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 open surgical repair and 2939 (45.5%) underwent thoracic endovascular aortic 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)

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.

Hospital readmission leads to increased healthcare use and cost. With an increased emphasis on value-based health care, hospital readmission has become an important metric for assessing quality of care. 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%. Identifying risk factors that lead...
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, 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). 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. 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.

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. Independent predictors of readmission have been identified across numerous aortic surgical procedures, including abdominal aortic aneurysm repair and Stanford Type A aortic dissection. Although several studies have investigated outcomes and short-term readmission rates after aortic dissection repair, 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 underwent 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.

**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

**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. 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). 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). 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.

**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 described 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. 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. To account for the sampling design of the NRD, we used probability discharge weights and
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. 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-R2 values with adjustments for complex survey samples were used to guide the selection of clinically relevant variables. 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%); patients in the OSR cohort 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

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

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**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                      |                 |             |               |               |
| <50 y                          | 1375 (21.3%)    | 758 (25.8%) | 617 (17.5%)   | <.001         |
| 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, j 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.
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 (%)    |                  |              |                |          |
| Large              | 5292 (82.0%)     | 2371 (80.7%) | 2921 (83.1%)   | .28      |
| 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, 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

| Characteristic     | Overall N = 6456 | OSR n = 2939 | TEVAR n = 3517 | 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 |

In-hospital outcomes

| 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.

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 = 5492 | OSR n = 2447 | TEVAR n = 3045 | P value* |
|--------------------|------------------|--------------|----------------|----------|
| 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%)    |          |
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| 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.

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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...
or open repair of TBAD. Because patients undergoing TEVAR or OSR for TBAD are a heterogeneous 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 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, 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 reported a 30-day readmission rate of 21% in a population of Medicare patients who underwent TEVAR for TBAD. Carroll and colleagues 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.

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 found increased comorbidity burden to be an independent predictor of 90-day readmission after the repair of acute TBAD. Kalesan and colleagues reported urgent or emergency procedures to be a predictor of readmission during the first 180 days after endovascular aortic surgery. Additionally, Deo and colleagues 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. Patient compliance with surveillance imaging at 6 and 12 months after acute aortic dissection is associated with improved survival. However, An and colleagues 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.

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...
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 colleagues14 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

![Readmission Within One Year After Open and Endovascular Repair of Stanford Type B Aortic Dissection](image_url)

**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.
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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References

1. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. N Engl J Med. 2009;360:1418-28.
2. American College of Surgeons. User guide for the 2014 ACS NSQIP participant use data file (PUF). Accessed January 13, 2022. https://www.facs.org/~media/quality/20programs/nsqip/nsqip_puf_userguide_2014.pdf
3. Kocher RP, Adashi EY. Hospital readmissions and the Affordable Care Act: paying for coordinated quality care. JAMA. 2011;306:1794-5.
4. Gonzalez AA, Girotti ME, Shih T, Wakefield TW, Dimick JB. Reliability of hospital readmission rates in vascular surgery. J Vasc Surg. 2014;59:1638-43.
5. Tahhan G, Farber A, Shah NK, Krafcik BM, Sachs TE, Kalish JA, et al. Characterization of planned and unplanned 30-day readmissions following vascular surgical procedures. Vasc Endovasc Surg. 2017;51:17-22.
6. Appoo JJ, Bozinovski J, Chu MW, El-Hamamsy I, Forbes TL, Moon M, et al. Canadian Cardiovascular Society/Canadian Society of Cardiac Surgeons/Canadian Society for Vascular Surgery joint position statement on open and endovascular repair for thoracic aortic disease. Can J Cardiol. 2016;32:703-13.
7. Hiratzka LF, Bakris GL, Beckman JA, Bersin RM, Caffrey VE, Casey DE Jr, et al. 2010 ACCF/AHA/ATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM guidelines for the diagnosis and management of patients with thoracic aortic disease. A report of the American College of Cardiology Foundation/American Heart Association task force on practice guidelines. American Association for Thoracic Surgery, American College of Radiology, American Stroke Association, Society for Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of Thoracic Surgeons, and Society for Vascular Medicine. J Am Coll Cardiol. 2010;55:e27-129.
8. Lombardi JV, Hughes GC, Appoo JJ, Bavaria JE, Beck AW, Cambria RP, et al. Society for Vascular Surgery (SVS) and Society of Thoracic Surgeons (STS) reporting standards for type B aortic dissections. Ann Thorac Surg. 2020;109:959-81.
9. MacGillivray TE, Gleason TG, Patel HJ, Aldea GS, Bavaria JE, Beaver TM, et al. The Society of Thoracic Surgeons/American Association for Thoracic Surgery clinical practice guidelines on the management of type B aortic dissection. Ann Thorac Surg. 2022;113:1073-92.
10. Suzuki T, Mehta RH, Ince H, Nagai R, Sakomura Y, Weber F, et al. Clinical profiles and outcomes of acute type B aortic dissection in the current era: lessons from the International Registry of Aortic Dissection (IRAD). Circulation. 2003;108(Suppl 1):II312-7.
11. Zhang H, Wang ZW, Zhou Z, Hu XP, Wu HB, Guo Y. Endovascular stent-graft placement or open surgery for the treatment of acute type B aortic dissection: a meta-analysis. Ann Vasc Surg. 2012;26:454-61.
12. Harky A, Hussain SMA, McCarthy-Oloso B, Ahmad MU. The role of thoracic endovascular aortic repair (TEVAR) of thoracic aortic diseases in patients with connective tissue disorders—a literature review. Br J Cardiovasc Surg. 2020;35:977-85.
13. Amin A, Ghanta RK, Zhang Q, Zea-Vera R, Rosengart TK, Prevost O, et al. Ninety-day readmission after open surgical repair of Stanford Type A aortic dissection. Ann Thorac Surg. 2022;113:1971-8.
14. Aiza F, Ferranti K, Lehman EB. Unplanned return to operating room after endovascular repair of abdominal aortic aneurysm (EVAR) is associated with increased risk of hospital readmission. Vascular. 2018;26:151-62.
15. Carroll BJ, Schermerhorn M, Kennedy KW, Swedlow N, Soriano KM, Yeh RW, et al. Readmissions after acute type B aortic dissection. J Vasc Surg. 2020;72:73-83.e2.
16. Shah RM, Zhang Q, Chatterjee S, Cheema F, Loor G, Lemaire SA, et al. Incidence, cost, and risk factors for readmission after coronary artery bypass grafting. Ann Thorac Surg. 2019;107:1782-9.
17. Agency for Healthcare Research and Quality. Introduction to the HCUP nationwide database (NRD). Accessed January 13, 2022. https://www.hcup-us.ahrq.gov/db/nation/nrd/NRD_Introduction_2014.jsp
18. Sachs T, Pomposelli F, Hagberg R, Hamdan A, Wyers M, Giles K, et al. Open and endovascular repair of type B aortic dissection in the Nationwide Inpatient Sample. J Vasc Surg. 2010;52:386-6; discussion 6.
19. Elixhauser A, Steiner C, Kruuzikas D. Comorbidity software documentation. Accessed January 13, 2022. https://www.hcup-us.ahrq.gov/reports/methods/ComorbiditySoftwareDocumentationFinal.pdf
20. Gasparini A. An R package for computing comorbidity scores. J Open Source Softw. 2018;3:648.

VIDEO 1. Brief presentation summarizing key points of the study. Video available at: https://www.jtcvs.org/article/S2666-2736(22)00297-2/fulltext.
21. R Core Team. The R Project for statistical computing. Accessed January 13, 2022. https://www.R-project.org/
22. Lumley T. Analysis of complex survey samples. *J Stat Softw*. 2004;9:1-19.
23. Lumley T. Pseudo-R2 statistics under complex sampling. *Aust N Z J Stat*. 2017; 59:187-94.
24. D’Oria M, Sen I, Day CN, Mandrekar J, Weiss S, Bower TC, et al. Burden and causes of readmissions following initial discharge after aortic syndromes. *J Vasc Surg*. 2021;73:836-43.e3.
25. Corsini A, Pacini D, Lovato L, Russo V, Lorenzini M, Foa A, et al. Long-term follow up of patients with acute aortic syndromes: relevance of both aortic and non-aortic events. *Eur J Vasc Endovasc Surg*. 2018;56:200-8.
26. Jones DW, Goodney PP, Nolan BW, Brooke BS, Fillinger MF, Powell RJ, et al. National trends in utilization, mortality, and survival after repair of type B aortic dissection in the Medicare population. *J Vasc Surg*. 2014;60:11-9, 9.e1.
27. Kalesan B, Cheng TW, Farber A, Zuo Y, Kalish JA, Jones DW, et al. Readmissions after thoracic endovascular aortic repair. *J Vasc Surg*. 2018;68:372-82.e3.
28. Wu D, Price MD, Amarasekara HS, Green SY, Woodside SJ, Tullos A, et al. Unplanned readmissions after open thoracoabdominal aortic aneurysm repair. *Ann Thorac Surg*. 2018;105:228-34.
29. Donze J, Lipsitz S, Bates DW, Schipper JL. Causes and patterns of readmissions in patients with common comorbidities: retrospective cohort study. *BMJ*. 2013; 347:f7171.
30. Deo SV, Sharma V, Altarabsheh SE, Raza S, Wilson B, Elgudin Y, et al. Home health care visits may reduce the need for early readmission after coronary artery bypass grafting. *J Thorac Cardiovasc Surg*. 2021;162:1732-9.e4.
31. Chaddha A, Eagle KA, Patel HI, Deeb GM, Yang B, Harris KM, et al. The clinical impact of imaging surveillance and clinic visit frequency after acute aortic dissection. *Aorta (Stamford)*. 2019;7:75-83.
32. An KR, de Mestral C, Tam DY, Qiu F, Ozzounian M, Lindsay TF, et al. Surveillance imaging following acute type A aortic dissection. *J Am Coll Cardiol*. 2021; 78:1863-71.
33. Suzuki T, Isselbacher EM, Nienaber CA, Pyeritz RE, Eagle KA, Tsai TT, et al. Type-selective benefits of medications in treatment of acute aortic dissection (from the International Registry of Acute Aortic Dissection [IRAD]). *J Vasc Surg*. 2012;55:122-7.
34. Finnesgard EJ, Weiss S, Kalra M, Johnstone JK, Oderich GS, Shuja F, et al. Performance of current claims-based approaches to identify aortic dissection hospitalizations. *J Vasc Surg*. 2019;70:53-9.

**Key Words:** nationwide readmissions database, readmissions, thoracic endovascular aortic repair, thoracoabdominal aortic dissection, type B aortic dissection
| 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 |

(Continued)
**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 |

**TABLE E2. Continued**

| Category | Cause of readmission |
|----------|----------------------|
| Postoperative complications | Bleeding, thoracic |
| | Bleeding, other |
| | Bleeding, source unknown |
| | Pericardial or pleural effusion |
| Pulmonary | Noninfectious respiratory disease |
| Renal | Renal failure |

TRAD, 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.*