Center-Level CABG and Valve Operative Outcomes and Volume-outcome Relationships in New York State

Running head: Center outcomes for different operations

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Abstract

Background: We analyzed center-level outcome correlations between valve surgery and coronary artery bypass graft (CABG) in New York (NY) State and how volume-outcome effect differ between case types.

Methods: We used the 2014-2016 NY cardiac surgery outcomes report. Center-level observedto-expected (O/E) ratio for operative mortality provided risk-adjusted operative outcomes for isolated CABG and valve operations. Correlation coefficient characterized the concordance in center-level outcomes in CABG and valve. Discordant outcomes were defined as having O/E ratio >2 in one operation type with O/E ratio ≤1 in another. Linearized slope of volume-outcome effect in case types offered insights into centers with discordant performances between procedures.

Results: Among 37 NY centers, annual center volumes were 220±120 cases for CABG and 190±178 cases for valve operations. Modest center-level correlation between CABG and valve O/E ratio was shown (R_2 = 0.31). Two centers had discordant performance between valve and CABG (O/E ≤1 for CABG while O/E > 2 for valve procedures). No centers had CABG O/E ratio > 2 while valve O/E ratio ≤1. Linearized slope describing volume-outcome effects showed stronger effect in valve operations compared to CABG: O/E ratio declined 0.1 units per 100 CABG volume increase, while O/E ratio declined 0.33 units per 100 valve volume increase.

Conclusions: In NY hospitals, favorable valve outcomes may indicate good CABG outcomes but good CABG outcomes may not ensure valve outcomes. Outcome variation in valve operation could be related to stronger volume-outcome effect in valve operations relative to CABG. Valve operations may benefit from regionalization.

Introduction

There are many procedure-specific risk models including the Society of Thoracic Surgeons Adult Cardiac Surgery (STS ACSD) risk models (1,2) that profile center and surgeon level performances in specific types of cardiac operations. However, our understanding is limited on whether centers that excel in one type of cardiac operation also excel in another. While this has been evaluated in a multicenter registry from a small number of centers (3), this potential concordance or discordance in performance within centers in cardiac surgery remains poorly understood. This has an important implication in policies to drive volume regionalization and informing the patients in understanding whether excellence in one type of operation serve as a marker for an overall good outcome across-different types of cardiac surgeries.

Center and surgeon volume can partially explain surgical outcomes (4-6), but how this relationship may differ between different case types have not been evaluated extensively in cardiac surgery. For example, while many studies demonstrated strong volume-outcome relationship in mitral valve repair (6), aortic valve replacement, and complex aortic operations (5.7), evidence conflicts on the volume-outcome relationship in CABG (8-11**)**. Volume-outcome relationship of different case types have not been directly compared in a large population-level data and may yield insight into effective strategies for volume regionalization, which has the potential to save thousands of lives.

Using a state-wide cardiac surgical outcomes report, we aimed to characterize the concordance between center-level risk-adjusted outcomes of CABG and valve operations and compare the strength of volume outcome relationship in CABG and valve operations. We

hypothesize that center-level outcomes between CABG and valve surgeries are related but valve operations likely have a higher volume threshold to achieve excellent outcomes compared with CABG.

Patients and Methods

Data source and study population

We used the publicly available center-level mortality and case volume data in New York State, reported by the New York State Cardiac Data Reporting System (12). The 2016 report consisted of center-level aggregate of patients who underwent isolated CABG or isolated valve between 2014 and 2016. Available data from the report included center name, center-level observed mortality rate (OMR), case volume and expected mortality rate. The expected mortality rates (EMR) were calculated from a multivariable risk model developed by the New York State Department of Public Health, accounting for patient-specific risk factors (12). The report includes isolated CABG cases and combined CABG and valve cases. Therefore, center-level data on isolated or concomitant valve case category was obtained by subtracting center isolated CABG data from the combined cases data. Outcomes specific to each valve operation type (aortic, mitral or tricuspid valve) were not available. Therefore, all valve operations were aggregated to comprise the valve operation data. The 2016 report included 38 cardiac surgery centers in the state of New York. One center was excluded from study because the center did not report CABG data in one of the years, resulting in 37 centers being included for our analysis. Yale Institutional Review Board reviewed and provided waiver for this study (IRB 2000023012)

Outcomes and Definitions

We evaluated OMR, EMR, and observed-to-expected mortality ratio (O-E ratio). O-E ratio is a commonly used metric to characterize center or surgeon-specific risk adjusted

outcomes, with 1 indicating the expected outcome, above 1 indicating worse outcome, and below 1 indicating better outcome given the patient risk. The NY state report defined mortality as allcause deaths that occurred during the hospitalization in which the patient underwent cardiac surgery, as well as deaths after hospital discharge but within 30 days of surgery.

Statistical Analysis

Center-level O-E ratios for operative mortality were used as a metric for risk-adjusted center performance. Concordance or discordance between center-level performance in CABG and valve operations was evaluated by Pearson correlation coefficient ranging from -1 to 1, with 0 denoting no correlation and 1 denoting perfect positive correlation between CABG and valve outcomes. Performance metrics did not violate normality assumptions based on examination of q-q plot. An O-E ratio of 1 is expected relative to state wide mortality, and a ratio of 2 is twice as much mortality given patient risk. Centers with an O-E ratio ≥2 in one operation type and an OE ratio <1 in another were reported as centers with discrepant outcomes. These thresholds were chosen based on intuitive interpretation that each point has: O-E ratio of 1 is performance as expected given the patient risk and 2 is double the mortality given the patient risk. In order to gain insights into the potential mechanism of discordance in center-level CABG and valve outcomes, volume-outcome relationships were evaluated via scatter plot of center annual volume and O-E ratio, with logarithmic regression lines fitted over the plots. Linearized slope of center volume and corresponding center outcome in each case type was calculated to compare the strengths of volume-outcome relationship in valve and CABG operations. Distributions of volume and outcome measures were expressed by mean and standard deviations. Statistical analysis was conducted using SAS 9.4 (SAS Institute, Cary NC).

Results

Among 37 centers used for this study that perform cardiac surgery across the state of NY in 2014 - 2016, there were 24,459 CABG cases and 21,098 valve operations, were analyzed. Given the New York State Cardiac Surgery report provided case volumes aggregated over a three-year period, yearly averages were calculated in order to find an average annual case volume. Annual center case volumes were 220±120 cases for CABG and 190±178 cases for valve operations. Mean observed state mortality for CABG and valve procedures was 3.30±0.72% and 1.54±0.52%, respectively. Center-level outcome and volume data are summarized in Table 1.

Variability of O-E ratio across centers, as seen in the standard deviation across centers, was larger for valve operations compared with that of CABG with the mean O-E ratio for CABG of 1.0±0.5 compared with the mean O-E ratio for valve operation of 1.3±0.7.

Comparisons between center-level O-E ratios for CABG and valve operations revealed modest correlation with Pearson Correlation coefficient of 0.31 as shown in (Figure 1). Two centers had significantly discrepant performances between valve and CABG operations as both centers had O-E ratios <1 for CABG operations but O-E ratios > 2 for valve operations. No centers with excellent valve outcomes had poor CABG outcomes: there were no centers with OE <1 for valve operation and O-E > 2 for CABG operations (Figure 1).

Comparing the linearized relationship between center volume and outcome for CABG and valve operations, valve operations exhibited stronger volume-outcome relationship compared with CABG operations. For CABG operations O-E ratio declined 0.095 units per 100

CABG volume increase, and O-E ratio declined by 0.332 units per 100 valve volume increase (Figure 2).

Discussion

Using rigorously audited state outcomes data, we demonstrated that in the entire state of New York, centers that performed well in CABG also tended to perform well in valve operations, although the correlation was modest. There were no centers with a combination of poor CABG outcomes (O-E $\geq$2) and excellent valve outcomes (O-E<1), while we found 2 centers that performed well in CABG with poor valve outcomes, which suggested that centers with favorable valve outcomes tended to perform well in CABG as well but the reverse may not be a reliable claim. The degree of volume-outcome relationship was stronger in valve operation than in CABG, corroborating the observation that valve operation may have a higher threshold of volume to achieve excellent results. Although regionalization is companied with many challenges, based on the stronger volume-outcome relationship in valve operations, our study supports the potential benefit of volume regionalization or forming associations between low and high performing centers for valve operation, while suggesting that the benefit of such effort may be low for CABG.

This study is important for several reasons. First, the concordance or discordance of outcomes between different cardiac operations at center-level has only been evaluated only in a small multicenter registry(3) and this relationship had not been reproduced in a larger scale. We used the state-wide dataset, which allowed us to examine the entire spectrum of volume and outcome variations that existed in the entire state of New York. Because the state-wide outcome reporting is mandatory our results do not suffer from the potential selection bias that exist in

registries created from voluntary participations. Second, to our knowledge, volume-outcome relationship between different types of cardiac operations have not been evaluated simultaneously. Although prior studies have suggested that volume-outcome relationship in CABG was weaker than other operations (8-11), this claim had been unvalidated in the absence of studies using the same dataset and methodology for risk adjustment to compare this in different operations simultaneously. Together, our study highlighted that excellent outcomes in CABG does not ensure excellent outcomes in valve operations at the same center, and that consumers of public reports should be aware of this potential discrepancy in choosing centers to undergo cardiac operations. From policy perspective, the potential impact of volume regionalization for CABG may be minimal compared to that of valve operations.

Previous study conducted by Johnston and colleagues also investigated whether correlation existed between center specific mortality rates after CABG and valve operations within 18 institutions in Virginia between 2008 and 2015 (3). They found with respect to morbidity O-E ratios, strong relationship exists between morbidities observed in institution CABG and valve operations. With respect to mortality, they found correlation coefficients for both CABG and valve cases to be weak (0.22 for aortic valve replacement and CABG, and 0.26 for mitral valve replacement and CABG). Authors concluded that sites that perform CABG with low mortality rates may not have concordantly low valve mortality rates. While their study appropriately used procedure specific risk adjustment, an improvement upon previous studies that failed to use procedure specific models (13-15), only 18 centers across the state of Virginia were analyzed. Including only centers that volunteered to participate in the registry may have compromised the representativeness with regards to the volume, care process, and outcomes

spectrum. This may explain their finding of weak correlation exists between CABG and valve mortality; a finding contradicted by our study.

Additionally, our finding of a weak volume outcome relationship in CABG outcomes is supported by multiple previous studies (8-11). For example, Shahian and colleagues investigated associations between hospital CABG procedural volume with mortality, morbidity and evidencebased care processes. Their study population consisted of 144,526 patients from 733 hospitals included in the STS ACSD. They reported that the CABG volume-mortality association was weak compared to the volume-outcome relationship reported in studies evaluating other complex cardiac procedures.

Strengths and Limitations

Improving upon previous studies, our study included 37 of all 38 institutions that perform cardiac surgery in the state of New York using a standardized method of risk adjustment. Following limitations remain. First, the dataset used in this study is based on 30-day mortality and not long-term outcomes which would likely provide better profiling of surgeon and centerlevel performances (16). Second, the data used for analysis are based on outcomes from a threeyear annual average, which limited the ability of estimate changes in outcomes over years. Third, outcome data for valve operations were reported as a combination of mitral, aortic, and tricuspid valve operations and outcomes specific to each type of valve operation could not be obtained for the publicly available report. This is a limitation when considering specific centers' performance with respect to particular valve operations. Lastly, New York is one of the most densely populated states in the U.S., and while our data may reflect centers operating at similar volume range, generalizing this data to the states where case densities deviate largely from New York data likely requires caution.

Conclusions

Our results suggest that excellent center-level outcomes in valve operation may indicate favorable CABG outcomes in the same center, while excellent CABG outcomes did not ensure excellent valve outcomes. Valve outcomes may be more susceptible to volume-outcome effect, requiring higher volume threshold to ensure excellent outcomes compared with CABG. These results may inform regionalization of cardiac procedures in the most effective manner.

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Table 1: Average annual center-level volume and outcomes measures in 2016 New York State Cardiac Data Reporting System

Center	CABG Volume	Valve Volume	Annual CABG RAMR (%)	Annual Valve RAMR (%)	CABG O/E	Valve O/E
1	245	203	4.73	1.57	1.02	1.43
2	71	19	7.39	2.06	1.34	2.24
3	123	93	7.44	2.82	1.83	0.49
4	189	68	7.44	0.95	0.62	2.25
5	446	248	3.11	1.68	1.09	0.94
6	197	91	4.36	1.44	0.94	1.32
7	102	41	7.66	1.95	1.27	2.32
8	269	147	2.89	1.48	0.96	0.88
9	100	83	1.25	0.55	0.36	0.38
10	89	46	5.67	2	1.3	1.72

11	234	154	3.17	1.73	1.12	0.96
12	356	165	7.67	2.13	1.38	2.32
13	188	136	6.1	0.75	0.49	1.85
14	199	105	3.24	2.66	1.73	0.98
15	361	757	1.9	1.5	0.97	0.57
16	111	36	4.78	1.03	0.67	1.45
17	116	66	1.31	0.49	0.32	0.4
18	416	646	2.08	0.98	0.64	0.63
19	190	385	2.48	0.88	0.57	0.75
20	199	452	3.2	1.8	1.17	0.97
21	416	361	2.65	0.86	0.56	0.8
22	374	357	3.3	1.52	0.99	1
23	192	92	7.37	2.48	1.61	2.23
24	498	419	3.13	1.53	0.99	0.95
25	408	442	2.06	1.52	0.99	0.62
26	122	91	2.53	1.33	0.86	0.76
27	351	311	3.82	1.24	0.81	1.16
28	181	48	5.92	1.88	1.22	1.79
29	219	224	5.69	1.67	1.08	1.72
30	133	67	10.18	2.69	1.75	3.08
31	41	23	7.16	4.59	2.98	2.17
32	252	169	3.72	0.9	0.58	1.13
33	30	20	8.16	1.29	0.84	2.47
34	166	153	0.5	0.75	0.49	0.15
35	179	93	4.47	2.28	1.48	1.35
36	203	147	2.51	1.03	0.67	0.76
37	187	84	2.59	1.56	1.01	0.79

CABG = coronary artery bypass grafting; O/E = observed-to-expected ratio; RAMR = risk-adjusted mortality rate

Figure 1: Center observed-to-expected ratios for CABG and valve operations

Scatter plot representative of correlation between coronary artery bypass graft (CABG) and valve operation observed-to-expected (O-E) ratios with correlation coefficient of R_2 =0.31. The area of each data point is proportional to the center volume. Solid line indicates the regression line.

Figure 2: Volume-outcome relationship in valve and CABG

The figure shows different degree of volume-outcome relationship between CABG and valve operations, with valve operations having a higher slope compared with CABG.