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Article

Costs and Readmissions Associated with Type A Aortic Dissections at High- and Low-Volume Centers

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Abstract

Background: Costs and readmissions associated with type A aortic dissection repairs are not well understood. We investigated statewide readmissions, costs, and outcomes associated with the surgical management of type A aortic dissection repairs at low- and high-volume centers. **Methods**: We identified all adult type A aortic dissection patients who underwent operative repair in the Maryland Health Services Cost Review Commission's database (2012–2020). Hospitals were stratified into high- (top quartile of total repairs) or low-volume centers. **Results**: Of the 249 patients included, 193 (77.5%) were treated at a high-volume center. Patients treated at high- and low-volume centers had no differences in age, sex, race, primary payer, or severity (all $p > 0.5$). High- compared to low-volume centers had a greater proportion of patients transferred in (71.5% *vs.* 17.9%, $p < 0.001$). High-volume centers also had longer lengths of stay (12 *vs.* 8 days, $p < 0.001$), similar inpatient mortality (13.0% *vs.* 16.1%, $p = 0.6$), and similar proportion of patients readmitted (54.9% *vs.* 51.8%, $p = 0.7$). High-volume centers had greater index admission costs ($114,859 *vs.* $72,090, $p < 0.001$) and similar readmission costs ($48,367 *vs.* $42,204, $p = 0.5$). At high-volume centers, transferred patients compared to direct admissions had greater severity of illness ($p = 0.05$), similar mortality ($p = 0.53$), and greater lengths of stay ($p = 0.05$). **Conclusions**: High-volume centers had a greater number of patients transferred from other institutions compared to low-volume centers. High-volume centers were associated with increased index admission resource utilization, with transfer patients having higher illness severity and greater resource utilization, yet similar mortality, compared to direct admission patients.

Keywords

type A aortic dissection; costs; outcomes; volume

Introduction

Type A aortic dissections (TAAD) are complex operative emergencies with high mortality rates. Despite decreases in TAAD mortality over the past few decades, inpatient mortality rates nationally still exceed 20% [1–3] and in-hospital complications are observed in >70% of patients [4]. For each hour from symptom onset, untreated TAAD mortality rates increase by 1–2% [5]. Consequently, prompt surgical intervention is essential, and the tradeoff associated with delaying surgery to transfer patients to an experienced center must be carefully considered.

While previous studies have demonstrated that higher center and surgeon operative repair volume is associated with improved TAAD outcomes [6–10], few studies have investigated resource utilization associated with TAAD repairs. A recent study by Dobaria *et al.* [8] found that high-volume centers were associated with greater costs compared to low-volume centers, despite similar lengths of stay. However, little is known regarding the breakdown of these costs. Additionally, no studies have investigated readmissions associated with operative TAAD repairs or compared outcomes and costs between transfer patients and direct admission patients at high volume centers.

We conducted a statewide retrospective review of operative TAAD repairs at high- and low-volume centers. We investigated outcomes and costs associated with index admissions and readmissions at high- and low-volume centers. We also separately compared outcomes and costs of TAAD repairs between transfer patients and direct admission patients at high-volume centers.

Materials and Methods

Data Source

This statewide retrospective analysis was performed using data from the Maryland Health Services Cost Review Commission (HSCRC) Inpatient Data Set. The HSCRC Inpatient Data Set contains discharge diagnosis codes, operative codes, and billing data for each inpatient admission, including readmissions, in the state of Maryland. This dataset was chosen given the quality and granularity of data relating to in-hospital admissions and their associated costs and readmissions. Additionally, since 2014, Maryland has utilized a global budget revenue (GBR) system, which caps annual hospital revenue and thereby incentivizing reductions in hospital expenditures and readmissions. This GBR model shifted the payment structure from a payment-per-inpatient-admission to a hospital bundled payment system and additionally emphasizes reducing 30-day readmission rates [11]. This study was approved by the Johns Hopkins Institutional Review Board (IRB00082345).

Study Population

This study included all patients with a diagnosis of thoracic aortic dissection who underwent operative TAAD repair in the HSCRC Inpatient Data Set between 1 July 2012 and 30 June 2020 (corresponding to fiscal years 2012–2020). To isolate patients who underwent an operative repair for TAAD, only aortic dissection repairs utilizing cardioplegia or involving valves or vessels of the heart were included (Fig. 1), as previously described [8,12–14]. Patients with a diagnosis of aortic aneurysm or penetrating aortic ulcer during the index admission were excluded. International Classification of Diseases (ICD)-9 diagnosis and procedure codes were used to identify patients from July 2012 to September 2015. ICD-10 diagnosis and procedure codes were used to identify patients from October 2015 to June 2020. Specific codes utilized can be found in **Supplementary Table 1**. Initial inpatient admissions during which patients underwent operative TAAD repair were labeled as index admissions. All subsequent inpatient admissions following the index admission were labeled as readmissions.

Center Volume Designation

Centers with a TAAD operative repair volume in the top quartile (25th percentile) during the study period were classified as high-volume centers. All other centers were classified as low-volume centers.

Baseline Characteristics

Baseline demographic and admission characteristics were compared using chi-squared testing. TAAD operative repair outcomes were compared using chi-squared testing for categorical variables and Wilcoxon rank-sum testing for continuous variables. Normality of distribution for all continuous variables was assessed using Shapiro-Wilk testing and histogram visualization. All Patient Refined-Diagnosis Related Group (APR-DRG) scores were used for severity of illness. This classification assigns patients to one of four subclasses of illness severity (1—minor, 2—moderate, 3—major, or 4—extreme) based a number of clinical factors, including admission indication, age, and comorbidities [15]. This severity scoring system has previously been shown to be closely associated with clinical outcomes, such as intensive care unit mortality [16].

Operative Outcomes

Hospital length of stay and total readmissions during the study period were compared between high- and low-volume centers using Wilcoxon log-rank tests and multivariable linear regressions. In-hospital mortality, in-hospital complications, unplanned readmissions during the 30 days post-discharge, and readmission at any point during the study period were compared between high- and low-volume centers using Chi-squared tests and multivariable logistic regressions. Multivariable regressions adjusted for covariates chosen a priori, which included age, sex, race, APR-DRG severity score, and primary payer. ICD-9 and ICD-10 codes (**Supplementary Table 2**) were used to identify index admission complications (stroke, pneumonia, acute renal failure, myocardial infarction, post-procedural hemorrhage, peripheral ischemia) associated with TAAD operative repair.

Index Admission Charges

Due to the limitations of the database, charges were used as a proxy for costs. Hospital costs are difficult to directly assess, and due to limitations of the database, cost-to-charge ratios were not available to be included. A number of prior studies have investigated charge data as a proxy for cost [17,18]. Additionally, given Maryland's all-payer model, pay for services are set by an independent commissioner [19]. As a result, charges and costs may be more aligned in Maryland than in other states. Individual charges were categorized into facility/admission-related charges, emergency care charges, anesthesia/surgery-related charges, imaging/testing charges, and physical medicine/rehabilitation charges. Charge data were analyzed as continuous variables, with normality of distribution assessed using Shapiro-Wilk testing and histogram visualization. Index admission charges were compared between high- and low-volume centers using Wilcoxon rank-sum testing and multivariable linear regression as described above.

Costs and Length of Stay Associated with Complications

Wilcoxon rank-sum testing and multivariable linear regressions, as described above, were used to compare median index admission costs and lengths of stay between patients who did and did not experience each in-hospital complication (stroke, pneumonia, acute renal failure, myocardial infarction, post-procedural hemorrhage, peripheral ischemia).

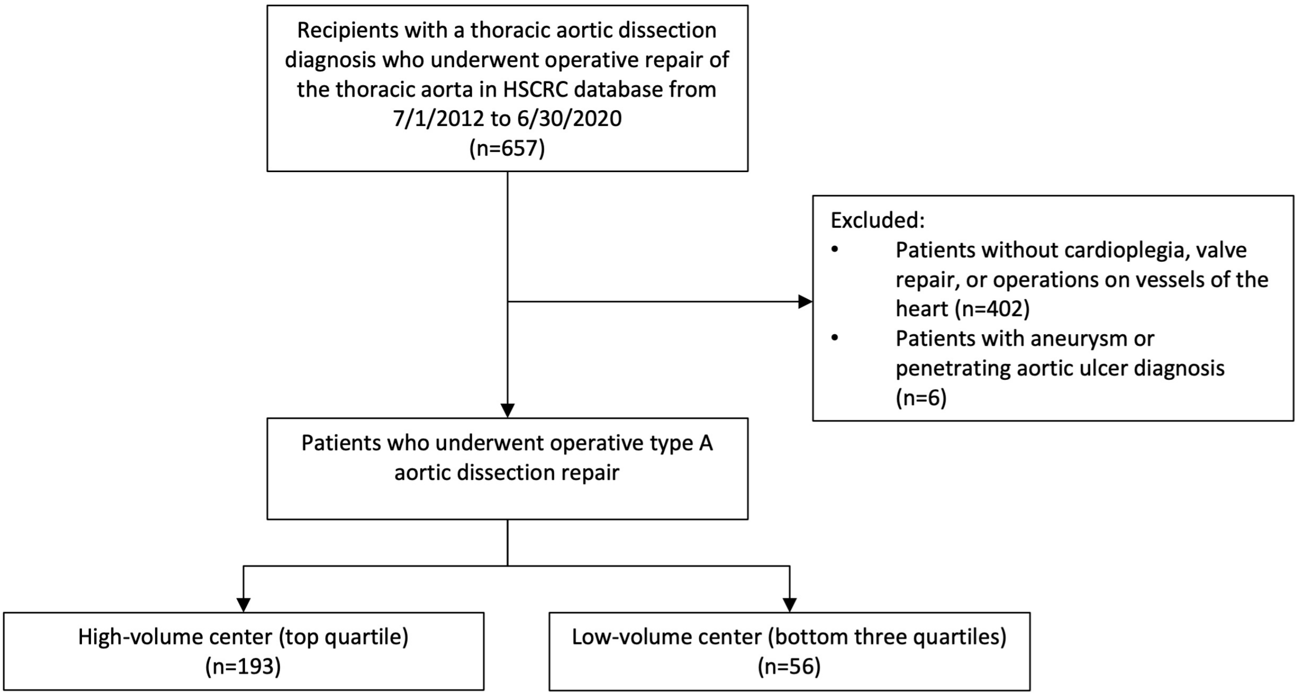

Fig. 1. Inclusion and exclusion criteria to generate study population. For specific International Classification of Diseases (ICD) codes used, refer to **Supplementary Table 1**. Abbreviations: HSCRC, Maryland Health Services Cost Review Commission.

Subgroup Analysis of Transferred Patients

A subgroup analysis of direct admission *vs.* transferred patients at high-volume centers was performed. Baseline characteristics were compared as described above. Similarly, outcomes and index admission charges were compared as described above.

Readmission Charges

Charges associated with all readmissions for each patient were summed, and total readmission charges per patient were compared between high- and low-volume centers using Wilcoxon rank-sum testing and multivariable linear regressions as described above. All statistics were performed using StataSE 17 (StataCorp, College Station, TX, USA). Two-tailed tests were utilized, with p-value < 0.05 indicating significance.

Results

Baseline Characteristics

In total, 249 patients during the study period underwent operative TAAD repair at a total of 8 centers. Of these, there were 2 high-volume centers that treated a total of 193 (77.5%) patients and 6 low-volume centers that treated a total of 56 (22.5%) patients. High- and low-volume centers performed a mean of 12 and 1.2 TAAD operative repairs per year, respectively. Demographic characteristics (Table 1) between patients treated at high- and low-volume centers were similar, with no significant difference in age group ($p = 0.24$), sex ($p = 0.16$), race ($p = 0.30$), or primary payer ($p = 0.62$). High-volume centers had a significantly greater proportion of transfers from other hospitals (71.5% *vs.* 17.9%) and a smaller proportion of admissions from home (23.8% *vs.* 78.6%) than low-volume centers ($p < 0.001$). The majority of patients had an APR-DRG severity score of 3 or 4, with a similar distribution of severity scores at high- and low-volume centers ($p = 0.75$).

Operative Outcomes

Patients treated at high-volume centers had significantly longer lengths of stay than patients treated at low-volume centers (median {interquartile range, IQR}: 12 {7–22} *vs.* 8 {5–13} days, $p = 0.001$; Table 2). This remained significant on adjusted analysis ($p = 0.006$). Overall in-hospital mortality rate was 13.7% and was similar between high- (16.1%) and low-volume (13.0%) centers ($p = 0.55$), even on adjusted analysis ($p = 0.85$). Of patients who died, there was no difference in time-to-death from admission date between high- and low-volume centers (3 {1–18} *vs.* 4 {2–19} days, $p = 0.61$). On univariate analysis, there were no statistically significant differences between high- and low-volume centers in rates of in-hospital stroke (12.4% *vs.* 12.5%, $p = 0.99$), pneumonia (13.0% *vs.* 7.1%, $p = 0.34$), acute renal failure (42.5% *vs.* 33.9%, $p = 0.25$), myocardial infarction (3.5% *vs.* 7.1%, $p = 0.27$), post-procedural hem-

Table 1. Baseline characteristics of patients by center Type A aortic dissection volume at index admissions.

Variable	Low volume (n = 56)	High volume (n = 193)	p-value
Female sex, n (%)	16 (28.6)	75 (38.9)	0.16
Age Group, n (%)			0.24
20–39	3 (5.4)	18 (9.3)	
40–59	27 (48.2)	72 (37.3)	
60–80	21 (37.5)	93 (48.2)	
80+	5 (8.9)	10 (5.2)	
Race, n (%)			0.30
White	32 (57.1)	104 (53.9)	
African American	15 (26.8)	72 (37.3)	
Other	4 (7.1)	8 (4.1)	
Unknown	5 (8.9)	9 (4.7)	
APR-DRG severity, n (%)			0.75
1 (minor)	2 (3.6)	12 (6.2)	
2 (moderate)	1 (1.8)	6 (3.1)	
3 (major)	21 (37.5)	77 (39.9)	
4 (extreme)	32 (57.1)	98 (50.8)	
Calendar Year, n (%)			0.99
2012	4 (7.1)	12 (6.2)	
2013	5 (8.9)	24 (12.4)	
2014	12 (21.4)	34 (17.6)	
2015	8 (14.3)	29 (15.0)	
2016	6 (10.7)	23 (11.9)	
2017	6 (10.7)	15 (7.8)	
2018	8 (14.3)	25 (13.0)	
2019	6 (10.7)	26 (13.5)	
2020	1 (1.8)	5 (2.6)	
Primary payer, n (%)			0.62
Medicare	18 (32.1)	78 (40.4)	
Medicaid	8 (14.3)	25 (13.0)	
Private insurance	29 (51.8)	79 (40.9)	
Charity/Self pay	0 (0.0)	2 (1.0)	
Other	1 (1.8)	9 (4.6)	
Source of Admission, n (%)			<0.001
Transfer within hospital	1 (1.8)	6 (3.1)	
Transfer between hospital	10 (17.9)	138 (71.5)	
Home or equivalent	44 (78.6)	46 (23.8)	
Unknown	1 (1.8)	3 (1.6)	

APR-DRG, All Patient Refined-Diagnosis Related Group.

orrhage (9.8% *vs*. 7.1%, $p = 0.54$), and peripheral ischemia (16.1% *vs*. 16.1%, $p = 1.00$). After adjusting for baseline characteristics, there was a greater likelihood of acute renal failure at high volume centers (adjusted odds ratio (aOR) 2.45 [95% CI: 1.14–5.25], $p = 0.02$).

Index Admission Charges

The median total charge per index admission across the entire study population was $107,779 ($72,161–$170,823). High-volume centers were associated with higher total index admission charges compared to low-volume centers ($114,858 [$85,329.17–$178,212.40] *vs*. $72,089.83 [$55,578.54–$114,022.84], $p < 0.001$), even after adjusting for baseline characteristics ($p < 0.001$). After breaking charges down by category, high-volume centers were associated with higher anesthesia/surgery charges ($64,114 [$45,857–$85,203] *vs*. $42,449 [$32,630–$61,007], $p < 0.001$), facility/admission charges ($23,973 [$14,720–$47,092] *vs*. $14,812 [$9899–$24,576], $p < 0.001$), and imaging/testing charges ($17,735 [$11,504–$33,729] *vs*. $12,565 [$7401–$16,468], $p < 0.001$), but lower emergency charges ($0 [$0–$25] *vs*. $658 [$0–$889], $p < 0.001$). These inferences held true on adjusted analysis (Table 3).

Table 2. General type A aortic dissection outcomes at low- and high-volume centers.

Variable	Low volume (n = 56)	High volume (n = 193)	Unadjusted *p*-value	Adjusted OR/coefficient (95% CI)	Adjusted *p*-value
Length of stay, median (IQR)	8 (5–13)	12 (7–22)	0.001	6.09 (1.74, 10.45)	0.006
In-hospital mortality, n (%)	9 (16.1)	25 (13.0)	0.55	1.09 (0.43, 2.76)	0.85
In-hospital complications, n (%)					
Stroke	7 (12.5%)	24 (12.4%)	0.99	1.31 (0.48, 3.57)	0.60
Pneumonia	4 (7.1%)	25 (13.0%)	0.34	2.34 (0.71, 7.78)	0.16
Acute renal failure	19 (33.9%)	82 (42.5%)	0.25	2.45 (1.14, 5.25)	0.02
Myocardial infarction	4 (7.1%)	7 (3.6%)	0.27	0.50 (0.12, 2.07)	0.34
Post-procedural hemorrhage	4 (7.1%)	19 (9.8%)	0.54	1.52 (0.46, 5.00)	0.49
Peripheral ischemia	9 (16.1%)	31 (16.1%)	1.00	0.97 (0.40, 2.34)	0.95
Unplanned readmission within 30-days, n (%)	6 (10.7)	20 (10.4)	0.94	0.89 (0.32, 2.46)	0.83
Any Readmission, n (%)	29 (51.8)	106 (54.9)	0.68	1.02 (0.54, 1.90)	0.95
Number of readmissions per patient*, median (IQR)	2 (1–3)	2 (1–4)	0.26	0.59 (–0.69, 1.87)	0.37

CI, confidence interval; IQR, interquartile range; OR, odds ratio. *Only accounts for patients that had any readmissions for both low-volume centers (n = 29) and high-volume centers (n = 106).

Table 3. Index admission charges related to hospital care at low- and high-volume centers.

Charge type ($), median (IQR)	Low volume (n = 56)	High volume (n = 193)	Unadjusted *p*-value	Adjusted coefficient (95% CI)	Adjusted *p*-value
Facility/Admission	14,812 (9899–24,576)	23,973 (14,720–47,092)	<0.001	16,120 (6261, 25,978)	0.001
Emergency	658 (0–889)	0 (0–25)	<0.001	–408 (–531, –284)	<0.001
Anesthesia/Surgery	42,449 (32,630–61,007)	64,114 (45,857–85,203)	<0.001	24,733 (12,326, 37,140)	<0.001
Imaging/Testing	12,565 (7401–16,468)	17,735 (11,504–33,729)	<0.001	18,768 (9739, 27,796)	<0.001
PMR	2620 (1665–4145)	4190 (2388–11,109)	<0.001	6105 (2286, 9922)	0.002
Total	72,090 (55,579–114,023)	114,859 (85,329–178,212)	<0.001	65,312 (35,848, 94,776)	<0.001

CI, confidence interval; IQR, interquartile range; PMR, physical medicine/rehabilitation.

Costs and Length of Stay Associated with Index Admission Complications

On adjusted analysis, patients who suffered pneumonia had greater median lengths of stay (28 {20–35} *vs.* 10 {6–15.5} days, $p < 0.001$) and total costs ($192,391 [$147,847–$270,732] *vs.* $105,547 [$69,670–$140,340], $p = 0.01$), as did patients who experienced hemorrhage (length of stay: 12 {8–46} *vs.* 11 {6–19} days, $p < 0.001$; total cost: $171,577 [$107,676–$395,046] *vs.* $106,544 [$70,891–$149,028], $p < 0.001$). Patients who experienced acute renal failure had longer median lengths of stay (17 {9–29} *vs.* 9 {6–13} days, $p = 0.03$), but had no difference in total costs on adjusted analysis ($145,578 [$100,567–$208,572] *vs.* $92,428 [$66,763–$121,808], $p = 0.13$; Table 4). On adjusted analysis, patients who experienced stroke, myocardial infarction, or peripheral ischemia had no differences in median length of stay or total index hospitalization costs.

Analysis of Direct Admission vs. Transferred Patients

Of patients treated at high-volume centers, 46 (23.8%) were direct admission patients and 138 (71.5%) were transferred from another center (Table 5). Patients who were transferred had greater APR-DRG severity scores on admission (56.5% *vs.* 34.8% with highest score, $p = 0.05$). Transferred patients had increased lengths of stay (13 {7–24} *vs.* 9 {6–16} days, $p = 0.05$) on univariate analysis, but after adjusting for covariates, this difference was no longer significant ($p = 0.32$; Table 6). Transfer and direct admission patients had no statistically significant difference in mortality (14.5% *vs.* 10.9%, $p = 0.53$). On univariate analysis, transferred patients had greater facility/admission charges ($26,660 [$15,352–$51,216] *vs.* $18,396 [$11,122–$33,064], $p = 0.02$), imaging/testing charges ($21,123 [$12,075–$37,093] *vs.* $14,539 [$10,058–$23,367], $p = 0.017$), and physical medicine/rehabilitation charges ($5572 [$2543–$13,131] *vs.* $2853 [$1758–$6196], $p = 0.005$), and trended towards greater total index admission charges ($119,147 [$89,868–$191,429] *vs.* $108,671 [$78,492–$139,778], $p = 0.09$). However, all of these differences were not significant on adjusted analysis.

Readmission Outcomes

Of all the patients in the study, 26 (10.4%) had at least one unplanned readmission within 30 days of discharge and 135 (54.2%) had at least one readmission overall. High-

Table 4. Length of stay and charges associated with different in-hospital complications after type A aortic dissection repair.

Variable	Without complication	With complication	Unadjusted *p*-value	Adjusted coefficient (95% CI)	Adjusted *p*-value
Stroke	N = 218	N = 31			
Length of stay, median (IQR)	10 (6–17)	18 (8–26)	0.02	1.03 (–4.82, 6.87)	0.73
Total charges ($), median (IQR)	106,326 (70,891–154,794)	147,873 (105,774–248,209)	0.001	18,119 (–22,320, 58,557)	0.38
Pneumonia	N = 220	N = 29			
Length of stay, median (IQR)	10 (6–15.5)	28 (20–35)	<0.001	10.33 (4.54, 16.13)	0.001
Total charges ($), median (IQR)	105,547 (69,670–140,340)	192,391 (147,847–270,732)	<0.001	52,675 (12,048, 93,302)	0.01
Acute renal failure	N = 148	N = 101			
Length of stay, median (IQR)	9 (6–13)	17 (9–29)	<0.001	4.82 (0.62–9.01)	0.03
Total charges ($), median (IQR)	92,428 (66,763–121,808)	145,578 (100,567–208,572)	<0.001	22,497 (–6735, 51,729)	0.13
Myocardial infarction	N = 238	N = 11			
Length of stay, median (IQR)	11 (7–19)	10 (4–16)	0.37	–5.26 (–14.49, 3.97)	0.26
Total charges ($), median (IQR)	107,557 (72,092–165,138)	110,925 (73,718–208,572)	0.77	–15,380 (–79,474, 48,712)	0.64
Hemorrhage	N = 226	N = 23			
Length of stay, median (IQR)	11 (6–19)	12 (8–46)	0.06	15.00 (8.77, 21.23)	<0.001
Total charges ($), median (IQR)	106,544 (70,891–149,028)	171,577 (107,676–395,046)	0.001	118,643 (76,144, 161,151)	<0.001
Peripheral ischemia	N = 209	N = 40			
Length of stay, median (IQR)	11 (6–19)	13 (7–31)	0.32	0.37 (–4.83, 5.57)	0.89
Total charges ($), median (IQR)	106,873 (71,684–154,794)	127,841 (81,342–248,569)	0.03	26,956 (–8907, 62,819)	0.14

CI, confidence interval; IQR, interquartile range.

Table 5. Baseline characteristics of transfer *vs.* direct admit patients treated at high-volume centers.

Variable	Home (n = 46)	Transferred (n = 138)	*p*-value
Female sex, n (%)	19 (41.3)	54 (39.1)	0.79
Age Group, n (%)			0.29
20–39	7 (15.2)	11 (8.0)	
40–59	19 (41.3)	50 (36.2)	
60–80	19 (41.3)	68 (49.3)	
80+	1 (2.2)	9 (6.5)	
Race, n (%)			0.58
White	24 (52.2)	75 (54.3)	
African American	20 (43.5)	49 (35.5)	
Other	1 (2.2)	7 (5.1)	
Unknown	1 (2.2)	7 (5.1)	
APR-DRG severity, n (%)			0.05
1 (minor)	5 (10.9)	7 (5.1)	
2 (moderate)	1 (2.2)	5 (3.6)	
3 (major)	24 (52.2)	48 (34.8)	
4 (extreme)	16 (34.8)	78 (56.5)	
Primary payer, n (%)			0.33
Medicare	16 (34.8)	57 (41.3)	
Medicaid	8 (17.4)	17 (12.3)	
Private insurance	21 (45.7)	55 (39.9)	
Charity/Self pay	1 (2.2)	1 (0.7)	
Other	0 (0.0)	8 (5.8)	

IQR, interquartile range.

and low-volume centers had similar proportions of patients with at least one readmission during the 30 days following discharge as well as during the entire study period (Table 2). Of those who were readmitted, patients treated at high- compared to low-volume centers had no differences in the median number of readmissions (2 {1–3} *vs.* 2 {1–4}, p = 0.26), even on adjusted analysis (p = 0.37). The median total readmission-related charges per patient across the entire study population was $45,795 (IQR: $16,196–$141,905). High-volume and low-volume centers had similar median total readmission-related charges (p = 0.46; Table 7), which held true on adjusted analysis (p = 0.74). When charges were broken down by category, high- and low-volume centers had no differences in readmission facilities/admission charges, emergency charges, anesthesia/surgery charges, imaging/testing charges, and physical medicine/rehabilitation charges, on both unadjusted and adjusted analysis.

Discussion

In this statewide retrospective review of TAAD operative repairs, high-volume centers treated the majority of TAADs and had a greater number of patients transferred from other centers. Although center volume was not found to be associated with differences in mortality or readmission outcomes, operative repair at a high-volume center was associated with increased index admission lengths of stay and charges. Of patients treated at high-volume centers, transfer patients had greater severity of illness and resource utilization, but similar mortality rates compared to direct admission patients. Patients who experienced post-operative complications during their index admissions had greater resource utilization.

Several previous studies have demonstrated improved inpatient mortality at high-volume centers compared to low-volume centers [7,8,10]. Of note, our study demonstrated no difference in inpatient mortality rates between high- and low-volume centers. This difference could be attributed to a number of reasons. First, our study included only patients from the last decade. In contrast, Dobaria *et al.* [8] reported on patients from 2005–2014 and Umana-Pizano *et al.* [10] reported on patients from 1999–2016. While mortality rates at high-volume centers in our study (13.0%) were comparable to previously reported high-volume center mortality rates (11%–14%) [8,10], the mortality rates at low-volume centers in our study (16.1%) were lower than previously reported (21%–24.0%) [8,10]. Additionally, our study found that over 70% of patients at high-volume centers were transferred from other centers. In contrast, only 46.1% of patients at high-volume centers in the study by Dobaria *et al.* [8] were transferred in. The similar outcomes between high- and low-volume centers observed in our study could therefore reflect either improvements in TAAD mortality rates at low-volume centers

Table 6. Outcomes and index admission costs of transfer *vs.* direct admit patients treated at high-volume centers.

Variable	Home (n = 46)	Transferred (n = 138)	Unadjusted *p*-value	Adjusted coefficient/OR (95% CI)	Adjusted *p*-value
Length of stay, median (IQR)	9 (6–16)	13 (7–24)	0.05	2.72 (–2.68, 8.13)	0.32
In-hospital mortality, n (%)	5 (10.9)	20 (14.5)	0.53	0.59 (0.18, 1.98)	0.39
In-hospital complications, n (%)					
Stroke	5 (10.9%)	18 (13.0%)	0.70	0.70 (0.20, 2.45)	0.58
Pneumonia	7 (15.2%)	16 (11.6%)	0.61	0.41 (0.13, 1.28)	0.13
Acute renal failure	16 (34.8%)	64 (46.4%)	0.17	1.11 (0.48, 2.57)	0.81
Myocardial infarction	2 (4.3%)	4 (2.9%)	0.64	0.28 (0.02, 3.42)	0.32
Hemorrhage	5 (10.9%)	13 (9.4%)	0.77	0.79 (0.23, 2.80)	0.72
Peripheral ischemia	4 (8.7%)	26 (18.8%)	0.11	2.43 (0.73, 8.04)	0.15
Index admission charge ($), median (IQR)					
Facility/Admission	18,396 (11,122–33,064)	26,660 (15,352–51,216)	0.02	5864 (–6677, 18,404)	0.36
Anesthesia/Surgery	62,857 (44,049–82,858)	65,804 (48,333–90,929)	0.39	–2990 (–17,867, 11,886)	0.69
Imaging/Testing	14,539 (10,058–23,367)	21,123 (12,075–37,093)	0.02	2069 (–9689, 13,828)	0.73
PMR	2853 (1758–6196)	5572 (2543–13,131)	0.005	2320 (–2621, 7260)	0.36
Total	108,671 (78,492–139,778)	119,147 (89,868–191,429)	0.09	6844 (–30,590, 44,278)	0.72

CI, confidence interval; IQR, interquartile range; PMR, physical medicine/rehabilitation; OR, odds ratio.

Table 7. Readmission visit hospital charges at low- and high-volume centers.

Charge type ($), median (IQR)	Low volume (n = 29)	High volume (n = 106)	Unadjusted *p*-value	Adjusted coefficient (95% CI)	Adjusted *p*-value
Facility/Admission	9810 (1897–25,660)	10,961 (3002–42,810)	0.58	–85.8 (–17,068, 16,896)	>0.99
Emergency	882 (399–1272)	931 (25–1983)	0.63	198 (–800, 1195)	0.70
Anesthesia/Surgery	10,873 (1468–29,086)	19,661 (1124–44,102)	0.64	3481 (–14,482, 21,444)	0.70
Imaging/Testing	7378 (1502–11,652)	5887 (1951–19,656)	0.57	3098 (–5373, 11,570)	0.47
PMR	4200 (1043–9023)	2993 (412–12,588)	0.76	–74.9 (–7548, 7398)	0.98
Total	42,204 (18,354–83,381)	48,367 (16,196–156,942)	0.46	7839 (–38,854, 54,532)	0.74

CI, confidence interval; IQR, interquartile range; PMR, physical medicine/rehabilitation.

in recent years or regional differences in patient transfer practices, with high-volume centers in our study receiving higher acuity transfer patients.

Among the surgery literature overall, there have been mixed findings with regard to center volume and cost. Prior studies have identified high-volume centers associated with greater costs for pediatric surgeries [20,21], though other studies have found very low-volume centers associated with higher case-mix-adjusted episode payments [22]. For type A aortic dissection interventions, our study found greater index admission charges at high-volume centers (p = 0.001), similar to Dobaria *et al*. [8], who previously reported increased total costs at high-volume centers. This is likely a reflection of a few factors. First, high-volume centers had greater overall length of stay, which directly contributes to resource utilization and hospital charges. Secondly, the majority (>70%) of patients treated at high-volume centers had been transferred from other institutions, and these patients were found to have greater disease severity and ultimately had longer lengths of stay. Therefore, some of the trends seen at high-volume centers are likely a reflection of the greater number of transfer patients. Our study further expands on these findings by breaking charges down by category. The difference in index admission charges between high- and low-volume centers were most attributable to charges related to anesthesia/surgery and facility/admission. Intringuingly, however, despite in-hospital complications being associated with greater costs and resource utilization as expected, we did not observe greater rates of in-hospital complications at high-volume centers compared to low-volume centers, suggesting that patients are not necessarily being kept longer due to complication rates. This suggests that one avenue for decreasing costs at high-volume centers would be through interventions aimed at decreasing lengths of stay.

Given the proportion of patients transferred from other institutions at high-volume centers, we performed a subgroup analysis of transfers *vs*. direct admissions to high-volume centers. Transfers were found to have greater severity of illness, for which there are two potential explanations: (1) transfer patients could represent a more severe group of patients who presented initially to low-volume centers and were then transferred to high-volume centers, which are equipped with additional resources and greater surgeon experience; or (2) patients who are transferred ultimately receive a delay in treatment and could be deteriorating in condition en route. On univariate analysis, transfers were also associated with greater lengths of stay, facility/admission charges, imaging/testing charges, and physical medicine/rehabilitation charges, and trended towards greater total charges. However, after adjusting for baseline characteristics, these differences were no longer significant, suggesting that the greater resource utilization by these patients could be attributable to differences in the patient populations. These results suggest that patients at high-volume centers who were transferred from other institutions were associated with increased resource utilization, likely due to the greater severity of illness at presentation. These results also suggest that the increased costs associated with high-volume centers could, in part, be attributed to the greater number of patients transferred from other centers. However, it remains to be known whether patients transferred to high-volume centers had greater severity of illness prior to transfer, or whether their clinical condition further deteriorated during the transfer due to delay in surgical intervention. Further studies should be conducted to understand whether the process of transferring patients confers additional risk and leads to greater resource utilization.

This was the first study to investigate readmission outcomes associated with TAAD operative repairs. We found no differences in the prevalence of readmissions or charges associated with readmissions between high- and low-volume centers. This suggests that despite receiving more transfer patients and having greater initial resource utilization, treatment at a high-volume center was not associated with increased risk of readmission. Once discharged, patients treated at high-volume centers no longer incurred greater resource utilization relative to patients treated at low-volume centers.

Lastly, this study was the first to show that operative complications were associated with significantly greater resource utilization. We demonstrated that patients who experienced pneumonia or acute renal failure during their index admission had almost double the length of stay as those who did not. Pneumonia and hemorrhage ere associated with significantly greater index admission charges, and acute renal failure was associated with greater length of stay. These results demonstrate that interventions aimed at decreasing post-operative complications could greatly reduce resource utilization associated with TAAD repairs.

This study has several limitations. First, given the retrospective nature of this study, the analysis was limited to the variables available in the database. Of note, while APR-DRG severity was included in the analysis, over half of the patients in our study population had a maximum severity score. No other variables were available to further stratify patients based on extent of dissection, surgical complexity, operative characteristics, or other more granular patient-level characteristics. Furthermore, longer-term outcomes, mortality, and quality of life assessments were not available in the dataset and could therefore not be assessed. Given that isolation of patients was performed on the basis of ICD codes, it is possible that misclassification has occurred. There is no unique classification code for intramural hematoma; therefore, our definition of TAAD may have captured intramural hematoma patients as well. Reassuringly, intramural hematoma represents a minority of acute aortic syndrome cases [23]. The study period of this analysis also included the transition from the 9th revision to the 10th revision of ICD in October of 2015. As such, two different sets of ICD codes were used to isolate patients. Codes were matched as closely as possible, and the steady prevalence of TAAD in our study population over time suggests that the codes corresponded well as a whole. Additionally, in this study, low and high volume centers performed an average of 1.2 and 12 TAAD operations per year, respectively. These results may not be generalized to other regions with a greater case volume difference between low and high volume centers. A national study could allow for greater generalizability. However, the statewide database used in this study offers a greater level of granularity into charge data by category and data on readmissions that are not available in larger datasets. Additional single-center studies could provide more granular insight into costs and readmissions associated with different subsets of patients within one hospital system but would not allow for comparisons between high- and low-volume centers. Future studies investigating other regions or other healthcare systems could be performed to enhance the generalizability of these findings. Lastly, there could be biases inherent to retrospective studies that were not accounted for in this analysis. Future prospective studies can be performed to gain additional insight into costs associated with TAAD repair.

Conclusions

Results from this retrospective statewide review demonstrate that TAAD operative repair at high- *vs.* low-volume centers was associated with no differences in mortality but had greater index admission resource utilization. High volume centers were found to treat a greater number of patients transferred from other centers. Transferred patients compared to direct admission patients at high-volume centers had greater severity of illness and increased resource utilization. Given Maryland's All-Payer Model promoting value-based care, further studies should be conducted to better understand the factors driving higher costs associated with high-volume centers and, in particular, patients transferred from other institutions and strategies for reducing costs in the surgical management of type A aortic dissection.

Abbreviations

TAAD, type A aortic dissection; HSCRC, Health Services Cost Review Commission; ICD, International Classification of Diseases; APR-DRG, All Patient Refined-Diagnosis Related Group.

Availability of Data and Materials

The data is publically available through the Maryland Health Services Cost Review Commission.

Author Contributions

ALZ: Conceptualization, Methodology, Software, Formal Analysis, Writing – Original Draft; LVY: Conceptualization, Methodology, Software, Formal Analysis, Writing – Original Draft; EWE: Conceptualization, Methodology, Data Curation, Writing – Original Draft; IB: Methodology, Investigation, Data Curation, Writing – Review & Editing; BLS: Methodology, Investigation, Writing – Review & Editing; HA: Conceptualization, Methodology, Writing – Review & Editing; CWC: Conceptualization, Methodology, Writing – Review & Editing; JSL: Conceptualization, Methodology, Writing – Review & Editing; AK: Conceptualization, Methodology, Writing – Review & Editing; Supervision. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study was approved by the Johns Hopkins Institutional Review Board (IRB00082345). No patients signed informed consent forms as the data is deidentified.

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Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.59958/hsf.6821.

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