Trends in utilization, timing, and outcomes of thoracic endovascular repair for type B aortic dissection in the United States

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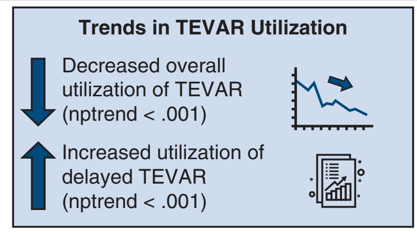
ABSTRACT

Background: Aortic dissection is the most common acute aortic syndrome in the United States. Type B aortic dissection (TBAD) can be managed medically, through open surgical repair, or with thoracic endovascular repair (TEVAR). The present study sought to assess contemporary trends in the use and timing of TEVAR.

Methods: Adult nonelective TBAD admissions were identified in the 2010 to 2020 Nationwide Readmissions Database. Patients were categorized as medical management (Medical Management), TEVAR at initial hospitalization (Early), or TEVAR during readmission (Delayed). Multivariable models were developed to assess associations with clinical outcomes and resource utilization.

Results: Of 85,753 patients, 8.7% underwent TEVAR at index hospitalization (Early). From 2010 to 2020, the proportion undergoing TEVAR decreased significantly (from 11.3% to 9.6%; nptrend < .001), while the proportion of TEVAR at a subsequent hospitalization increased (from 13.0% to 21.6%; nptrend < .001). Compared to Medical Management, the Early group was younger (median. 63 [interquartile range (IQR), 52-74] years vs 69 [IQR, 57-81] years), and more frequently privately insured (27.7% vs 17.5%; $P < .001$). Following adjustment, the Early group had a reduced odds of mortality (adjusted odds ratio [aOR], 0.56; 95% confidence interval [CI], 0.48-0.66) and increased hospitalization costs ($\beta = +\$50{,}000$; 95% CI, $48,000-$53,000). Among 4267 TEVAR patients with available procedure timing data, 15.7% were categorized as Delayed. The Early and Delayed groups did not differ in terms of demographics. The Delayed group had a decreased likelihood of major adverse events (aOR, 0.50; 95% CI, 0.39-0.64); however, this did not affect 90-day cumulative hospitalization costs ($\beta = +\$2700$; 95% CI, -$5000-$11,000, ref: Early).

Conclusions: This study suggests changes to TBAD management in both treatment modality and TEVAR timing. Focused analysis on the timing and long-term costs of TEVAR are needed to optimize care delivery. (JTCVS Open 2024;21:35-44)



The use of TEVAR for TBAD is decreasing, while the proportion of delayed TEVAR is increasing.

CENTRAL MESSAGE

From 2010 to 2020, there was an increase in the rate of thoracic endovascular aortic repair (TEVAR) performed at a readmission relative to the index hospitalization. Compared to early TEVAR, delayed TEVAR may be safer without additional costs.

PERSPECTIVE

A subset of patients with type B aortic dissection (TBAD) are managed with thoracic endovascular repair (TEVAR). The optimal timing of TEVAR is controversial, however. We found an increase in the performance of TEVAR at a readmission relative to the index hospitalization from 2010 to 2020. This is relevant for informing the evolving management of TBAD patients.

Aortic dissection remains the most common acute aortic syndrome, with an estimated lifetime incidence of 3.5 to 6.0 per 100,000 persons.[1] Whereas Stanford type A aortic dissection (TAAD) warrants emergency open surgical repair, in modern practice most type B dissections (TBAD) are managed medically, with a select group

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Abbreviations and Acronyms

aOR	= adjusted odds ratio
CI	= confidence interval
ICD	= International Classification of Diseases
LOS	= length of stay
MAE	= major adverse event
NRD	= Nationwide Readmissions Database
TAAD	= type A aortic dissection
TBAD	= type B aortic dissection
TEVAR	= thoracic endovascular aortic repair

receiving thoracic endovascular (TEVAR) or open repair.[2] However, despite the widespread adoption of endovascular methods, 30-day mortality associated with TEVAR in the acute setting remains a major concern, with reported rates of nearly 8.0%.[3]

Prior work by Trimarchi and colleagues[4] examining >5000 TBAD patients found that the use of TEVAR has nearly doubled over the last 2 decades. Nonetheless, the optimal timing of TEVAR in such patients remains controversial. Some studies have recommended delaying intervention for 2 to 4 weeks after the onset of symptoms to reduce the risk of retrograde TAAD and promote favorable aortic remodeling,[5] while others have suggested that intervention within 2 weeks of presentation is associated with beneficial long-term aortic outcomes.[6] Moreover, Carroll and colleagues[7] reported that nearly 25% of their patients required repeat hospitalization following any type of management for TBAD, and 5.2% required an aortic intervention on readmission. Nonetheless, studies of clinical and financial outcomes of endovascular repair for TBAD on a large scale remain sparse.

In the present study, we used a nationally representative cohort to evaluate temporal trends, resource utilization, and timing of TEVAR over the past decade. We hypothesized that there would be an increasing use of TEVAR relative to medical management over the study period. We further hypothesized that TEVAR performed during readmission would be associated with reduced costs and complications compared to immediate repair.

METHODS

Data Source

This was a retrospective cohort study of the 2010-2020 Nationwide Readmissions Database (NRD) The NRD provides accurate estimates for nearly 60% of discharges nationally using survey weight methodology. Readmissions are tracked within each state and calendar year through unique linkage numbers.[8] This study was exempted from full review by the Institutional Review Board at the University of California, Los Angeles.

Study Population

All adult (≥18 years) nonelective hospitalizations for aortic dissection were identified using relevant International Classification of Diseases (ICD), Ninth Revision and Tenth Revision codes.[9] Patients undergoing cardiac surgery (defined as use of cardioplegia, valve repair, and operations on vessels of the heart) were categorized as type A in accordance with prior literature and not included for analysis.[10] Patients with previous diagnosis of aortic aneurysm or rupture, open aortic repair at index hospitalization, or missing key data also were excluded from analysis. Additionally, patients admitted after September 30 of each year were excluded, to ensure at least 90 days of follow up (Figure 1).

Variable Definitions and Study Outcomes

Patients undergoing TEVAR at index hospitalization were classified as Early, patients undergoing TEVAR at readmission within 90 days were classified as Delayed, and patients who did not undergo TEVAR at either initial or subsequent hospitalization within 90 days were classified as Medical Management. Patient and hospital characteristics, including age, sex, income, insurance status, and hospital teaching status, were reported in accordance with the NRD data dictionary.[8] The van Walraven modification of the Elixhauser Comorbidity Index, a composite measure of more than 30 conditions, was used to quantify the burden of chronic disease.[11] Specific diagnoses, including congestive heart failure, hypertension, and Marfan syndrome, as well as procedures including spinal drain placement and subclavian revascularization were defined using previously validated ICD codes.[12,13] Similarly, complications including intraoperative, thromboembolic, blood transfusion, infectious, renal, respiratory, cardiac, and neurologic complications were defined in accordance with prior literature.[9] A major adverse event (MAE) was classified as a binary composite endpoint of any complication or in-hospital mortality. Inpatient costs were calculated using hospital-specific cost-to-charge ratios and adjusted for inflation using the 2020 Personal Health Index.[14] Cumulative costs over 90 days were calculated by summing hospitalization charges within 90 days of initial admission. Additionally, the annual volume of endovascular procedures was tabulated for each center (Table E1). To facilitate comparison, hospitals were classified into quartiles based on the annual caseload of endovascular procedures, with the top quartile considered high volume. Endovascular volume was considered in a continuous manner for risk-adjusted models.

The primary outcome of interest was in-hospital mortality. Secondary outcomes included clinical complications, hospitalization costs, length of stay (LOS), and 90-day nonelective readmission. A subgroup analysis was performed to evaluate the independent association of TEVAR use at readmission with outcomes of interest.

The timing of procedures was recorded accurately in the NRD beginning in 2014.[8] Thus, comparison of outcomes between the Early and Delayed groups were performed for records following this date, while trends were reported for the overall study period. Patients undergoing TEVAR on the day of admission were excluded from the Early versus Delayed comparisons, to mitigate the influence of possible rupture, malperfusion, or other uncaptured complication necessitating emergent intervention.

Statistical Analysis

The significance of temporal trends was assessed using the Cuzick nonparametric rank-based test (nptrend). The Pearson χ^2 and Mann-Whitney U tests were used to assess the significance of intergroup differences for categorical and continuous variables, respectively. Categorical variables are reported as frequency (%), and continuous covariates are shown as mean with standard deviation (SD) or median with interquartile range (IQR). Variable selection was guided by elastic net regularization. In brief, this method uses a penalized least-squares methodology to admit covariates while minimizing bias and collinearity.[15] Model discrimination was assessed using receiver operating characteristics or the coefficient of determination. Model outputs are reported as β coefficient for linear models and as adjusted odds ratio (aOR) for logistic models, both with 95% confidence interval (CI). All statistical analysis was performed using Stata 16.1 (StataCorp).

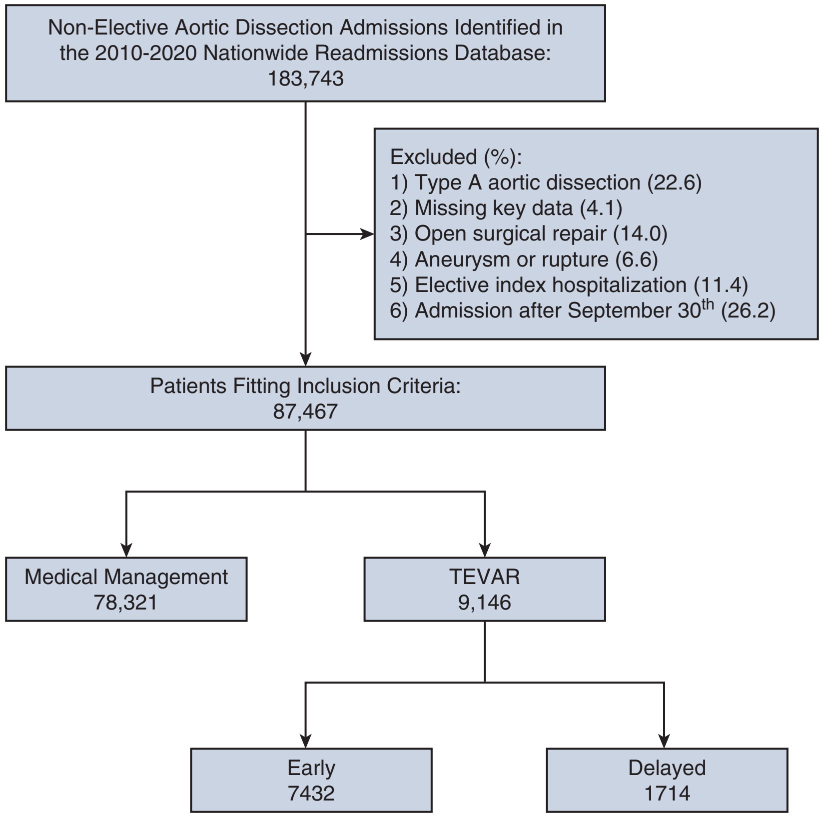

FIGURE 1. CONSORT diagram. *TEVAR*, Thoracic endovascular aortic repair.

RESULTS

Characteristics of Study Cohort

Of an estimated 85,753 patients presenting with TBAD, 8.7% received TEVAR at initial hospitalization and thus were classified as Early. Compared to the Medical Management group, the Early group was younger (median, 63 [IQR, 52-74] years vs 69 [IQR, 57-81] years), less commonly female (38.4% vs 44.3%; $P < .001$), and more frequently privately insured (27.7% vs 17.5%; $P < .001$). Additionally, Early patients had a lower mean Elixhauser Comorbidity Index (4.1 $\pm$ 1.6 vs 4.5 $\pm$ 1.7; $P < .001$) and were more commonly treated at metropolitan teaching centers (87.6% vs 76.2%; $P < .001$) (Table 1). Early more frequently received care at centers in the highest quartile of endovascular volume (26.6% vs 25.2%; $P < .001$) and more commonly experienced interhospital transfer (9.7% vs 4.5%; $P < .001$).

Trends in Use, Timing, and Outcomes of TEVAR

The proportion of patients undergoing early TEVAR increased steadily until 2015 and declined thereafter, going from 9.5% in 2010 to 12.5% in 2015, then to 7.2% in 2020 (Figure 2). Overall use of TEVAR in the Early and Delayed groups also declined over the study period (from 11.3% in 2010 to 9.6% in 2020; nptrend < .001). However, the proportion of patients undergoing TEVAR at subsequent admissions compared to initial admission increased from 13.0% in 2010 to 21.6% in 2020, with a peak of 25.0% in 2017 (nptrend < .001). In-hospital mortality following TEVAR decreased over the study period, from 11.5% in 2010 to 5.3% in 2020 (nptrend < .001).

Factors Associated With TEVAR Versus Medical Management at Index Hospitalization

On adjustment, older age (aOR, 0.98 per year; 95% CI, 0.98-0.99), increasing Elixhauser Index (aOR, 0.92 per unit; 95% CI, 0.88-0.95), and Medicaid coverage (aOR, 0.72; 95% CI, 0.62-0.84; reference: private insurance) were associated with decreased likelihood of TEVAR compared to medical management at the index hospitalization. Conversely, receiving care at a metropolitan teaching center was associated with significantly increased odds of TEVAR at initial hospitalization relative to medical management (aOR, 5.21; 95% CI, 2.93-9.26; reference: nonmetropolitan). Notably, facility endovascular volume did not alter the odds of receiving TEVAR (aOR, 1.00 per 10 cases; 95% CI, 1.00-1.00).

TABLE 1. Demographic, clinical, and hospital characteristics of patients receiving medical management versus TEVAR at initial hospitalization

Characteristic	Medical management group (N = 78,321)	Early TEVAR group (N = 7432)	*P* value
Age, y, median (IQR)	69 (57-81)	63 (52-74)	<.001
Female sex, %	44.3	38.4	<.001
Elixhauser Comorbidity Index, mean ± SD	4.5 ± 1.7	4.1 ± 1.6	<.001
Income quartile, %			.36
76-100	19.1	17.6	
51-75	23.1	23.1	
26-50	26.0	26.6	
0-25	31.9	32.7	
Insurance coverage, %			<.001
Private	17.5	27.7	
Medicare	62.1	46.0	
Medicaid	11.8	13.5	
Uninsured	4.9	7.8	
Other payer	3.6	4.9	
Comorbidities, %			
Congestive heart failure	24.7	14.2	<.001
Diabetes mellitus	19.4	14.4	<.001
Coronary artery disease	31.7	22.5	<.001
Hypertension	60.7	59.8	.42
Valvular disease	18.7	9.9	<.001
Marfan syndrome	2.1	1.6	.07
Hospital teaching status, %			<.001
Nonmetropolitan	4.3	1.0	
Metropolitan nonteaching	19.4	11.5	
Metropolitan teaching	76.2	87.6	
Hospital bed size, %			.001
Large	70.0	82.7	
Medium	21.6	14.1	
Small	8.7	3.2	

Statistical significance was set at $\alpha = 0.05$. *TEVAR*, Thoracic endovascular aortic repair; *IQR*, interquartile range; *SD*, standard deviation.

Clinical and Financial Outcomes of Early TEVAR Versus Medical Management

On unadjusted analysis, patients in the Early group died less frequently during hospitalization compared to those in the Medical Management group (8.2% vs 13.1%; $P < .001$). Renal (28.4% vs 23.2%; $P < .001$), respiratory (26.2% vs 17.1%; $P < .001$), and neurologic (6.6% vs 4.1%; $P < .001$) complications were more frequent in the Early group compared to the Medical Management group (Table E2).

On adjusted analysis with medical management as reference, early TEVAR was associated with significantly reduced odds of mortality (aOR, 0.56; 95% CI, 0.48-0.66). Early TEVAR also was independently associated with the development of renal (aOR, 1.26; 95% CI, 1.15-1.36), respiratory (aOR, 1.60; 95% CI, 1.43-1.78), and neurologic (aOR, 1.33; 95% CI, 1.10-1.61) complications compared to medical management. Early TEVAR was inversely associated with both cardiac (aOR, 0.72; 95% CI, 0.61-0.85) and infectious (aOR, 0.78; 95% CI, 0.66-0.94) complications.

Receipt of TEVAR at the index hospitalization was associated with significantly increased inpatient costs relative to medical management ($\beta = +\$50,000$; 95% CI, \$48,000-\$53,000). TEVAR at the index hospitalization also was associated with increased LOS (β +5.96 days, 95% CI 5.44-6.49) and increased 90-day nonelective readmissions (aOR, 1.28; 95% CI, 1.15-1.41).

Clinical Characteristics of Early Versus Delayed TEVAR

Among 4267 patients with available data on the timing of TEVAR, excluding those undergoing the operation on the day of admission, 672 (15.7%) underwent repair at a readmission and were classified as Delayed. In the Delayed group, 22.4% were admitted electively. Relative to the Early group, the time from index admission to TEVAR was significantly longer in the Delayed group (median, 25

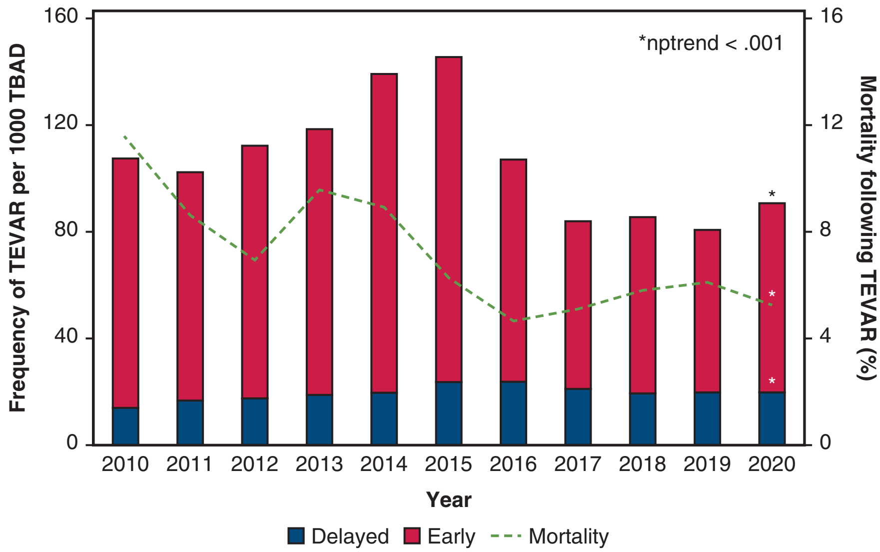

FIGURE 2. Trends in use of thoracic endovascular aortic repair (*TEVAR*). The proportion of patients undergoing TEVAR within 90 days (Early and Delayed groups combined) decreased over the study period (nptrend < .001). Among TEVAR patients, the proportion undergoing repair in a delayed manner has increased significantly (nptrend < .001), while the overall mortality following TEVAR has decreased (nptrend < .001). *TBAD*, Type B aortic dissection.

[IQR, 13-46] days vs 4 [IQR, 2-7] days; $P < .001$) (Figure 3). The Early and Delayed groups did not differ significantly in demographic composition (Table 2). Comparisons of demographic data between the Delayed and Medical Management groups are provided in Table E3.

Outcomes and Resource Utilization Among Patients Undergoing Early Versus Delayed TEVAR

On unadjusted comparison with the Delayed group, the Early group had higher rates of in-hospital mortality (5.3% vs 2.3%; $P < .05$) and MAE (56.1% vs 38.4%;

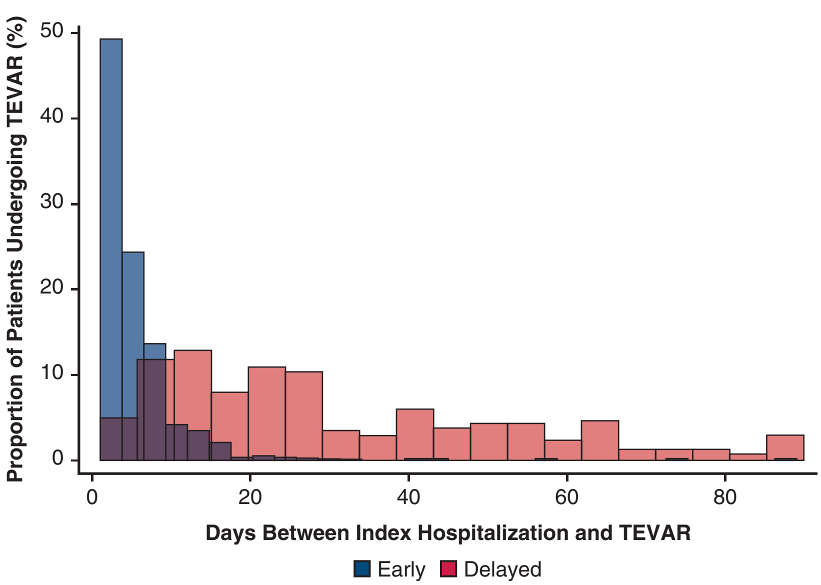

FIGURE 3. Distribution of procedure timing among patients undergoing thoracic endovascular aortic repair (*TEVAR*). Patients who underwent TEVAR on the day of admission were excluded. The time between initial presentation and endovascular repair was significantly higher in the delayed group relative to the early group (median, 25 [IQR, 13-46] days vs 4 [IQR, 2-7] days; $P < .001$). This analysis was performed in patients with available procedure timing information. *IQR*, Interquartile range.

TABLE 2. Demographic, clinical, and hospital characteristics of patients receiving a delayed versus early TEVAR

Characteristic	Delayed TEVAR group (N = 672)	Early TEVAR group (N = 3595)	*P* value
Age, y median (IQR)	63 (54-71)	64 (54-74)	.45
Female (%)	42.6	41.0	.60
Elixhauser Comorbidity Index, mean ± SD	4.2 ± 1.6	4.2 ± 1.6	.80
Income quartile, %			<.01
76-100	20.0	18.3	
51-75	28.7	21.0	
26-50	20.2	26.4	
0-25	31.0	34.4	
Insurance coverage, %			.09
Private	20.6	25.9	
Medicare	50.8	48.4	
Medicaid	19.2	14.6	
Uninsured	6.7	6.7	
Other payer	4.3	4.3	
Comorbidities, %			
Congestive heart failure	17.9	16.3	.49
Diabetes mellitus	16.1	16.1	.99
Coronary artery disease	24.1	23.5	.82
Hypertension	47.7	51.0	.30
Valvular disease	12.2	11.2	.63
Marfan syndrome	1.8	1.5	.66
Hospital teaching status, %			.77
Nonmetropolitan	0.9	0.5	
Metropolitan nonteaching	8.8	8.8	
Metropolitan teaching	90.4	90.7	
Hospital bed size, %			.35
Large	83.7	80.7	
Medium	13.6	13.6	
Small	2.6	2.6	

Patients who underwent TEVAR on the day of admission were excluded. This analysis was performed in patients with available procedure timing information. Statistical significance was set at $\alpha = 0.05$. *TEVAR*, Thoracic endovascular aortic repair; *IQR*, interquartile range; *SD*, standard deviation.

$P < .001$) following TEVAR (Table E4). After adjustment, delayed TEVAR was associated with decreased likelihood of MAE compared to early TEVAR (aOR, 0.50; 95% CI, 0.39-0.64) (Figure 4). Although delayed TEVAR did not affect 90-day cumulative inpatient costs ($\beta = +\$2700$; 95% CI, -\$5000 to \$11,000; reference: Early group), it was associated with a −3.55-day decrement in LOS compared to early TEVAR (95% CI, −4.60 to −2.49 days).

DISCUSSION

In this national study, we noted reduced use of TEVAR over the past decade. Importantly, delaying TEVAR until a readmission has become an increasingly common practice in US centers. Compared to intervention at the index hospitalization, TEVAR at readmission for patients with uncomplicated TBAD was associated with reduced MAEs and similar hospitalization costs. These findings warrant further investigation.

We found that TBAD patients increasingly were managed nonoperatively from 2010 to 2020. Previous studies using dated cohorts reported increases in TEVAR use, possibly related to ongoing improvement of outcomes in TEVAR patients. Indeed, Wang and colleagues[16] reported increased TEVAR use from 2000 to 2012, which they attributed to improved patient selection. Of note, previously reported national studies have not evaluated patients undergoing TEVAR at readmission. In the present study, when examining receipt of TEVAR over 90 days, we found that the trend of decreased TEVAR use persisted. The shift toward medical management observed here appears to have occurred despite a lack of evidence for the superiority of nonoperative management over TEVAR. Conversely, a significant body of research has emerged supporting the use of TEVAR for aortic dissection. Notably, in a retrospective analysis of 357 patients with acute uncomplicated TBAD, Xiang and colleagues[17] found better

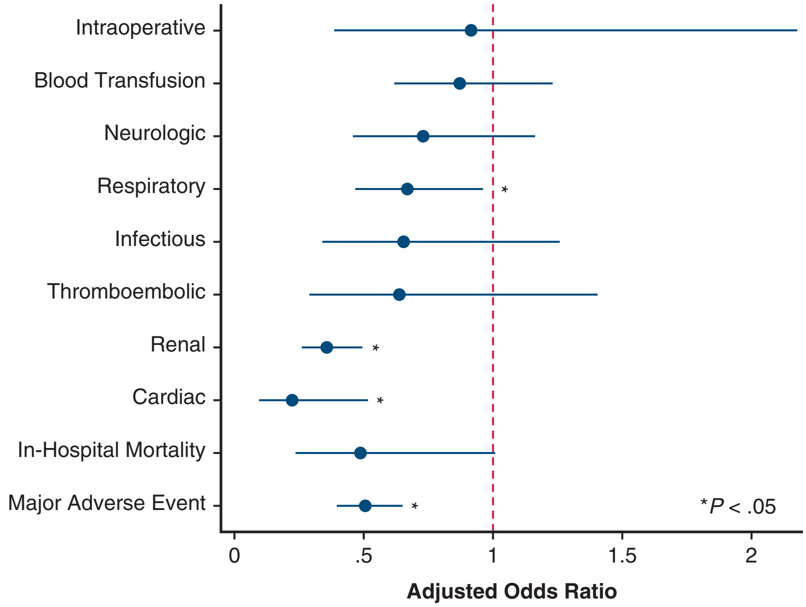

FIGURE 4. Adjusted odds of developing complications among patients undergoing thoracic endovascular aortic repair (*TEVAR*) during a readmission compared to TEVAR at the initial (index) hospitalization. Patients who underwent TEVAR on the day of admission were excluded. The analysis was performed in patients with available procedure timing information.

long-term survival in recipients of TEVAR compared to recipients of medical management. Similarly, a 2022 meta-analysis including both observational studies and clinical trials noted a significant survival advantage conferred by TEVAR relative to medical therapy.[18]

A possible explanation for the decreased use of TEVAR may be the associated hospitalization costs. Congruent with our findings, Iannuzzi and colleagues[19] reported significantly higher expenditures associated with TEVAR compared to medical therapy alone. Irrespective of the increased acute expenditures, studies of cumulative costs are needed to support the use of medical or surgical therapies.

Over the study period, there was an increasing utilization of TEVAR during readmission compared to at the index admission, which may reflect an evolving understanding of the optimal timing for this modality. A 2013 randomized trial of 140 TBAD patients found that the combination of medical therapy and TEVAR (performed at a median of 12 days following randomization) reduced disease progression relative to medical therapy alone.[6] Interestingly, our present findings indicate that an increase in delayed TEVAR has occurred in the 2 years following this trial. This finding aligns with more recent studies suggesting that delayed intervention promotes positive aortic remodeling, contributing to fewer aortic-related complications, such as rupture and retrograde TAAD.[20]

Although our findings suggest a benefit for patients undergoing delayed TEVAR, the improved outcomes also may be attributable to a healthier cohort receiving delayed intervention in a less acute setting. With increased use of delayed TEVAR, additional research aimed at determining the optimal window for timing TEVAR is warranted.

In the present work, Medicaid insurance conferred reduced odds of TEVAR at initial hospitalization as opposed to medical management. The association between insurance status and receipt of TEVAR in the present work suggests the presence of socioeconomic disparities. The persistence of this association after adjustment for center-level endovascular expertise may in part be explained by variability in longitudinal access and follow-up among disadvantaged patients. More than a decade ago, Johnston and colleagues[21] found increased use of TEVAR for thoracic aortic conditions in patients with lower household incomes. The authors ascribed their findings to the fact that disadvantaged patients may present on a delayed timeline and with more advanced disease. In the present study, we made efforts to exclude patients who would have required immediate intervention through the removal of patients with diagnosis of rupture, as well as those undergoing repair on the day of admission. In an evaluation of racial differences following endovascular repair among a cohort of TBAD patients, Diaz-Castrillon and colleagues[22] reported an increasing incidence of dissection and increased likelihood of emergent intervention among Black patients. Given the evidence of disparities in TEVAR care, further investigation of nonclinical factors that may impact decision making is needed to enhance the equity of care delivery for TBAD patients.

The present study has several important limitations. The NRD lacks granularity in laboratory values, radiologic findings, and intraoperative events. In addition, the NRD relies on accurate ICD coding, which may vary based on local or regional practices. Surgeon experience also could not be assessed; however, endovascular volume was included to account for facility experience. Furthermore, ICD coding does not classify aortic dissections based on anatomic features, presence of complications, or chronicity. To identify our study cohort, we identified TAAD based on relevant ICD codes for thoracic aortic dissections, cardiopulmonary bypass use, and cardiac operations, as described previously,[7,10] Furthermore, the NRD includes data from inpatient encounters and does not capture information regarding out-of-hospital events, such as death. Additionally, timing data were not available until 2014, limiting comparisons of the Early and Delayed groups, and the results might not be representative of outcomes in prior years. The Elixhauser Index relies on accurate coding of diagnoses in the medical record, and coding errors and inconsistencies can lead to misclassification of comorbidities and potentially biased results. And finally, our results may be skewed owing to selection bias, with both the use and timing of TEVAR potentially varying due to patient health and condition.

CONCLUSIONS

Our present findings contribute to the growing body of evidence suggesting a shift in the management and timing of TEVAR. This evolution appears to be driven by a more selective approach to patient management, potentially leading to improved patient outcomes. However, the long-term implications of this shift, particularly in terms of cost-effectiveness and quality of life, remain to be fully explored. Our findings underscore the need for continued investigation and development of treatment algorithms that maximize the value of care in patients with TBAD.

Conflict of Interest Statement

Dr Benharash has received proctor fees from Atricure as a surgical proctor. All other authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: aortic dissection, type B aortic dissection, thoracic endovascular repair

TABLE E1. Relevant ICD-9 and ICD-10 codes for endovascular procedures

ICD revision	Endovascular procedure codes
ICD-9	39.71, 39.72, 39.73, 39.74, 39.75, 39.76, 39.77, 39.78, 37.79, 39.90
ICD-10	047H4, 047J4, 047N4, 047R4, 047S4, 047T4, 047U4, 047C4, 047D4, 047E4, 047F4, 047H4, 047J4, 047K4, 047L4, 047V4, 047W4, 047Y4, 04BC4, 04BD4, 04BE4, 04BF4, 04BH4, 04BJ4, 04BK4, 04BL4, 04BM4, 04BN4, 04BP4, 04BQ4, 04BR4, 04BS4, 04BT4, 04BU4, 04BV4, 04BW4, 04BY4, 04CH4, 04CJ4, 04CN4, 04CR4, 04CS4, 04CT4, 04CU4, 04CC4, 04CD4, 04CE4, 04CF4, 04CH4, 04CJ4, 04CK4, 04CL4, 04CV4, 04CW4, 04CY4, 03724, 03734, 03744, 03754, 03764, 03774, 03784, 03794, 037A4, 037B4, 037C4, 03B24, 03B34, 03B44, 03B54, 03B64, 03B74, 03B84, 03B94, 03BA4, 03BB4, 03BC4, 03C24, 03C34, 03C44, 03C54, 03C64, 03C74, 03C84, 03C94, 03CA4, 03CB4, 03CC4, 047H3, 047J3, 047N3, 047R3, 047S3, 047T3, 047U3, 047C3, 047D3, 047E3, 047F3, 047H3, 047J3, 047K3, 047L3, 047V3, 047W3, 047Y3, 04BC3, 04BD3, 04BE3, 04BF3, 04BH3, 04BJ3, 04BK3, 04BL3, 04BM3, 04BN3, 04BP3, 04BQ3, 04BR3, 04BS3, 04BT3, 04BU3, 04BV3, 04BW3, 04BY3, 04CH3, 04CJ3, 04CN3, 04CR3, 04CS3, 04CT3, 04CU3, 04CC3, 04CD3, 04CE3, 04CF3, 04CH3, 04CJ3, 04CK3, 04CL3, 04CV3, 04CW3, 04CY3, 03723, 03733, 03743, 03753, 03763, 03773, 03783, 03793, 037A3, 037B3, 037C3, 03B23, 03B33, 03B43, 03B53, 03B63, 03B73, 03B83, 03B93, 03BA3, 03BB3, 03BC3, 03C23, 03C33, 03C43, 03C53, 03C63, 03C73, 03C83, 03C93, 03CA3, 03CB3, 03CC3

ICD-9, International Classification of Diseases, Ninth Revision; *ICD-10*, International Classification of Diseases, Tenth Revision; *ICD*, International Classification of Diseases.

TABLE E2. Unadjusted outcomes of patients receiving medical management versus TEVAR at initial hospitalization

Outcome	Medical management group (N = 78,321), %	Early TEVAR group (N = 7432), %	*P* value
In-hospital mortality	13.1	8.1	<.001
MAE	51.6	58.9	<.001
Blood transfusion	8.8	18.9	<.001
Perioperative complications			
Neurologic	4.1	6.6	<.001
Renal	23.2	28.4	<.001
Cardiac	11.1	7.7	<.001
Respiratory	17.1	26.2	<.001
Thromboembolic	3.1	3.0	.80
Intraoperative	0.0	2.4	<.001
Infection	7.3	5.8	<.005

Statistical significance was set at $\alpha = 0.05$. *TEVAR*, Thoracic endovascular aortic repair; *MAE*, major adverse events.

TABLE E3. Demographic, clinical, and hospital characteristics of patients receiving medical management versus delayed TEVAR

Characteristic	Medical management group (N = 78,321)	Delayed TEVAR group (N = 672)	*P* value
Age, y, median (IQR)	69 (57-81)	63 (54-71)	<.001
Female sex, %	44.3	42.6	.54
Elixhauser Comorbidity Index, mean ± SD	4.5 ± 1.7	4.2 ± 1.6	<.001
Income quartile, %			<.05
76-100	19.1	20.0	
51-75	23.1	28.7	
26-50	26.0	20.2	
0-25	31.9	31.0	
Insurance coverage, %			<.001
Private	17.5	20.6	
Medicare	62.1	50.8	
Medicaid	11.8	19.2	
Uninsured	4.9	6.7	
Other payer	3.6	4.3	
Comorbidities, %			
Congestive heart failure	24.7	17.9	<.001
Diabetes mellitus	19.4	16.1	.14
Coronary artery disease	31.7	24.1	<.005
Hypertension	60.7	47.7	<.001
Valvular disease	18.7	12.2	<.01
Marfan syndrome	2.1	1.8	.66
Hospital teaching status, %			<.001
Nonmetropolitan	4.3	0.9	
Metropolitan nonteaching	19.4	8.8	
Metropolitan teaching	76.2	90.4	
Hospital bed size, %			<.001
Large	70.0	83.7	
Medium	21.6	13.6	
Small	8.7	2.6	

Patients who underwent TEVAR on the day of admission were excluded. This analysis was performed in patients with available procedure timing information. Statistical significance was set at $\alpha = 0.05$. *TEVAR*, Thoracic endovascular aortic repair; *IQR*, interquartile range; *SD*, standard deviation.

TABLE E4. Unadjusted outcomes of patients receiving delayed versus early TEVAR

Outcome	Delayed TEVAR group (N = 672), %	Early TEVAR group (N = 3595), %	*P* value
In-hospital mortality	2.3	5.3	<.05
MAE	38.4	56.1	<.001
Blood transfusion	11.8	14.6	.17
Perioperative complications			
Neurologic	7.2	10.0	.14
Renal	15.1	32.0	<.001
Cardiac	1.5	7.1	<.001
Respiratory	12.9	20.5	<.005
Thromboembolic	1.7	3.2	.11
Intraoperative	1.9	2.3	.66
Infection	3.5	5.6	.11

Patients who underwent TEVAR on the day of admission were excluded. This analysis was performed in patients with available procedure timing information. Statistical significance was set at $\alpha = 0.05$. *TEVAR*, Thoracic endovascular aortic repair; *MAE*, major adverse events.