Nationwide database analysis of one-year readmission rates after open surgical or thoracic endovascular repair of Stanford Type B aortic dissection

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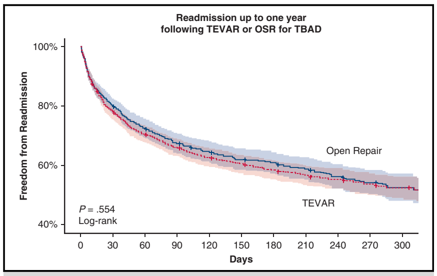
ABSTRACT

Objective: We examined readmissions and resource use during the first postoperative year in patients who underwent thoracic endovascular aortic repair or open surgical repair of Stanford type B aortic dissection.

Methods: The Nationwide Readmissions Database (2016-2018) was queried for patients with type B aortic dissection who underwent thoracic endovascular aortic repair or open surgical repair. The primary outcome was readmission during the first postoperative year. Secondary outcomes included 30-day and 90-day readmission rates, in-hospital mortality, length of stay, and cost. A Cox proportional hazards model was used to determine risk factors for readmission.

Results: During the study period, type B aortic dissection repair was performed in 6456 patients, of whom 3517 (54.5%) underwent thoracic endovascular aortic repair and 2939 (45.5%) underwent open surgical repair. Patients undergoing thoracic endovascular aortic repair were older (63 vs 59 years; $P < .001$) with fewer comorbidities (Elixhauser score of 11 vs 17; $P < .001$) than patients undergoing open surgical repair. Thoracic endovascular aortic repair was performed electively more often than open surgical repair (29% vs 20%; $P < .001$). In-hospital mortality was 9% overall and lower in the thoracic endovascular aortic repair cohort than in the open surgical repair cohort (5% vs 13%; $P < .001$). However, the 90-day readmission rate was comparable between the thoracic endovascular aortic repair and open surgical repair cohorts (28% vs 27%; $P = .7$). Freedom from readmission for up to 1 year was also similar between cohorts ($P = .6$). Independent predictors of 1-year readmission included length of stay more than 10 days ($P = .005$) and Elixhauser comorbidity risk index greater than 4 ($P = .033$).

Conclusions: Approximately one-third of all patients with type B aortic dissection were readmitted within 90 days after aortic intervention. Surprisingly, readmission during the first postoperative year was similar in the open surgical repair and thoracic endovascular aortic repair cohorts, despite marked differences in preoperative patient characteristics and interventions. (JTCVS Open 2022;11:1-13)



Readmission within 1 year after open or endovascular repair of TBAD.

CENTRAL MESSAGE

Patients who undergo open surgical or thoracic endovascular repair of TBAD experience high 1-year readmission rates, regardless of intervention.

PERSPECTIVE

Readmission after surgery is associated with adverse patient outcomes and high healthcare costs. In a large nationwide database analysis, we found that patients who underwent open surgical or thoracic endovascular repair of TBAD had a high incidence of readmission. Targeted strategies in all phases of perioperative patient care are needed to reduce readmission risk.

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Hospital readmission leads to increased healthcare use and cost.[1] With an increased emphasis on value-based health care, hospital readmission has become an important metric for assessing quality of care.[2,3] Many studies have shown that cardiovascular procedures are associated with high readmission rates, with 30-day readmission rates reported to be as high as 28.5%.[4,5] Identifying risk factors that lead

Abbreviations and Acronyms

AHRQ = Agency for Healthcare Research and Quality
CI = confidence interval
HR = hazard ratio
ICD-10-CM = International Classification of Diseases, Tenth Revision, Clinical Modification
IQR = interquartile range
LOS = length of stay
NRD = Nationwide Readmissions Database
OSR = open surgical repair
TBAD = type B aortic dissection
TEVAR = thoracic endovascular aortic repair

to readmission after major operations may help to reduce the incidence and cost of readmission after aortic procedures.

Stanford type B aortic dissection (TBAD) is associated with high morbidity and mortality rates. Although TBAD is often managed medically,[6,7] surgical repair is indicated if the dissection is complicated or has high-risk features (ie, presence of malperfusion, rupture, refractory pain, concerning morphologic features, or progressive aortic dilatation).[8,9] Among these repair techniques, thoracic endovascular aortic repair (TEVAR) has become increasingly common relative to open surgical repair (OSR), which is typically reserved for patients whose anatomy is unsuitable for TEVAR.[10,11] However, because OSR is believed to have better durability than TEVAR, it remains the preferred approach in patients who are younger or have connective tissue disorders.[12]

Beginning in 2012, the Centers for Medicare and Medicaid Services started imposing hospital penalties for readmissions that occurred within 30 days of discharge after various surgical procedures and diagnoses.[1] Independent predictors of readmission have been identified across numerous aortic surgical procedures, including abdominal aortic aneurysm repair and Stanford Type A aortic dissection.[13,14] Although several studies have investigated outcomes and short-term readmission rates after aortic dissection repair,[15,16] risk factors that lead to readmission during the first postoperative year remain unknown. Using a large nationwide database, we analyzed the features of patients with TBAD who undergo TEVAR or OSR and determined the rates and risk factors of readmission during the first postoperative year. Because the decision to perform TEVAR or OSR is based on a combination of anatomic features and patient comorbidities, determining the superiority of TEVAR versus OSR was not a goal of this study. We hypothesized that patients undergoing OSR have higher rates of readmission than patients undergoing TEVAR for TBAD.

MATERIALS AND METHODS

Data Source

The Nationwide Readmissions Database (NRD) is the largest publicly available all-payer database of hospital readmissions. The NRD uses a complex survey design with clustering and poststratification that allows for national estimates of outcomes when survey-based statistics are applied. A defining characteristic of the NRD is its ability to provide reliable linkage between different admissions, making it optimal for studying readmissions. The NRD contains deidentified demographic, clinical, cost-related, and hospital-specific information on more than 35 million discharges annually.[17] We accounted for the survey-based design in all aspects of the study and used survey-adjusted variances to calculate our statistics. Because patient and hospital information contained in the NRD are deidentified to comply with Health Insurance Portability and Accountability Act guidelines, Institutional Review Board approval and informed patient consent were not required for this study.

Study Cohort

We queried the NRD from January 2016 to December 2018 for thoracic and thoracoabdominal aortic dissections by using International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) diagnosis codes I71.01 and I71.03. All admissions, classified as elective or nonelective, were included. Because ICD-10-CM coding does not differentiate among acute, subacute, or chronic aneurysms, all patients diagnosed with aneurysm or rupture (I71.1-I71.9) were excluded. To further narrow the cohort to patients with descending thoracic or thoracoabdominal aortic dissection, we excluded patients with ICD-10-CM procedure codes indicative of type A aortic dissection repair or cardiac procedures other than TBAD repair, similar to previous studies (Table E1).[15,18] Additionally, in-hospital deaths were excluded from calculations other than inpatient mortality. Patients were then stratified by dissection repair technique as TEVAR (ICD-10-CM: 02VW3DZ) or OSR (ICD-10-CM: 02RW0, 02QW0, or 02VW0). Patients who underwent both TEVAR and OSR (n = 27) were excluded from the analysis. A flow chart detailing the application of all inclusion and exclusion criteria is shown in Figure 1.

Patient and Hospital Characteristics

The patient characteristics studied included age, sex, payer, and median household income quartile. Comorbidity burden was assessed with the Elixhauser comorbidity index as defined by the Agency for Healthcare Research and Quality (AHRQ).[19,20] The admission characteristics examined included elective admission. Hospital characteristics were teaching status, bed size (small, medium, or large), and urban location as defined by the NRD.[17]

Readmission Event Outcomes

The primary outcome of this study was hospital readmission within 1 year. Secondary outcomes included 30-day and 90-day readmission rates, costs, hospital length of stay (LOS), mortality, and diagnosis. Causes for readmission were determined by the principal cause of readmission listed for each diagnosis (I10_DX1) according to updated ICD-10 diagnosis codes. These causes for readmission were then grouped into clinically relevant categories as previously described13 and further grouped into broad categories for clarity (Table E2). In-hospital mortality and LOS were evaluated for each discharge record. Admission costs were calculated from cost-to-charge ratios provided by the AHRQ.[13,16] Disposition after surgery (ie, routine discharge, transfer to short-term hospital, transfer to skilled nursing facility or rehabilitation, or home health care) was also assessed.

Statistical Analysis

We used R version 4.1 for all statistical analyses.[21] To account for the sampling design of the NRD, we used probability discharge weights and

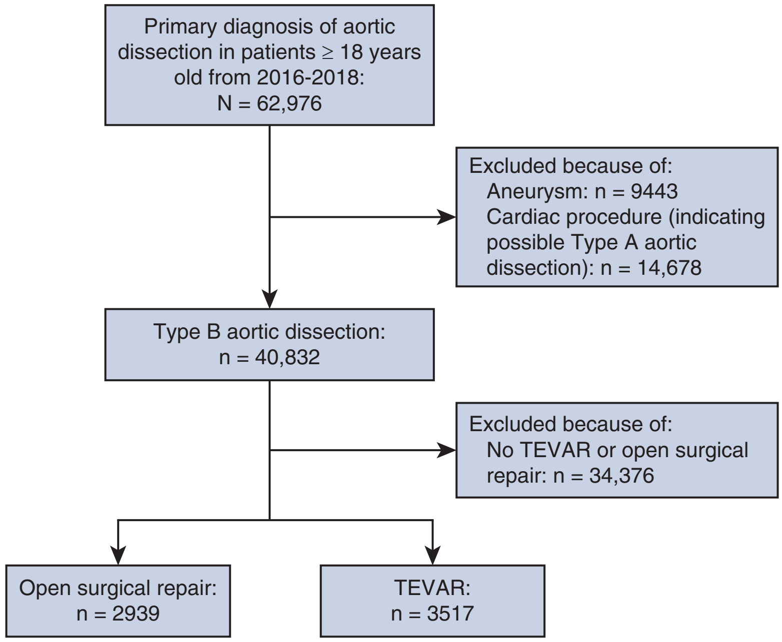


FIGURE 1. Flow diagram detailing the application of inclusion and exclusion criteria and the final analytic cohort. *TEVAR*, Thoracic endovascular aortic repair.

accounted for clustering and stratification by using the classifications provided by the NRD to generate national estimates and variances by using the "survey" package in R.[22] We assessed TEVAR and OSR patient outcomes by using chi-square tests with the Rao and Scott adjustment for survey-based data for categorical variables. Continuous variables that were not normally distributed were compared by using Kruskal–Wallis analysis of variance. Results were presented as the frequency and percentage or as median values with the interquartile range (IQR), as appropriate. Less than 1% of values were missing in any category in our cohort. We handled missing values by replacing continuous values with the median of that variable for the overall cohort and replacing categorical values with the mode of that variable for the overall cohort.

The effect of surgical TBAD repair on early and late readmissions was assessed by performing multivariable logistic regression analysis and adjusting for preoperative comorbidity risk index (Elixhauser index) as defined by the AHRQ, sex, old age, bottom income quartile of patient ZIP code, urgency of the procedure, and OSR, with readmission as the dependent variable for the models. Nagelkerke and Cox-Snell pseudo-R^2 values with adjustments for complex survey samples were used to guide the selection of clinically relevant variables.[23] Additionally, regression models were tested by dividing the underlying data into a training group (80% of the data) and a testing group (the remaining 20% of the data) by using a fixed-seed randomization function. This created a random yet reproducible division of the data so that there were approximately equal proportions in the training and testing groups.

All survey regression models accounted for outcome clusters and the sampling design of the NRD. Categorical variables are presented as a percentage and continuous variables as the mean ± standard deviation. Regression results are reported as the hazard ratio (HR) and 95% confidence interval (CI) with *P* values from a survey-adjusted Wald test.

RESULTS

Preoperative Characteristics

Between 2016 and 2018, 6456 patients survived after TBAD repair; 3517 (54.5%) of those underwent TEVAR, and 2939 (45.5%) underwent OSR. Although the patients in the TEVAR cohort were older than the patients in the OSR cohort (median age, 63 vs 59 years; *P* < .001; Table 1), patients in the TEVAR cohort had a lower comorbidity burden (Elixhauser score of 11 vs 17; *P* < .001) than patients in the OSR cohort (Table 2). Patients in the TEVAR cohort were less likely to have preoperative arrhythmias (29.6% vs 44.7%; *P* < .001), valvular heart disease (13.1% vs 29.0%; *P* < .001), liver disease (5.8% vs 8.3%; *P* = .008), coagulopathies (15.7% vs 44.2%; *P* < .001), or electrolyte disorders (41.9% vs 58.4%; *P* < .001) than patients in the OSR cohort (Table 2). With respect to comorbidities, patients in the TEVAR cohort were more likely to have chronic obstructive pulmonary disease (COPD) than patients in the OSR cohort (23.8% vs 19.4%; *P* = .004; Table 2). Payer status was also significantly different between groups, with more patients in the TEVAR group than in the OSR group having Medicare (48.4% vs 39.7%) and fewer patients in the TEVAR group having private insurance (26.7% vs 36.0%; *P* < .001; Table 1). TEVAR was performed electively more often than OSR (29.2% vs 19.5%; *P* < .001; Table 1). Hospital characteristics were similar between groups, with the majority being large teaching hospitals in metropolitan areas (Table 3).

Index Hospitalization Outcomes

During index hospitalization, in-hospital mortality rates were higher for patients in the OSR group than in the TEVAR group (13.0% vs 5.2%; *P* < .001; Table 4); patients who did not survive were excluded from further univariate analysis. Patients who underwent TEVAR had a shorter

TABLE 1. Characteristics of patients with type B aortic dissection undergoing open surgical repair or thoracic endovascular aortic repair

Characteristic	Overall N = 6456	OSR n = 2939	TEVAR n = 3517	*P* value*
Median age, y (IQR)	61 (51-71)	59 (49-69)	63 (54-73)	<.001
Age group				<.001
<50 y	1375 (21.3%)	758 (25.8%)	617 (17.5%)	
50-64 y	2421 (37.5%)	1123 (38.2%)	1298 (36.9%)	
65-80 y	2098 (32.5%)	866 (29.5%)	1232 (35.0%)	
>80 y	563 (8.7%)	192 (6.5%)	370 (10.5%)	
Women, n (%)	2233 (34.6%)	995 (33.8%)	1238 (35.2%)	.46
Elective, n (%)	1596 (24.8%)	572 (19.5%)	1024 (29.2%)	<.001
Income quartile,† n (%)				<.001
1	1945 (30.6%)	828 (28.6%)	1117 (32.2%)	
2	1701 (26.7%)	709 (24.5%)	992 (28.6%)	
3	1463 (23.0%)	701 (24.2%)	762 (22.0%)	
4	1254 (19.7%)	660 (22.8%)	595 (17.2%)	
Primary payer, n (%)				<.001
Medicaid	928 (14.4%)	429 (14.6%)	499 (14.2%)	
Medicare	2869 (44.4%)	1168 (39.7%)	1702 (48.4%)	
Private insurance	1998 (30.9%)	1058 (36.0%)	940 (26.7%)	
Self-pay	381 (5.9%)	157 (5.3%)	224 (6.4%)	

OSR, Open surgical repair; *TEVAR*, thoracic endovascular aortic repair; *IQR*, interquartile range. *Kruskal–Wallis rank-sum test for complex survey samples; chi-square test with Rao and Scott's second-order correction. †Residence within quartile of median household income ZIP code.

hospital LOS (8 days vs 11 days; $P < .001$) and a lower cost of hospitalization ($57,038 vs $69,587; $P < .001$) than patients who underwent OSR (Table 4). Disposition was also different between groups. Patients in the TEVAR group were more likely to be discharged home (58.8% vs 35.4%) and less likely to be transferred to a skilled nursing facility or intermediate care facility (17.5% vs 31.5%; $P < .001$) than patients in the OSR group (Table 4).

Readmission Rates at 30 Days and 90 Days

Actual 30-day and 90-day readmission rates were similar between groups. The overall 30-day readmission rate was 17.8%, and the 30-day readmission rate was 18.6% for the TEVAR group and 16.8% for the OSR group ($P = .21$). The overall 90-day readmission rate was 27.6%, and the 90-day readmission rate was 27.9% for the TEVAR group and 27.2% for the OSR group ($P = .73$; Table 4).

TABLE 2. Comorbidities of patients with type B aortic dissection undergoing open surgical repair or thoracic endovascular aortic repair

Characteristic	Overall N = 6456	OSR n = 2939	TEVAR n = 3517	*P* value*
Elixhauser score, median (IQR)	13 (3-23)	17 (8-26)	11 (2-19)	<.001
Congestive heart failure	1131 (17.5%)	554 (18.8%)	577 (16.4%)	.13
Arrhythmia	2356 (36.5%)	1314 (44.7%)	1042 (29.6%)	<.001
Valve disease	1311 (20.3%)	851 (29.0%)	460 (13.1%)	<.001
Pulmonary circulation disorder	287 (4.4%)	119 (4.0%)	168 (4.8%)	.36
Hypertension	3948 (61.1%)	1833 (62.4%)	2115 (60.1%)	.24
COPD	1407 (21.8%)	570 (19.4%)	838 (23.8%)	.004
Diabetes mellitus	514 (8.0%)	241 (8.2%)	274 (7.8%)	.71
Renal failure	1447 (22.4%)	641 (21.8%)	806 (22.9%)	.48
Liver disease	446 (6.9%)	244 (8.3%)	203 (5.8%)	.008
Coagulopathy	1854 (28.7%)	1300 (44.2%)	553 (15.7%)	<.001
Electrolyte disorder	3187 (49.4%)	1715 (58.4%)	1472 (41.9%)	<.001
Deficiency anemia	146 (2.3%)	42 (1.4%)	103 (2.9%)	.01
Alcohol abuse	343 (5.3%)	167 (5.7%)	176 (5.0%)	.43
Drug abuse	511 (7.9%)	206 (7.0%)	305 (8.7%)	.13

Categorical variables are presented as the number (%). *OSR*, Open surgical repair; *TEVAR*, thoracic endovascular aortic repair; *IQR*, interquartile range; *COPD*, chronic obstructive pulmonary disease. *Kruskal-Wallis rank-sum test for complex survey samples; chi-square test with Rao and Scott's second-order correction.

TABLE 3. Hospital characteristics of patients undergoing type B aortic dissection with open surgical repair or thoracic endovascular aortic repair

Characteristic	Overall N = 6456	OSR n = 2939	TEVAR n = 3517	*P* value*
Bed size,† n (%)				.28
Large	5292 (82.0%)	2371 (80.7%)	2921 (83.1%)	
Medium	968 (15.0%)	460 (15.7%)	507 (14.4%)	
Small	197 (3.0%)	108 (3.7%)	89 (2.5%)	
Teaching,‡ n (%)				.54
Metro nonteaching	494 (7.7%)	240 (8.2%)	254 (7.2%)	
Metro teaching	5924 (91.8%)	2677 (91.1%)	3247 (92.3%)	
Nonmetro	38 (0.6%)	21 (0.7%)	17 (0.5%)	
City size,§ n (%)				.21
Large metropolitan	4168 (64.6%)	1955 (66.5%)	2213 (62.9%)	
Micropolitan	38 (0.6%)	21 (0.7%)	17 (0.5%)	
Small metropolitan	2250 (34.8%)	963 (32.8%)	1287 (36.6%)	

OSR, Open surgical repair; *TEVAR*, thoracic endovascular aortic repair. *Chi-square test with Rao and Scott's second-order correction. †The bed size cutoff points created small, medium, and large classifications, resulting in approximately one-third of hospitals with each region, location, and teaching status combination falling within each bed size category. ‡Hospitals were classified as teaching hospitals if they had an American Medical Association–approved residency program, were members of the Council of Teaching Hospitals, or had a ratio of full-time equivalent interns and residents to beds of 0.25 or greater. §The urban-rural designation of the hospital is based on the county of the hospital, as identified by the American Hospital Association.

Readmission Within the First Postoperative Year

A Kaplan–Meier curve for freedom from readmission (Figure 2) showed that, at 180 days, patients who underwent TEVAR had a 34.7% readmission rate and those who underwent OSR had a 32.7% readmission rate. By 300 days, both groups had a readmission rate of 40%. No difference in readmission during the first postoperative year was observed between patients who underwent TEVAR or OSR ($P = .55$; Figure 2).

Using a survey-adjusted Cox proportional hazards model, we found that predictors of 1-year readmission included an index hospitalization LOS more than 10 days (HR, 1.25, 95% CI, 1.07-1.47; $P = .005$) and an Elixhauser risk index more than 4 (HR, 1.2, 95% CI, 1.02-1.41; $P = .033$). Hospital characteristics (eg, bed size, teaching status, location) and socioeconomic factors (eg, income quartile, primary payer) were not correlated with 1-year readmission risk. All variables

TABLE 4. Outcomes of patients with type B aortic dissection undergoing open surgical repair or thoracic endovascular aortic repair

In-hospital outcomes				
Characteristic	**Overall N = 6456**	**OSR n = 2938**	**TEVAR n = 3516**	***P* value***
In-hospital mortality, n (%)	565 (8.8%)	383 (13.0%)	182 (5.2%)	<.001
LOS, d	10 (6-16)	11 (8-21)	8 (5-14)	<.001
Index hospitalization cost (USD)	63,242 (43,368-96,325)	69,587 (49,276-110,997)	57,038 (39,711-86,598)	<.001
Outcomes after discharge				
Characteristic	**Overall N = 5492†**	**OSR n = 2447**	**TEVAR n = 3045**	***P* value***
Disposition, n (%)				<.001
Home	2658 (48.4%)	867 (35.4%)	1791 (58.8%)	
Home health care	1481 (27.0%)	787 (32.1%)	694 (22.8%)	
SNF or ICF	1302 (23.7%)	770 (31.5%)	533 (17.5%)	
Short-term hospital	31 (0.6%)	14 (0.6%)	17 (0.6%)	
30-d readmissions, n (%)	975 (17.8%)	410 (16.8%)	565 (18.6%)	.21
90-d readmissions,‡ n/N (%)	1326/4812 (27.6%)	611/2249 (27.2%)	715/2563 (27.9%)	.73
Died on readmission,§ n/N (%)	47/1911 (2.5%)	13/840 (1.6%)	34/1071 (3.2%)	.07
Readmission LOS	4 (2-8)	4 (2-9)	4 (2-8)	.07
Readmission cost (USD)	12,131 (6334-27,794)	11,124 (6429-25,885)	12,449 (6260-30,639)	.70
Elective readmission, n/N (%)	323/1911§ (16.9%)	137/840 (16.3%)	186/1071 (17.4%)	.70

Continuous variables are presented as the median (IQR). *OSR*, Open surgical repair; *TEVAR*, thoracic endovascular aortic repair; *LOS*, length of stay; *USD*, United States dollars; *SNF*, skilled nursing facility; *ICF*, intermediate care facility. *Kruskal–Wallis rank-sum test for complex survey samples; chi-square test with Rao and Scott's second-order correction. †Denominator represents patients who survived the index admission and had at least 30 days of exposure in the database. ‡Denominator represents patients who survived the index admission and had at least 90 days of exposure in the database. §Denominator represents the number of patients who were readmitted.

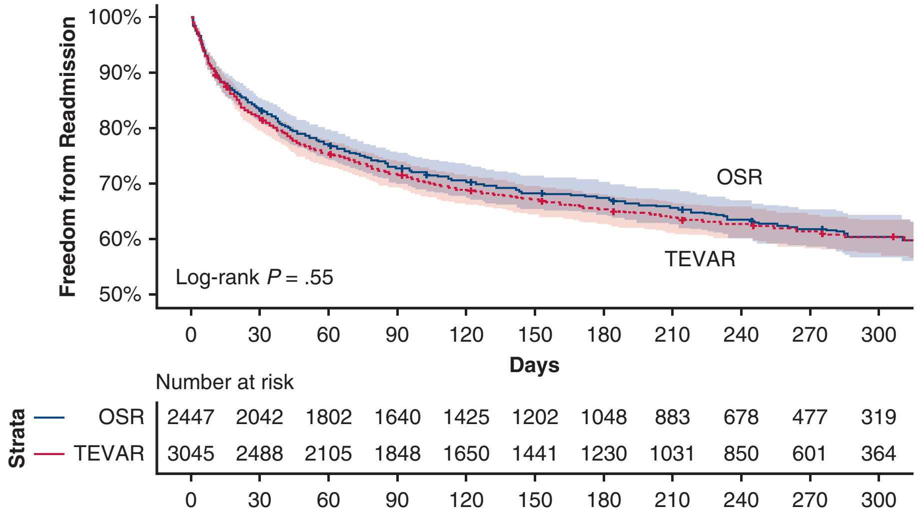


FIGURE 2. Kaplan–Meier estimates of readmission after OSR or TEVAR for TBAD. Freedom from readmission within 1 year was similar in patients who underwent OSR or TEVAR (P = .55, long-rank test). *Shaded areas* represent 95% CIs. *OSR*, Open surgical repair; *TEVAR*, thoracic endovascular aortic repair.

included in the Cox proportional hazards model are listed in Table E3.

Causes of readmission were similar between groups. However, patients who underwent TEVAR were readmitted because of TBAD-related causes more often than patients treated with OSR. In patients who underwent TEVAR, the most common reasons for readmission were TBAD-related (23.7%), cardiovascular (20.0%), and infectious (11.5%) causes. Patients who underwent OSR were most commonly readmitted for cardiovascular (23.5%), infectious (15.4%) and TBAD-related etiologies (14.5%) (Figure 3).

Outcomes during readmission were similar between patients in the TEVAR and OSR groups. For patients readmitted after TEVAR, the median hospital LOS was 4 days (IQR, 2-8 days), the median cost was $12,449 (IQR, $6260-$30,639), and the rate of mortality was 3.2% (n = 34). For patients readmitted after OSR, the median hospital LOS was 4 days (IQR, 2-9 days), the median cost was $11,124 (IQR, $6429-$25,885), and the rate of mortality was 1.6% (n = 13) (Table 4).

DISCUSSION

In this study, we used the most recently available data from a nationally representative database to identify the incidence of and risk factors for readmission within the first postoperative year in patients who underwent endovascular

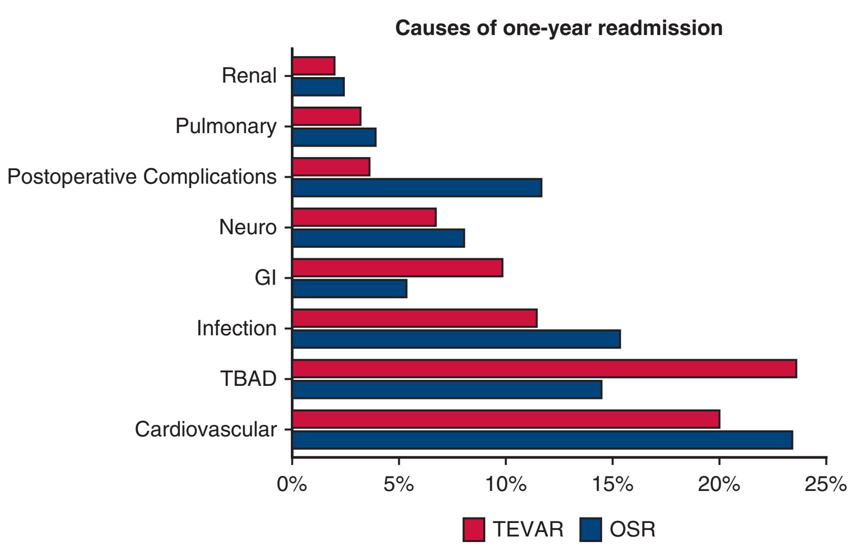


FIGURE 3. Clinical reasons for 1-year readmission after the repair of TBAD, listed by category. *TEVAR*, Thoracic endovascular aortic repair; *OSR*, open surgical repair; *GI*, gastrointestinal; *TBAD*, type B aortic dissection.

or open repair of TBAD. Because patients undergoing TEVAR or OSR for TBAD are a heterogenous group with varying levels of dissection chronicity, we sought to determine postoperative outcomes and areas of potential quality improvement in this population. A major finding was that 40% of patients who underwent intervention for TBAD were readmitted to the hospital within 1 year. Moreover, the rate of readmission within 1 year was high whether patients underwent TEVAR or OSR. This was unexpected, given that readmission rates after OSR are generally thought to be higher than those after TEVAR. Thus, the high comorbidity burden of these patients as well as the underlying pathology of TBAD may be larger drivers of readmission than the treatment modality. We also identified greater comorbidity burden and longer index hospitalization as independent predictors of 1-year readmission, with TBAD-related, cardiovascular, and infectious etiologies being the most common reasons for readmission.

To our knowledge, this is the first study to use the NRD (or any large nationwide cohort) to assess the midterm readmission rates in patients who undergo TBAD repair. For patients who underwent open or endovascular treatment for TBAD, we found that the risk of readmission within the first year was high, with rates of 40% for both groups by 300 days. Previously, in a small (n = 117) county-wide study, D'Oria and colleagues[24] assessed the long-term readmission rates for patients with various aortic syndromes (aortic dissection, intramural hematoma, and penetrating aortic ulcer) and found the cumulative incidence of readmission to be 45% at 2 years and 69% at 10 years. Furthermore, the authors found aortic and cardiovascular causes to be the most common reason for readmission during the early and late follow-up periods, respectively, which is consistent with our findings. In a similar study in Italy,[25] long-term rehospitalization rates for aortic causes and non-aortic cardiovascular causes in patients who underwent surgical repair (OSR, TEVAR, or a hybrid of both) for acute TBAD were 35% and 12.5%, respectively. These studies both showed a high rate of readmission, driven primarily by cardiovascular causes, as seen in our patient cohort.

We found that the 30-day overall readmission rate was 18%, which was consistent with the readmission rates previously reported by others. Jones and colleagues[26] reported a 30-day readmission rate of 21% in a population of Medicare patients who underwent TEVAR for TBAD. Carroll and colleagues[15] reported 30-day nonelective readmission rates of 20.2% and 20.1% in patients who underwent OSR or TEVAR, respectively, for acute TBAD. Others have reported rates of 10.4% and 11% after TEVAR and OSR, respectively, in patients with aortic disease.[27,28]

We identified patients with a greater comorbidity burden and those with longer admission durations as having a greater risk of readmission within the first year after surgical TBAD repair. Although no other studies, to our knowledge, have analyzed predictors of readmission during the first postoperative year after TBAD repair, our findings are similar to those of studies in which risk factors were assessed during shorter durations. Carroll and colleagues[15] found increased comorbidity burden to be an independent predictor of 90-day readmission after the repair of acute TBAD. Kalesan and colleagues[27] found increased diagnosis-related severity, a measure of comorbidity burden, to be an independent predictor of 180-day readmission after endovascular aortic surgery. Notably, these studies reported additional predictors of readmission not identified in our 1-year analysis. Carroll and colleagues[15] found that discharge to a skilled nursing facility, chronic kidney disease, fluid and electrolyte disorders, and hypertension were predictors of 90-day readmission after acute TBAD repair.[15] Kalesan and colleagues[27] reported urgent or emergency procedures to be a predictor of readmission during the first 180 days after endovascular aortic surgery. Although these characteristics were predictive of readmission for up to 6 months, their importance likely diminished during the course of 1 year. When Donze and colleagues[29] assessed the causes of readmission in general, they found that the primary reason for readmission was related to the patient's underlying comorbidities rather than the primary diagnosis at the index hospitalization. Given these findings, monitoring patients with a higher comorbidity burden closely after discharge is warranted to prevent costly and potentially avoidable readmission. Additionally, Deo and colleagues[30] demonstrated that use of home health care significantly reduced early readmission after coronary artery bypass grafting, which may also be applicable for postoperative TBAD patients with a high comorbidity burden. Postoperative follow-up would also include guideline-directed imaging surveillance after acute aortic dissection. The 2010 American College of Cardiology/American Heart Association guidelines recommend that this be done at the time of discharge; at 1, 6, and 12 months; and then annually.[7] Patient compliance with surveillance imaging at 6 and 12 months after acute aortic dissection is associated with improved survival.[31] However, An and colleagues[32] reported that adherence to guideline-directed imaging surveillance after acute type A aortic dissection is poor, with a rate of 14%. It is likely that adherence to TBAD surveillance imaging may be similarly poor and represents an opportunity for more reliable follow-up adherence in conjunction with primary care providers. Finally, evidence from the International Registry of Aortic Dissection demonstrated that long-term survival is improved after TBAD for patients discharged on calcium channel blockers.[33]

Among the patients who survived to discharge, the causes of readmission were similar overall, with TBAD-related causes being most common in patients who underwent TEVAR and other cardiovascular causes being most common in patients who underwent OSR. After the endovascular

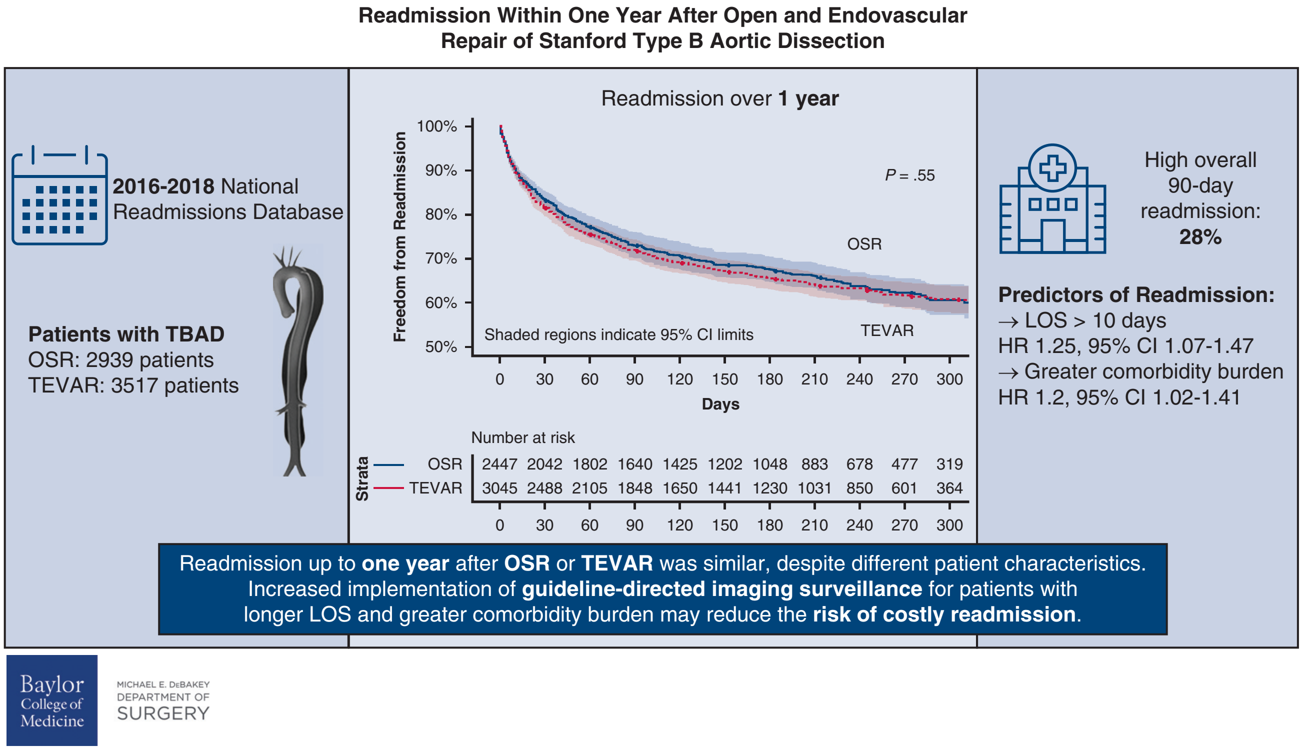


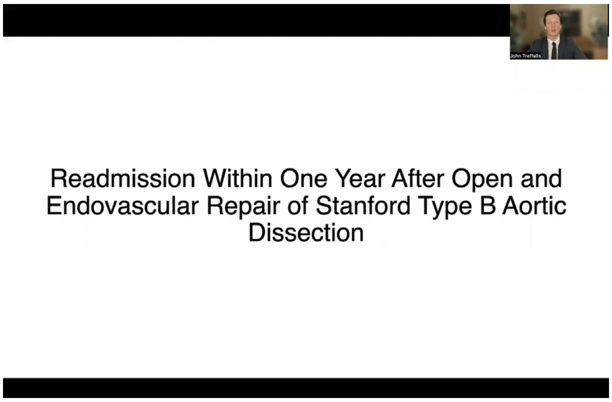
FIGURE 4. Readmissions within 1 year after open or endovascular repair of Stanford TBAD. From 2016 to 2018, 6456 patients underwent surgical TBAD repair, of whom 3517 (54.5%) underwent TEVAR and 2939 (45.5%) underwent OSR. The 90-day readmission rate was comparable between patients in the TEVAR (27.9%) and OSR (27.2%; $P = .73$) groups. Freedom from readmission within 1 year was also similar between the TEVAR and OSR ($P = .55$) groups. Using a survey-adjusted Cox proportional hazards model, predictors of 1-year readmission included an index hospital LOS more than 10 days (HR, 1.25; 95% CI, 1.07-1.47; $P = .005$) and an Elixhauser risk index greater than 4 (HR, 1.2; 95% CI, 1.02-1.41; $P = .03$). *OSR*, Open surgical repair; *TBAD*, type B aortic dissection; *TEVAR*, thoracic endovascular aortic repair; *LOS*, length of stay; *HR*, hazard ratio; *CI*, confidence interval.

repair of any aortic injury (dissection, ruptured or unruptured aneurysm), common causes of readmission are related to the heart, aorta, or infection.[27] Residual aortic disease, complications with grafts, and preexisting cardiovascular comorbidities were found to be the main drivers of readmission after TBAD repair. Additionally, Aziz and colleagues[14] showed that the most common cause of readmission after the endovascular repair of abdominal aortic aneurysm was infection, including superficial and deep surgical site infection. As the third most common reason for readmission in our overall cohort, infection is a preventable complication that should be addressed through targeted strategies to reduce readmission and associated costs during the first postoperative year.

Study Limitations

This study has a few important limitations. First, we analyzed 2 disparate patient populations: those treated endovascularly or those treated with open surgery for TBAD. As expected, both groups differed in comorbidity burden and in-hospital outcomes. They most likely also differed in ways not captured by the NRD, such as anatomic features and dissection chronicity. Accordingly, we did not attempt to compare the superiority of a surgical or endovascular approach for readmissions. Second, the NRD is a clustered, poststratified database derived from hospital claims data and not individual medical records. Therefore, inconsistencies and inaccuracies in the diagnoses may be present. The ICD-10 coding system does not differentiate type A aortic dissection and TBADs; however, we excluded indicators of ascending aortic dissection. Furthermore, a recent single-center study that adjudicated aortic dissections by using billing codes demonstrated a specificity of 99% for both TEVAR and OSR, validating the use of this national registry.[34]

Third, although we used the primary diagnosis for the cause of readmission, some patients are readmitted for multiple diagnoses. Thus, the reasons for readmission may be multifactorial, which is not accounted for by our analysis. Specifically, we were not able to assess whether the cause of readmission was related to a patient's procedure, or whether a procedure was for the purpose of aortic reintervention. In addition, the NRD uses Healthcare Cost and Utilization Project State Inpatient Databases and thus can identify readmissions only if they are within the same state. Readmissions to hospitals in states different from that of the



VIDEO 1. Brief presentation summarizing key points of the study. Video available at: https://www.jtcvs.org/article/S2666-2736(22)00297-2/fulltext.

index hospitalization are not recorded, so true readmission rates may be higher than those reported in these databases. Additionally, the NRD focuses on inpatient care and may not capture information on patients who died outside the hospital setting. Thus, we are unable to provide goodness of follow-up data. However, the larger sample size that databases such as the NRD can provide produce more generalizable results, and the survey-adjusted statistics implemented in this study take into account the estimated variance from the assumptions used in the NRD's design.

CONCLUSIONS

Despite disparate patient populations, the rate of readmission during the first year after patients undergo surgical TBAD repair was similar between patients who underwent an open or endovascular repair approach. Not unexpectedly, in-hospital mortality was significantly higher in the OSR group. Patients in both groups were commonly readmitted because of residual aortic disease or other cardiovascular causes. Furthermore, patients with an increased comorbidity burden and those admitted for longer durations were most likely to be readmitted (Video 1). Thus, the use of additional outpatient resources such as home health care to promote optimal medical management and guideline-directed imaging surveillance for sicker patients may reduce the rates of costly readmission (Figure 4). Our findings may point to opportunities for quality improvement in the repair of aortic dissection. To maximize patient outcomes, the patient selection process should be continually reviewed so that patients are directed to the optimal treatment.

Conflict of Interest Statement

The 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: nationwide readmissions database, readmissions, thoracic endovascular aortic repair, thoracoabdominal aortic dissection, type B aortic dissection

TABLE E1. Probable acute type A aortic dissection International Classification of Diseases, 10th Revision, Procedure Coding System codes

Procedure	ICD-10-PCS code
Heart and great vessels, repair, coronary artery, 1 artery	02Q0
Heart and great vessels, repair, coronary artery, 2 arteries	02Q1
Heart and great vessels, repair, coronary artery, 3 arteries	02Q2
Heart and great vessels, repair, coronary artery, 4 or more arteries	02Q3
Heart and great vessels, repair, coronary vein	02Q4
Heart and great vessels, repair, atrial septum	02Q5
Heart and great vessels, repair, atrium, right	02Q6
Heart and great vessels, repair, atrium, left	02Q7
Heart and great vessels, repair, conduction mechanism	02Q8
Heart and great vessels, repair, chordae tendineae	02Q9
Heart and great vessels, repair, superior vena cava	02QV
Heart and great vessels, repair, thoracic aorta, ascending/arch	02QX
Heart and great vessels, replacement, atrial septum	02R5
Heart and great vessels, replacement, atrium, right	02R6
Heart and great vessels, replacement, atrium, left	02R7
Heart and great vessels, replacement, chordae tendineae	02R9
Heart and great vessels, replacement, heart	02RA
Heart and great vessels, replacement, papillary muscle	02RD
Heart and great vessels, replacement, aortic valve	02RF
Heart and great vessels, replacement, aortic valve	02RG
Heart and great vessels, replacement, pulmonary valve	02RH
Heart and great vessels, replacement, tricuspid valve	02RJ
Heart and great vessels, replacement, ventricle, right	02RK
Heart and great vessels, replacement, ventricle, left	02RL
Heart and great vessels, replacement, ventricular septum	02RM
Heart and great vessels, replacement, pericardium	02RN
Heart and great vessels, replacement, pulmonary trunk	02RP
Heart and great vessels, replacement, pulmonary artery, right	02RQ
Heart and great vessels, replacement, pulmonary artery, left	02RR
Heart and great vessels, replacement, pulmonary vein, right	02RS
Heart and great vessels, replacement, pulmonary vein, left	02RT
Heart and great vessels, replacement, superior vena cava	02RV
Heart and great vessels, replacement, thoracic aorta, ascending/arch	02RX
Heart and great vessels, bypass	021

ICD-10-PCS, International Classification of Diseases, 10th Revision, Procedure Coding System.

TABLE E2. Causes of readmission categories

Category	Cause of readmission
TBAD	
	Abdominal aortic aneurysm, without rupture
	Aneurysm of iliac artery
	Dissection of abdominal aorta
	Dissection of thoracic aorta
	Dissection of thoracoabdominal aorta
	Dissection of unspecified site of aorta
	Thoracic aortic aneurysm, without rupture
	Thoracoabdominal aortic aneurysm, ruptured
	Thoracoabdominal aortic aneurysm, without rupture
	Leakage of aortic (bifurcation) graft (replacement), initial encounter
	Other specified complication of vascular prosthetic devices, implants
	Displacement of aortic (bifurcation) graft (replacement)
	Leakage of other vascular grafts, initial encounter
	Other mechanical complication of other cardiac and vascular devices
	Leakage of other cardiac and vascular devices and implants
Cardiovascular	
	Atherosclerosis (aorta or peripheral vessels)
	Hypertension or heart failure
	Conduction disorder
	Ischemic heart disease
	Valve disorder
	Heart disease, other
	Pericarditis
GI	
	Gastrointestinal
	Bleeding, gastrointestinal
Infection	
	Confirmed or suspected infection
Miscellaneous	
	Musculoskeletal
	Venous thromboembolism
	Endocrine, nutritional and metabolic diseases
	Neoplasm
	Nutritional, hemolytic, or unspecified anemias
	Coagulation defect
Neuro	
	Psychiatric and (nonischemic) neurological or sensory disorders
	Cerebrovascular disease (including stroke or TIA)
	Bleeding, intracranial
Postoperative complications	
	Bleeding, thoracic
	Bleeding, other
	Bleeding, source unknown
	Pericardial or pleural effusion
Pulmonary	
	Noninfectious respiratory disease
Renal	
	Renal failure

(Continued)

TBAD, Type B aortic dissection; *GI*, gastrointestinal; *TIA*, transient ischemic attack.

TABLE E3. Cox proportional hazards model results

Variable	Adjusted HR (95% CI)	Adjusted *P* value
LOS > 10 d	1.25 (1.07-1.47)	.005
Elixhauser risk > 4	1.2 (1.02-1.41)	.03
Lowest income quartile ZIP code	1.11 (0.99-1.25)	.09
Female	1.05 (0.91-1.21)	.52
Elective procedure	0.95 (0.8-1.13)	.59
Age >70 y	0.93 (0.8-1.08)	.33
OSR	0.9 (0.78-1.03)	.13

HR, Hazard ratio; *CI*, confidence interval; *LOS*, length of stay; *OSR*, open surgical repair.