dissection patients in the OTAR group among other differences, which cannot be ignored when interpreting the results of our comparison. The results may not be generalizable as the institutional experience with this demanding disease has driven refinements in techniques, particularly for the selection of OTAR. In addition, this study, which includes a small sample of patients from a single center, may be underpowered to identify differences in the outcome variables, particularly if the postoperative events (SCI, stroke) are rare. Also, the sample size limits our ability to perform more sophisticated statistics, such as a Cox multivariable regression model, and to make more generalizable results. The sample size is even smaller at 5 years which adversely affects our survival estimates of both groups. This limitation may be magnified in the TEVAR group since this cohort is older and had a higher prevalence of coronary artery disease. Finally, the majority of our long-term follow-up is based on the Social Security Index thereby allowing us to comment on all-cause mortality only as opposed to disease-

specific mortality. This factor in conjunction with not reporting reintervention rates prevents us from making more substantial conclusions regarding long-term outcomes, particularly since TEVAR patients often require additional procedures for endoleak. A follow-up study is needed to address this shortcoming. Cost analysis is an increasingly important driver of treatment strategy; we did not capture cost data for this project, but have previously published in this regard.³⁶ A follow-up study regarding resource utilization would be interesting since we found that an equal number of patients were discharged home following TEVAR and OTAR.

Conclusions

TEVAR continues to show improved perioperative outcomes with decreased 30-day mortality and fewer major adverse events compared to OTAR. However, with the routine use of end-organ preservation strategies during OTAR, neurologic deficits, particularly SCI, can be safely reduced to comparable levels with those of TEVAR and 1-year all-cause mortality rates are similar between the groups. These OTAR results may serve as a benchmark as TEVAR is increasingly applied for other aortic pathologies, such as chronic dissection, wherein long-term efficacy is not proven.

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Figure I.
Kaplan-Meier Estimates of 5-year Survival

Table I**Preoperative Characteristics**

Variables	TEVAR, n=62	OTAR, n=56	P-value
Mean age, years (SD)	67.6 (12.9)	56.4 (14.3)	<.001
Male gender, # (%)	33 (53)	38 (68)	.105
Hypertension, # (%)	55 (89)	43 (77)	.085
Smoking history, # (%)	36 (58)	20 (36)	.015
Coronary artery disease, # (%)	21 (34)	5 (9)	.001
Chronic obstructive pulmonary disease, # (%)	16 (26)	5 (9)	.017
Baseline eGFR, ml/min/1.73m ² (SD)	77.15 (27.3)	87.91 (23.2)	.024
Peripheral vascular disease, # (%)	15 (24)	6 (11)	.056
Diabetes mellitus, # (%)	10 (16)	6 (11)	.391
Symptomatic, # (%)	25 (40)	30 (54)	.150
<i>Aortic Pathology</i>			<.001
Dissection, # (%)	11 (18)	35 (63)	
Degenerative aneurysm, # (%)	46 (74)	17 (30)	
Pseudoaneurysm, # (%)	5 (8)	1 (2)	
Other, # (%)	0 (0)	3 (5)	
Mean aneurysm size, cm (SD)	5.9 (1.3)	6.3 (1.0)	.079

Abbreviations: SD, standard deviation; eGFR, estimated glomerular filtration rate

Table II**Operative Details**

Operative Data	
TEVAR (n = 62)	
LSA bypass, # (%)	13 (21)
CSF drain, # (%)	47 (76)
Median length of aortic coverage, cm (IQR)	23.5 (17–30)
Median number devices deployed, cm (IQR)	2 (1–3)
Median blood loss, cc (IQR)	200 (100–300)
OTAR (n = 56)	
LSA bypass, # (%)	2 (4)
CSF drain, # (%)	51 (91)
Partial LHB, # (%)	28 (50)
Full bypass with HCA, # (%)	28 (50)
Reimplantation of intercostal arteries, # (%)	18 (32)
Median length of aortic replacement, cm (IQR)	16.4 (13–20)
Median blood loss, cc (IQR)	3200 (1375–7000)

Abbreviations: TEVAR, thoracic endovascular aneurysm repair; LSA, left subclavian artery; CSF, cerebrospinal fluid; IQR, interquartile range; OTAR, open thoracic aneurysm repair; LHB, left heart bypass; HCA, hypothermic circulatory arrest

Table III

Outcomes

Variables	TEVAR, n=62	OTAR, n=56	P-value
Median length of stay, days (IQR)	6 (3–9)	13 (10–20)	<.001
Median ICU length of stay, days (IQR)	2 (1–3)	4 (3–9)	<.001
Discharge to home, # (%)	52 (83.9)	41 (73.2)	0.157
Myocardial infarction, # (%)	0 (0)	1 (1.8)	.475
Pneumonia, # (%)	4 (6.5)	13 (23.2)	.016
Rebleeding, # (%)	0 (0)	5 (8.9)	.022
Wound infection, # (%)	2 (3.2)	3 (5.4)	.667
Acute Kidney Injury, # (%) ^a	6 (9.7)	19 (34.6)	.001
Hemodialysis, # (%)	0 (0)	4 (6.9)	.048
Overall neurologic complication, # (%)	5 (8.1)	7 (12.5)	.546
<i>Spinal cord ischemia, # (%)</i>	2 (3.2)	4 (7.1)	.421
<i>Stroke, # (%)</i>	3 (4.8)	3 (5.4)	.99
Persistent neurologic deficit at 30 days, # (%)	0 (0)	3 (5.4)	.104
30-day mortality, # (%)	1 (1.6)	5 (8.9)	.100
1-year mortality, # (%) ^b	6 (12.2)	7 (14.0)	.796
5-year mortality, # (%) ^c	14 (53.9)	11 (44.0)	.482

Abbreviations: IQR, interquartile range; ICU, intensive care unit;

^a Acute Kidney Injury, includes RIFLE classes R, I, and F.

^b Based on data from n=99 patients

^c Based on data from n=51 patients

Table IV

Predictors of 1-year Survival

Variables	Univariate	
	HR [95% CI]	P-value
TEVAR approach	0.874 [0.282 – 2.709]	.815
Age	1.044 [0.997 – 1.094]	.064
Male Gender	0.845 [0.268 – 2.662]	.773
Coronary artery disease	1.719 [0.518 – 5.710]	.376
Diabetes mellitus	0.529 [0.683 – 4.099]	.542
Smoking history	1.029 [0.332 – 3.191]	.960
Hypertension	0.586 [0.159 – 2.166]	.423
Baseline eGFR (per 10 ml/min/1.73m ²)	0.977 [0.957 – 0.998]	.028
Chronic obstructive pulmonary disease	2.322 [0.699 – 7.713]	.169
Symptomatic	1.659 [0.526 – 5.230]	.387
Aneurysm size	1.229 [0.778 – 1.940]	.377
Acute Kidney Injury ^a	2.761 [0.876 – 8.703]	.083
Overall Neurologic Complication	5.066 [1.524 – 16.836]	.008
CSF drain	0.476 [0.129 – 1.757]	.265

Abbreviations: TEVAR, thoracic endovascular aneurysm repair; eGFR, estimated glomerular filtration rate

^aAcute Kidney Injury, includes RIFLE classes R, I, and F.