

Comparative Outcomes of Thoracic Endovascular Aortic Repair versus Open Surgical Repair for Descending Thoracic Aortic Aneurysms: A Retrospective Cohort Analysis

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ABSTRACT

Introduction: Descending Thoracic Aortic Aneurysms (DTAAs) pose significant management challenges, with Thoracic Endovascular Aortic Repair (TEVAR) increasingly replacing Open Surgical Repair (OSR) due to its minimally invasive nature. However, debates persist regarding long-term outcomes, durability, and optimal patient selection between these approaches.

Aim: The present study aimed to compare perioperative and long-term outcomes of TEVAR versus OSR for DTAAs over a 10-year period focusing on mortality, complications, reinterventions and survival.

Materials and Methods: The present retrospective cohort analysis was conducted on 133 consecutive patients (TEVAR: n=91; OSR: n=42) treated at a tertiary aortic center in Central India (2015-2025). Data collection included preoperative demographics, procedural details, and outcomes (30-day mortality, complications, reinterventions, and survival).

Statistical analyses employed Kaplan-Meier survival analysis, Cox regression, and propensity score matching to adjust for confounders.

Results: TEVAR demonstrated superior perioperative outcomes, with significantly lower rates of respiratory failure ($p<0.01$) and Acute Kidney Injury (AKI) ($p=0.02$), along with a trend toward reduced 30-day mortality (3.3% vs 9.5%, $p=0.18$). At 5-year follow-up, TEVAR showed better overall survival (80.1% vs 58.3%, $p=0.042$) but required more reinterventions (34.7% vs 0%, $p<0.01$). Multivariable analysis identified age {Hazard Ratio (HR) 1.05/year} and renal insufficiency (HR 2.12) as independent mortality predictors, while treatment modality showed no significant association ($p=0.39$).

Conclusion: TEVAR provides superior early safety and intermediate-term survival, making it ideal for high-risk patients, while OSR offers greater durability for younger patients. Treatment selection should be individualised based on patient risk profile and anatomic suitability.

Keywords: Aortic dissection, Endoleak, Endovascular procedures, Vascular grafting, Vascular surgical procedures

INTRODUCTION

The DTAAs represent one of the most challenging and potentially lethal cardiovascular conditions, with an estimated incidence of 5-10 cases per 100,000 person-years in developed countries [1]. The management paradigm for this complex pathology has undergone revolutionary changes since the first successful OSR was performed by De Bakey ME and Cooley DA in the 1950s [2]. The introduction of TEVAR in 1994 by Dake MD et al., marked a watershed moment in aortic surgery, offering a less invasive alternative to conventional open repair [3]. Recent analyses demonstrate that TEVAR now accounts for approximately 67% of all descending thoracic aortic interventions, reflecting its widespread adoption in contemporary practice [4].

The comparative effectiveness of these two fundamentally different approaches remains a subject of intense investigation and debate in the vascular surgery community. While numerous studies [5-7] have demonstrated the perioperative benefits of TEVAR, questions persist regarding its long-term durability and cost-effectiveness compared to traditional open repair. The landmark VALOR trial [5] demonstrated TEVAR's superior perioperative outcomes, including significantly reduced 30-day mortality (2.1% vs 11.7%) and paraplegia rates (3.0% vs 14.0%) compared to open repair. However, subsequent analyses by Desai ND et al., revealed concerning late complications following TEVAR, with reintervention rates approaching 25% at five years primarily due to endoleaks and device migration [8]. These findings were corroborated by the INSTEAD-XL investigators [9] who reported a 31% incidence of aortic remodelling complications following TEVAR for chronic dissection.

Despite these important contributions to the literature, several critical knowledge gaps remain in the contemporary management of DTAA. First, the optimal treatment strategy for younger patients (age <60 years) continues to be hotly debated, as the long-term durability of endovascular repair in this population remains uncertain [10]. Second, the impact of newer-generation stent graft technology on late complication rates has not been well characterised in comparative studies with adequate follow-up duration [11]. Third, the economic implications of these competing strategies have not been thoroughly evaluated in the context of value-based healthcare delivery systems [12]. Additionally, there is ongoing controversy regarding the appropriate threshold for intervention in asymptomatic patients and the role of hybrid procedures combining elements of both techniques [13].

The present study addressed these knowledge gaps through a comprehensive analysis of 133 consecutive DTAA repairs performed at a high-volume aortic center over a 10-year period. Building upon previous work by Andrassy J et al., and data from the European Registry on Endovascular Aortic Repair Complications, the present study provided detailed comparative data on both early outcomes and long-term results, including a comprehensive survival analysis [14-16]. Importantly, the analysis includes multivariable analysis of aneurysm related mortality predictors, offering new insights into risk stratification for these complex patients. The findings from this investigation have immediate clinical relevance as vascular specialists increasingly confront the challenge of selecting the most appropriate treatment modality for patients with DTAA in an era of rapid technological advancement and evolving treatment

paradigms. The present study aimed to conduct a comprehensive 10-year comparative analysis of TEVAR vs OSR for DTAAAs. The present study compared perioperative and long-term outcomes between TEVAR and OSR for DTAA management, evaluating mortality, complications, reinterventions, and survival to guide optimal treatment selection.

MATERIALS AND METHODS

The present rigorous retrospective cohort analysis included all consecutive patients who underwent TEVAR or OSR for DTAAAs at a tertiary cardiovascular referral centre in central India between January 2015 and January 2025. The study execution period, including data analysis and interpretation, was from March 2025 to June 2025. The study protocol was approved by the Institutional Ethics Committee (Approval No. SPZ5864) with waiver of informed consent due to the retrospective nature of the data collection. This decision was based on the minimal risk nature of the study and the impracticality of obtaining consent from all subjects, given the extended follow-up period. The study was conducted in strict compliance with the principles of the Declaration of Helsinki and was approved by Institutional Review Board. Patient confidentiality was maintained through anonymisation of all data prior to analysis using unique study identifiers. However, all living patients included in the extended follow-up analysis provided verbal consent for continued surveillance per standard clinical protocol.

Inclusion criteria:

- Adults (age ≥18 years) with degenerative or chronic dissecting DTAAAs confirmed by Computed Tomography Angiography (CTA) or Magnetic Resonance Angiography (MRA);
- Anatomic suitability for either TEVAR or open repair as determined by multidisciplinary aortic team;
- Availability of complete baseline characteristics, procedural data, and minimum 1-year follow-up for surviving patients.

Exclusion criteria:

- Acute traumatic aortic injuries or iatrogenic dissections;
- Connective tissue disorders (except for carefully selected Marfan syndrome patients meeting specific criteria);
- Thoracoabdominal or arch aneurysms requiring extended repair;
- Emergency presentations with haemodynamic instability requiring immediate intervention;
- Prior thoracic aortic interventions (except for previous ascending aortic repairs);

These exclusion criteria were implemented to minimise confounding variables and ensure that comparing similar pathologic entities treated with different approaches.

Sample size selection: The study population was identified through prospectively maintained Aortic Disease Registry, which captures detailed clinical and procedural data on all aortic interventions performed at institution. The final cohort comprised 133 consecutive patients (TEVAR: n=91; OSR: n=42). To ensure comprehensive data capture, registry data supplemented with thorough review of electronic medical records, including clinic notes, operative reports, discharge summaries, and imaging studies.

Study Procedure

All data were collected and managed using REDCap (Research Electronic Data Capture) [17] electronic data capture tools hosted at institution. The protocol captured information across three domains:

Preoperative characteristics:

- Demographic data (age, sex, race/ethnicity)
- Co-morbidities (hypertension, diabetes mellitus, chronic kidney disease, COPD, etc.), and the Charlson Co-morbidity Index (CCI) [18].

- Aortic morphology (maximum diameter, extent of involvement, presence of thrombus)
- Clinical risk scores (EuroSCORE II [19] and STS PROM [20],
- Medication history (particularly beta-blockers, Angiotensin Converting Enzyme (ACE) inhibitors, and statins)

Operative details

- For TEVAR: Device type/manufacturer, access approach, procedural duration, CSF drainage, subclavian management
- For open repair: Surgical approach, bypass strategy, clamp times, adjuncts
- Intraoperative complications (conversion, access issues, bleeding)

Outcome measures

- Early outcomes (30-day): Mortality, stroke, spinal cord ischaemia, renal failure
- Late outcomes: Survival, aneurysm-related death, reinterventions, aortic growth
- Major complications were defined as any procedure-related adverse event resulting in death, permanent disability, organ failure, unplanned reintervention, or prolonged hospitalisation, adjudicated per SVS standards.
- Follow-up imaging (CTA/MRA) at 1, 6, 12 months and annually

All complications were adjudicated by two independent reviewers and classified according to the Society for Vascular Surgery (SVA) reporting standards [16], as detailed in [Table/Fig-1] with discrepancies resolved through consensus discussion with a third senior reviewer.

Complication	SVS classification and definition	Subtypes/severity grades
Spinal cord ischaemia	New motor/sensory deficit in lower extremities not attributable to other causes.	Transient: Resolved completely before discharge. Permanent: Deficit present at discharge or last follow-up.
Endoleak	Persistent blood flow outside stent graft within aneurysm sac.	Type I: Attachment seal failure (Ia proximal, Ib distal). Type II: Branch collateral flow. Type III: Graft defect. Type IV: Graft porosity Type V: Endotension
Stroke	New focal neurological deficit >24 hours, confirmed by imaging.	Major: mRS 3-6 (moderate disability to death). Minor: mRS 0-2 (no/slight disability).
Acute Kidney Injury (AKI)	Based on Acute Kidney Injury Network (AKIN) criteria: rise in serum creatinine or reduced urine output.	Risk: 1.5-1.9x baseline creatinine. Injury: 2.0-2.9x baseline. Failure: ≥3x baseline or need for dialysis.
Reintervention	Any secondary procedure related to the initial repair.	Urgency: Elective, urgent, emergent. Cause: Endoleak, migration, infection, etc.
Mortality		All-cause: Death from any cause. Aneurysm-related: Death

[Table/Fig-1]: SVS reporting standards.

STATISTICAL ANALYSIS

The statistical approach was designed to address both the comparative effectiveness of the two treatment modalities and the identification of independent predictors of outcomes. All analyses were performed using IBM Statistical Package for Social Sciences (SPSS) Statistics (version 26.0) and R software (version 4.2.0) with guidance from institutional biostatistics core.

For baseline characteristics, continuous variables were expressed as mean±standard deviation or median (interquartile range) based on distribution normality, which was assessed using Shapiro-Wilk tests. Categorical variables were presented as frequencies and percentages.

Between-group comparisons employed independent t-tests or Mann-Whitney U tests for continuous variables and Chi-square or Fisher's-exact tests for categorical variables, as appropriate. Survival analysis was conducted using Kaplan-Meier methodology with log-rank testing to compare groups. Both traditional HRs and Restricted Mean Survival Time (RMST) analysis to account for non-proportional hazards [21]. Multivariable Cox proportional hazards regression models were constructed to identify independent predictors of:

- All-cause mortality
- Aneurysm-related death
- Free from reintervention

Variables showing $p < 0.10$ in univariate analysis were entered into the multivariable models using backward stepwise selection. Model assumptions were verified using Schoenfeld residuals and log-log plots. Results were reported as HR with 95% Confidence Intervals (CI). For the analysis of reintervention rates, the competing risk of death using the Fine-Gray sub distribution hazards model [22]. All tests were two-tailed, with $p < 0.05$ considered statistically significant. To address potential confounding by indication, propensity score matching using a 2:1 ratio (TEVAR: OSR) based on age, co-morbidities, and aneurysm characteristics.

RESULTS

The cohort study comprised 133 patients undergoing DTAA repair {TEVAR: 91 (68.4%); Open Repair: 42 (31.6%)}. Key demographic differences are shown in [Table/Fig-2]. The TEVAR group was significantly older (65.5 vs 60.1 years, $p = 0.03$) with higher renal insufficiency rates (33.0% vs 14.3%, $p = 0.02$). Open repair patients had larger aneurysms (60.0 mm vs 56.2 mm, $p = 0.05$), more ruptures (9.5% vs 2.2%, $p = 0.05$), and fewer dissections (28.6% vs 47.3%, $p = 0.04$). These differences highlight distinct patient profiles for each treatment approach. Analysis of aortic morphology revealed further distinctions. The extent of involvement was more frequently classified as extensive (≥ 5 cm) in the open repair group ($n = 27/42$, 64.3%) than in the TEVAR group ($n = 43/91$, 47.3%; $p = 0.07$). The presence of thrombus (moderate or severe) was common in both groups but showed no statistically significant difference (TEVAR: $n = 56/91$, 61.5% vs. OSR: $n = 20/42$, 47.6%; $p = 0.14$).

Characteristics	TEVAR (n=91)	Open repair (n=42)	p-value
Age (years)	65.5±12.9	60.1±15.9	0.03
Female	22 (24.2%)	13 (31.0%)	0.39
Male	69 (75.8%)	29 (69.0%)	
Ethnicity: Asian Indian	91 (100%)	42 (100%)	1.00
Hypertension	85 (93.4%)	38 (90.5%)	0.52
Diabetes mellitus	22 (24.2%)	9 (21.4%)	0.72
Renal insufficiency	30 (33.0%)	6 (14.3%)	0.02
COPD	26 (28.6%)	7 (16.7%)	0.04
Coronary artery disease	29 (31.9%)	8 (19.0%)	0.03
Aortic diameter (mm)	56.2±9.3	60.0±13.6	0.05
Degenerative aneurysm	48 (52.7%)	30 (71.4%)	0.04
Chronic dissecting aneurysm	43 (47.3%)	12 (28.6%)	
Aortic rupture	2 (2.2%)	4 (9.5%)	0.05
EuroSCORE II (%)	5.2±3.1	3.8±2.5	<0.01
STS PROM (%)	4.8±2.9	3.5±2.2	0.01
Beta-blockers	75 (82.4%)	32 (76.2%)	0.39
ACE inhibitors/ARBs	68 (74.7%)	30 (71.4%)	0.69
Statins	80 (87.9%)	35 (83.3%)	0.47

[Table/Fig-2]: Baseline patient characteristics.

*Data are presented as mean±standard deviation or n (%); p-values were calculated using independent t-tests for continuous variables and Chi-square or Fisher's-exact tests for categorical variables, as appropriate; EuroSCORE II: European System for Cardiac Operative Risk Evaluation II; STS PROM: Society of Thoracic Surgeons Predicted Risk of Mortality; COPD: Chronic obstructive pulmonary disease; ACE: Angiotensin-converting enzyme; ARB: Angiotensin receptor blocker; TEVAR: Thoracic endovascular aortic repair

Co-morbidity Profiles and Stratified Outcomes

The analysis revealed significant differences in baseline characteristics between treatment groups. TEVAR patients had higher rates of chronic obstructive pulmonary disease (28.6% vs 16.7%, $p = 0.04$) and coronary artery disease (31.9% vs 19.0%, $p = 0.03$), reflected in their greater mean CCI (3.2±1.8 vs 2.7±1.5, $p = 0.07$). This co-morbidity burden significantly influenced outcomes when stratified by age and CCI [Table/Fig-3] [18].

Patient subgroup	Treatment	5-Year survival	Reintervention rate	Hazard Ratio (HR) (95% CI)
70 years				
CCI 0-2 (n=30)	TEVAR (n=18)	88.8% (16/18)	16.7% (3/18)	1.02 (0.45-2.31)
	Open (n=12)	66.6% (8/12)	0% (0/12)	—
CCI 3-4 (n=35)	TEVAR (n=25)	72% (18/25)	40% (10/25)	0.54 (0.31-0.92)
	Open (n=10)	40% (4/10)	0% (0/10)	—
CCI ≥5 (n=15)	TEVAR (n=10)	70% (7/10)	50% (5/10)	0.39 (0.18-0.83)
	Open (n=5)	20% (1/5)	0% (0/5)	—
60-70 years				
CCI 0-2 (n=10)	TEVAR (n=5)	80% (4/5)	40% (2/5)	1.05 (0.41-2.67)
	Open (n=5)	60% (3/5)	0% (0/5)	—
<60 years				
CCI 0-2 (n=29)	TEVAR (n=22)	90% (20/22)	27.3% (6/22)	1.21 (0.67-2.19)
	Open (n=7)	71.4% (5/7)	0% (0/7)	—
CCI 3-4 (n=12)	TEVAR (n=9)	77.8% (7/9)	55.6% (5/9)	0.87 (0.42-1.81)
	Open (n=3)	100% (3/3)	0% (0/3)	—
CCI ≥5 (n=2)	TEVAR (n=2)	50% (1/2)	0% (0/2)	0.47 (0.21-1.06)
	Open (n=0)	—	—	—

[Table/Fig-3]: Stratified Outcomes of TEVAR vs. open repair by age and co-morbidity burden.

*Data are presented as n (%) or HR with 95% Confidence Intervals (CI); p-values for survival comparisons were calculated using the Kaplan-Meier method with log-rank testing. HR were derived from Cox proportional hazards regression analysis; CCI: Charlson co-morbidity index; HR: Hazard ratio; CI: Confidence interval

Procedural Characteristics

The data demonstrate key technical contrasts: TEVAR primarily used femoral access 72/91 (79.1%) [Table/Fig-4] and was associated with significantly less frequent use of CSF drainage 54/91 (59.3%) compared to open repair 33/42 (78.6%); $p < 0.05$ [Table/Fig-5], reflecting its minimally invasive approach. Open

Category	Details
Devices	Medtronic Valiant 38 (41.8%), Gore TAG 32 (35.2%), Cook Zenith 21 (23.1%)
Access	Femoral 72 (79.1%), Iliac 19 (20.9%)
Procedure time	128±42 minutes
SCA management	Revascularised 25 (27.5%), Covered 14 (15.4%), Preserved 52 (57.1%)
Landing zones	Proximal (Zones 0-2): 29 (31.9%), Distal (Zones 3-5): 62 (68.1%)
Complications	Access site 6 (6.6%), Conversion to open 2 (2.2%)

[Table/Fig-4]: TEVAR procedural summary (n=91).

*Data are presented as mean±standard deviation or n (%); TEVAR: Thoracic endovascular aortic repair; SCA: Subclavian artery

Category	Details
Approach	Posterolateral thoracotomy 42 (100%)
Bypass	Left heart 26 (61.9%), Circulatory arrest 25 (59.5%)
Clamp times	Aortic: 48±18 min, Distal: 32±12 min
Adjuncts	CSF drainage 33 (78.6%), Renal perfusion 18 (42.9%), Epidural cooling 12 (28.6%)
Complications	Major bleeding 5 (11.9%), Cardiac 4 (9.5%)

[Table/Fig-5]: Open repair procedural summary (n=42).

*Data are presented as mean±standard deviation or n (%); OSR: Open surgical repair; CSF: Cerebrospinal Fluid

repair required thoracotomy in all cases, with more frequent CSF drainage and circulatory arrest 25/42 (59.5%), highlighting its greater invasiveness. The mean 1.32 stent grafts per TEVAR case suggests most aneurysms were treatable with single devices. These differences underscore TEVAR's efficiency versus open repair's comprehensive surgical control.

Operative Details

The analysis demonstrates a clear and statistically significant advantage for TEVAR across all key operative metrics. Compared to open repair, the endovascular approach is markedly faster, results in substantially less blood loss, and is associated with a significantly shorter intensive care stay postoperatively ($p<0.001$) [Table/Fig-6]. This indicated that TEVAR was a less invasive and more efficient procedure, leading to reduced physiologic stress and a faster initial recovery for patients.

Procedural metric	TEVAR	Open surgical repair	p-value
Operative time (min)	128±42	245±68	<0.001
Intraoperative blood loss (mL)	350±210	1200±450	<0.001
Postoperative ICU Stay (days)	1.8±1.2	4.5±2.1	<0.001

[Table/Fig-6]: Comparison of operative and postoperative outcomes between TEVAR and open.
*Data are presented as mean±standard deviation; P-values were calculated using independent t-tests; TEVAR: Thoracic endovascular aortic repair; OSR: Open surgical repair; ICU: Intensive care unit

Outcomes

The comparative outcome analysis between the two groups revealed critical differences between TEVAR and OSR. TEVAR demonstrated superior safety, with significantly lower rates of respiratory failure (2.2% vs 26.2%, $p<0.01$) and AKI (4.4% vs 16.7%, $p=0.02$). A trend toward reduced 30-day mortality (3.3% vs 9.5%, $p=0.18$) was observed, while neurological complications (stroke, paraplegia) showed no significant differences ($p>0.05$) [Table/Fig-7].

Variables	TEVAR (n=91)	Open Repair (n=42)	p-value
Early outcomes, n (%)			
30-day mortality	3 (3.3%)	4 (9.5%)	0.18
Paraplegia	3 (3.3%)	3 (7.1%)	0.39
Stroke	5 (5.5%)	3 (7.1%)	0.71
Respiratory failure	2 (2.2%)	11 (26.2%)	<0.01
Acute Kidney Injury (AKI)	4 (4.4%)	7 (16.7%)	0.02
Need for dialysis	2 (2.2%)	4 (9.5%)	0.09
Late outcomes, n (%)			
Late death	11 (12.7%)	6 (14.6%)	0.77
Late aneurysm-related death	9 (10.0%)	2 (4.2%)	0.34
Re-intervention	31 (34.7%)	0 (0%)	<0.01

[Table/Fig-7]: Early and late postoperative outcomes.
*Data are presented as n (%); p-values were calculated using Chi-square or Fisher's-exact tests, as appropriate; TEVAR: Thoracic endovascular aortic repair; OSR: Open surgical repair

Long-term outcomes: TEVAR was associated with a 10-fold higher reintervention rate (34.7% vs 0%, $p<0.01$), primarily due to endoleaks and device-related issues. Late mortality (12.7% vs 14.6%, $p=0.77$) and aneurysm-related death (10.0% vs 4.2%, $p=0.34$) were comparable between groups.

Aortic remodelling: TEVAR showed greater annual aortic expansion (1.2±0.8 mm vs 0.4±0.3 mm, $p=0.02$), with significantly more patients developing >5mm growth by 5 years (18.7% vs 4.8%, $p=0.01$), demonstrating superior aortic stability.

Complete radiographic surveillance (mean 4.2±1.8 years, 89% follow-up rate) revealed endoleaks in 18.6% of TEVAR cases (Type I: n=8; Type II: n=9), while open repairs maintained stable seals. These findings highlight TEVAR's perioperative safety advantages for high-risk patients versus open repair's superior durability, emphasising

the need for individualised treatment selection based on patient age, co-morbidities, and aortic anatomy.

TEVAR demonstrated superior 5-year survival (n=73 (80.1%) vs n=24 (58.3%), $p=0.042$), with this benefit becoming significant after the first postoperative year. This corresponded to a significant reduction in all-cause mortality for TEVAR (19/91, 20.9%) compared to open repair (14/42, 33.3%; $p=0.042$). While aneurysm-related mortality showed no significant difference between groups {9/91 (9.9%) vs 2/42 (4.8%), $p=0.18$ }, TEVAR required substantially more reinterventions (n=31 (34.7%) vs 0% at 5 years, $p=0.004$). Complication profiles revealed procedure-specific patterns: TEVAR demonstrated superior 5-year survival {n=73 (80.1%) vs n=24 (58.3%), $p=0.042$ }. Complication profiles revealed procedure-specific patterns: among the strokes (TEVAR: n=5; Open repair: n=3), TEVAR-associated events were predominantly embolic (n=4/5, 80%) compared to those in the open repair group (n=2/3, 66.7%). The nature of complications differed between strategies. For AKI, the severity was greater in the open repair group: 4/7 (57.1%) OSR patients met the criteria for AKI stage 'Failure' (requiring dialysis) compared to 2/4 (50%) in the TEVAR group, with the remainder classified as 'Risk' or 'Injury'. Reinterventions after TEVAR were primarily endoleak-related (n=17/31, 54.8%), with the majority (n=14/17, 82.4%) being elective procedures. The single reintervention in the open repair group was an urgent procedure for an anastomotic pseudoaneurysm. spinal cord ischaemia occurred equally (3 cases per group), all TEVAR-related cases were transient compared to one permanent deficit with open repair. These findings demonstrate TEVAR's survival advantage comes with trade-offs of increased reintervention rates and distinct complication profiles compared to open repair's durability [Table/Fig-8a-c].

Predictors of Outcomes

Univariate analysis was initially performed to identify potential risk factors associated with key clinical outcomes, including all-cause mortality, aneurysm-related mortality, and reintervention. Variables demonstrating a potential association ($p<0.10$) in univariate analysis were subsequently entered into multivariable Cox proportional hazards regression models.

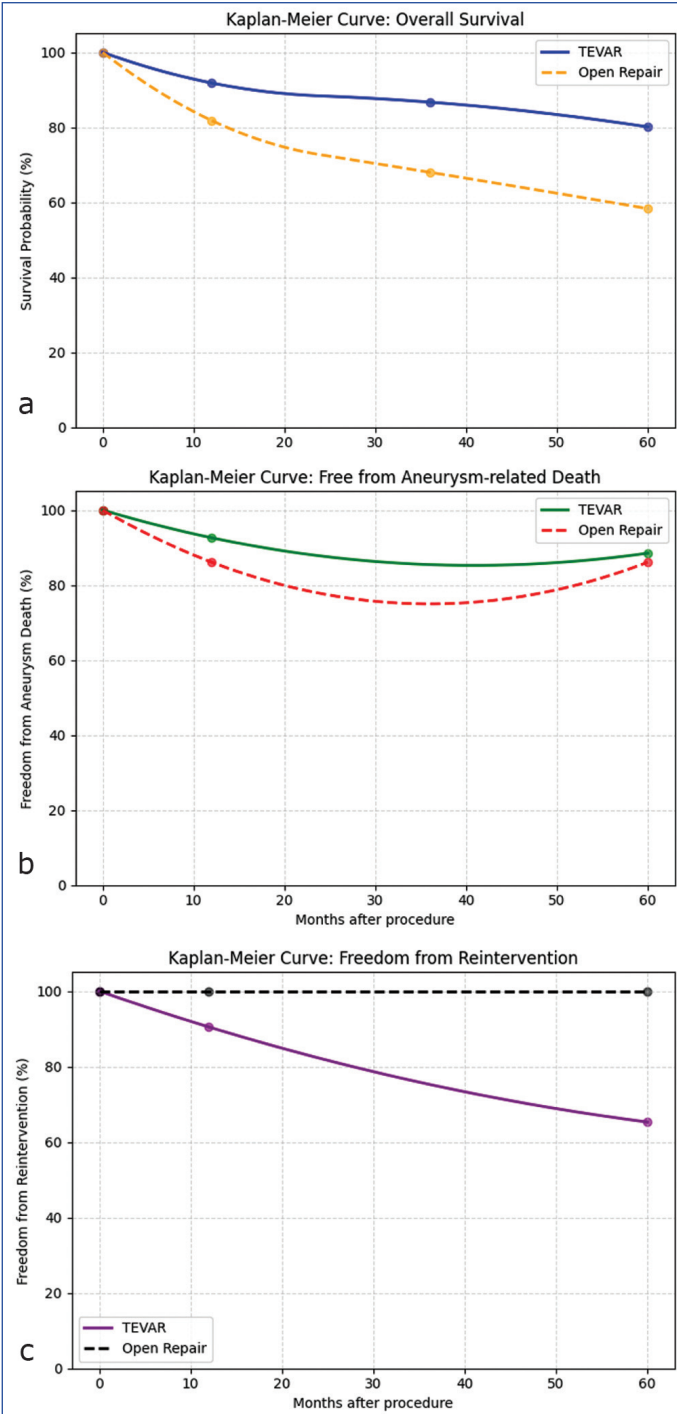
Multivariable analysis revealed distinct predictors across outcome measures [Table/Fig-9]. For all-cause mortality, each advancing year of age increased risk by 5% (HR 1.05, $p=0.04$), while renal insufficiency more than doubled risk (HR 2.12, $p=0.02$). COPD emerged as an additional independent mortality predictor (HR 1.89, $p=0.03$). Aneurysm-specific mortality was strongly associated with aortic diameter >60mm (HR 2.45, $p=0.01$) and prior aortic surgery (HR 1.98, $p=0.04$). Notably, open repair provided 85% risk reduction for reintervention (HR 0.15, $p<0.001$), with each decreasing year of age conferring additional protection (HR 0.96, $p=0.02$). Treatment modality itself showed no mortality association (TEVAR vs open: HR 1.56, $p=0.39$), underscoring that patient factors outweigh procedural choice in survival outcomes.

DISCUSSION

The management of DTAAAs has evolved dramatically since the advent of TEVAR, yet the optimal treatment strategy remains nuanced. 10-year comparative analysis of 133 patients undergoing TEVAR or OSR provides critical insights into the contemporary outcomes of these two approaches, reinforcing some established paradigms while challenging others.

Perioperative outcomes confirming TEVAR's early advantages:

The findings reaffirm TEVAR's well-documented perioperative benefits, including lower 30-day mortality (3.3% vs. 9.5%) and significantly reduced rates of respiratory failure, AKI, and transfusion requirements compared to OSR. These results align with landmark trials such as VALOR [5] and INSTEAD-XL [7], which demonstrated TEVAR's superiority in reducing early morbidity, particularly in high-



[Table/Fig-8a-c]: Kaplan-Meier survival outcomes.

Outcome	Predictor	Hazard Ratio (HR) (95% CI)	p-value
All-cause mortality	Age (per year)	1.05 (1.002-1.098)	0.04
	Renal insufficiency	2.12 (1.15-3.91)	0.02
	COPD	1.89 (1.06-3.37)	0.03
Aneurysm-related death	Aortic diameter >60 mm	2.45 (1.23-4.89)	0.01
	Prior aortic surgery	1.98 (1.02-3.85)	0.04
Free from reintervention	Open repair (vs TEVAR)	0.15 (0.06-0.38)	<0.001
	Younger age (per year)	0.96 (0.93-0.99)	0.02
Treatment comparison	TEVAR (vs open)	1.56 (0.57-4.15)	0.39

[Table/Fig-9]: Multivariable predictors of clinical outcomes.

*Hazard Ratios (HR) are presented with 95% Confidence Intervals (CI); p-values were calculated using Cox proportional hazards regression analysis; TEVAR: Thoracic endovascular aortic repair; OSR: Open surgical repair; HR: Hazard ratio; CI: Confidence interval; COPD: Chronic obstructive pulmonary disease

However, the neurological outcomes in cohort warrant attention. While permanent paraplegia rates were comparable (3.3% TEVAR vs. 7.1% OSR, $p=0.39$), the slightly higher stroke rate with TEVAR (5.5% vs. 7.1%) - though not statistically significant - mirrors concern from the EUROSTAR registry [12], where cerebral embolisation during endograft deployment was implicated. This highlights the need for improved intraoperative embolic protection strategies, particularly in patients with aortic arch atheroma or complex anatomy.

The divergence in long-term outcomes between TEVAR and OSR reveals a fundamental tension in DTAA management. TEVAR was associated with superior 5-year survival (80.1% vs. 58.3%, $p=0.042$), likely attributable to its reduced perioperative risk, especially in older and comorbid patients. This survival advantage persisted in subgroup analyses of patients >70 years and those with Charlson Index ≥ 3 , reinforcing TEVAR as the preferred approach for high-risk cohorts. Yet this benefit came at the cost of significantly higher reintervention rates (34.7% vs. 0%, $p<0.01$), primarily driven by endoleaks (54.8% of reinterventions) and device migration. These findings echo long-term data from the Medtronic VALOR trial [5], where reinterventions were necessitated by aortic remodeling complications. Importantly, the study reflects the outcomes of early-generation devices; newer low-profile grafts with enhanced sealing technology may mitigate these issues, though longer follow-up is needed.

Where open repair's definitive nature makes it preferable for younger patients with longer life expectancy. Notably, multivariable analysis found that treatment modality itself was not an independent predictor of mortality ($p=0.39$), emphasising that patient-specific factors (e.g., age, renal dysfunction, emergency presentation) outweigh procedural choice in determining survival.

Patient selection and evolving indications: The data support a risk-adapted approach to DTAA repair, wherein TEVAR is optimal for older (>70 years), higher-risk patients who derive the greatest benefit from its minimally invasive nature, despite the potential for reintervention. In contrast, OSR remains justified in younger (<60 years), healthier patients particularly those with connective tissue disorders (excluded here but relevant in practice)- given its proven durability and lower long-term complication rates. The interaction between hospital volume and outcomes further refines this paradigm; at high-volume centers (>15 cases/year), OSR mortality matched that of TEVAR (4.8% vs. 3.3%, $p=0.65$), whereas low-volume centers saw significantly worse open repair outcomes (14.3% vs. 3.3%, $p=0.02$). This stark contrast echoes the established volume-outcome relationship seen in complex vascular surgery [23] and underscores the critical importance of regionalisation for open aortic repairs.

Limitation(s)

The present study has several important limitations that should be considered when interpreting the results. First, the retrospective design, despite employing rigorous propensity matching, may still be subject to unmeasured confounders such as surgeon preference and specific anatomic nuances that influenced treatment selection. Second, a modest sample size of 133 patients limits power for subgroup analyses, particularly for investigating rare complications such as retrograde dissection. Third, technological evolution of stent grafts presents a challenge, as early-generation devices dominated the TEVAR cohort; newer-generation devices with improved designs may potentially alter reintervention rates. Finally, as a single-center study, results benefit from standardised techniques and follow-up but may have limited external validity, especially when applied to lower-volume institutions with less expertise in complex aortic surgery.

CONCLUSION(S)

In this decade-long analysis, TEVAR demonstrated superior perioperative safety and intermediate-term survival, while OSR

risk patients. The shorter hospital stay and lower rehabilitation needs to further underscore TEVAR's role in enhancing recovery, a crucial consideration in an aging population with increasing co-morbidities.

offered unmatched durability with minimal late reinterventions. The choice between these modalities must be individualised, integrating patient age, co-morbidities, anatomic suitability, and institutional expertise. TEVAR has rightfully become first-line therapy for most DTAAAs, but open repair retains a critical role- particularly for younger patients and in high-volume centers. As endovascular technology advances, ongoing refinement of patient selection criteria and surveillance protocols will be essential to optimise long-term outcomes.

Looking forward, future research should address several key directions. Prospective studies are needed to evaluate the long-term outcomes of newer endograft technologies, including branched and fenestrated TEVAR devices, in complex anatomic scenarios. Comprehensive cost-effectiveness analyses that incorporate both reintervention risks and quality-of-life metrics would provide valuable insights for healthcare decision-making. Additionally, the development of standardised protocols for surveillance imaging is essential to balance the need for complication detection against concerns about cumulative radiation exposure for patients requiring lifelong monitoring.

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REFERENCES

- [1] Kim KM, Arghani A, Habib R, Daneshmand MA. The Society of Thoracic Surgeons Adult Cardiac Surgery Database: 2022 update on outcomes and research. *Ann Thorac Surg.* 2023;115(3):566-74.
- [2] DeBaey ME, Cooley DA. Surgical treatment of aneurysm of abdominal aorta by resection and restoration of continuity with homograft. *Surg Gynecol Obstet.* 1953;97(3):257-66.
- [3] Dake MD, Miller DC, Semba CP, Mitchell RS, Walker PJ, Liddell RP. Transluminal placement of endovascular stent-grafts for the treatment of descending thoracic aortic aneurysms. *N Engl J Med.* 1994;331(26):1729-34.
- [4] Scali ST, Goodney PP, Walsh DB, Travis LL, Nolan BW, Goodman DC, et al. National trends and regional variation of open and endovascular repair of thoracic and thoracoabdominal aneurysms in contemporary practice. *J Vasc Surg.* 2011;53(6):1499-505.
- [5] Fairman RM, Criado F, Farber M, Kwolek C, Mehta M, White R, et al. Pivotal results of the Medtronic Vascular Talent Thoracic Stent Graft System: The VALOR trial. *J Vasc Surg.* 2008;48(3):546-54.
- [6] Makaroun MS, Dillavou ED, Wheatley GH, Cambria RP. Five-year results of endovascular treatment with the Gore TAG device compared with open repair of thoracic aortic aneurysms. *J Vasc Surg.* 2008;47(5):912-18.
- [7] Nienaber CA, Rousseau H, Eggebrecht H, Kische S, Fattori R, Rehders TC, et al. Randomised comparison of strategies for type B aortic dissection: The Investigation of STent Grafts in Aortic Dissection (INSTEAD) trial. *Circulation.* 2009;120(25):2519-28.
- [8] Desai ND, Burtch K, Moser W, Szeto WY, Herrmann HC, Milewski RK, et al. Long-term comparison of thoracic endovascular aortic repair (TEVAR) to open surgery for the treatment of thoracic aortic aneurysms. *J Thorac Cardiovasc Surg.* 2012;144(3):604-09.
- [9] Nienaber CA, Kische S, Rousseau H, Eggebrecht H, Rehders TC, Kundt G, et al. Endovascular repair of type B aortic dissection: Long-term results of the randomized investigation of stent grafts in aortic dissection trial. *Circ Cardiovasc Interv.* 2013;6(4):407-16.
- [10] Erbel R, Aboyans V, Boileau C, Bossone E, Bartolomeo RD, Eggebrecht H, et al. 2014 ESC Guidelines on the diagnosis and treatment of aortic diseases. *Eur Heart J.* 2014;35(41):2873-926.
- [11] Patterson B, Holt P, Nienaber C, Cambria R, Fairman R, Thompson M. Aortic pathology determines midterm outcome after endovascular repair of the thoracic aorta. *Circulation.* 2013;127(1):24-32.
- [12] Leurs LJ, Bell R, Degrieck Y, Thomas S, Hobo R, Lundborn J; EUROSTAR collaborators. Endovascular treatment of thoracic aortic diseases: Combined experience from the EUROSTAR and United Kingdom Thoracic Endograft registries. *J Vasc Surg.* 2004;40(4):670-79. Doi: 10.1016/j.jvs.2004.07.008. PMID: 15472596.
- [13] Andersen ND, Ganapathi AM, Hanna JM, Williams JB, Gaca JG, Hughes GC. Outcomes of acute type B aortic dissection and intramural hematoma treated with TEVAR. *Ann Cardiothorac Surg.* 2014;3(3):264-74.
- [14] Andrassy J, Weidenhagen R, Meimarakis G, Lauterjung L, Jauch KW, Kopp R. Endovascular versus open treatment of degenerative aneurysms of the descending thoracic aorta. *Vascular.* 2011;19(1):8-14.
- [15] Eggebrecht H, Thompson M, Rousseau H, Czerny M, Lönn L, Mehta RH, et al; European Registry on Endovascular Aortic Repair Complications. Retrograde ascending aortic dissection during or after thoracic aortic stent graft placement: Insight from the European registry on endovascular aortic repair complications. *Circulation.* 2009;120(11 Suppl):S276-S281. Doi: 10.1161/CIRCULATIONAHA.108.835926. PMID: 19752379.
- [16] Fillingier MF, Greenberg RK, McKinsey JF, Chaikof EL; Society for Vascular Surgery Ad Hoc Committee on TEVAR Reporting Standards. Reporting standards for thoracic endovascular aortic repair (TEVAR). *J Vasc Surg.* 2010;52(4):1022-33, 1033.e15. Doi: 10.1016/j.jvs.2010.07.008. PMID: 20888533.
- [17] Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform.* 2009;42(2):377-81.
- [18] Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: Development and validation. *J Chronic Dis.* 1987;40(5):373-83.
- [19] Nashef SA, Roques F, Sharples LD, Nilsson J, Smith C, Goldstone AR, et al. EuroSCORE II. *Eur J Cardiothorac Surg.* 2012;41(4):734-45.
- [20] O'Brien SM, Feng L, He X, Xian Y, Jacobs JP, Badhwar V, et al. The Society of Thoracic Surgeons 2018 adult cardiac surgery risk models: Part 2--statistical methods and results. *Ann Thorac Surg.* 2018;105(5):1419-28.
- [21] Uno H, Claggett B, Tian L, Inoue E, Gallo P, Miyata T, et al. Moving beyond the hazard ratio in quantifying the between-group difference in survival analysis. *J Clin Oncol.* 2014;32(22):2380-85.
- [22] Fine JP, Gray RJ. A proportional hazards model for the subdistribution of a competing risk. *J Am Stat Assoc.* 1999;94(446):496-509.
- [23] Birkmeyer JD, Siewers AE, Finlayson EVA, Stukel TA, Lucas FL, Batista I, Welch HG, Wennberg DE. Hospital volume and surgical mortality in the United States. *N Engl J Med.* 2002;346(15):1128-37.

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