Original research

Evaluation of hospital readmission rates as a quality metric in adult cardiac surgery

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ABSTRACT

Objective To assess the reliability of 30-day non-elective readmissions as a quality metric for adult cardiac surgery.

Background Unplanned readmissions is a quality metric for adult cardiac surgery. However, its reliability in benchmarking hospitals remains under-explored.

Methods Adults undergoing elective isolated coronary artery bypass grafting (CABG), surgical aortic valve replacement/repair (SAVR) or mitral valve replacement/repair (MVR) were tabulated from 2019 Nationwide Readmissions Database. Multi-level regressions were developed to model the likelihood of 30-day unplanned readmissions and major adverse events (MAE). Random intercepts were estimated, and associations between hospital-specific risk-adjusted rates of readmissions and were assessed using the Pearson correlation coefficient (r).

Results Of an estimated 86 024 patients meeting study criteria across 298 hospitals, 62.6% underwent CABG, 22.5% SAVR and 14.9% MVR. Unadjusted readmission rates following CABG, SAVR and MVR were 8.4%, 9.3% and 11.8%, respectively. Unadjusted MAE rates following CABG, SAVR and MVR were 35.1%, 32.3% and 37.0%, respectively. Following adjustment, interhospital differences accounted for 4.1% of explained variance in readmissions for CABG, 7.6% for SAVR and 10.0% for MVR. There was no association between readmission rates for CABG and SAVR (r=0.10, p=0.09) or SAVR and MVR (r=0.09, p=0.1). A weak association was noted between readmission rates for CABG and MVR (r=0.20, p<0.001). There was no significant association between readmission and MAE for CABG (r=0.06, p=0.2), SAVR (r=0.04, p=0.4) and MVR (r=−0.03, p=0.6).

Conclusion Our findings suggest that readmissions following adult cardiac surgery may not be an ideal quality measure as hospital factors do not appear to influence this outcome.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ With the launch of Hospital Readmissions Reduction Program (HRRP), Centers for Medicaid and Medicare Services has considered postoperative readmission rates as a hospital quality metric and subsequently enacted financial penalties to low-quality centres. However, a growing body of literature has questioned the reliability of readmission rates in benchmarking hospitals.

WHAT THIS STUDY ADDS

⇒ We found negligible inter-hospital variation in readmission rates and non-significant association between hospital-specific readmission rates within cardiac service line or with major adverse events.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our findings suggest that readmissions following adult cardiac surgery may not be an ideal quality measure as hospital factors do not appear to influence this outcome. A critical appraisal of Hospital Readmissions Reduction Programme (HRRP)-related penalisation of hospitals based on readmissions following adult cardiac surgery is warranted.

INTRODUCTION

Aligned with efforts to curb the rising costs of healthcare in the USA, the Centers for Medicaid and Medicare Services (CMS) has implemented several measures to penalise low-quality hospitals.[1 2] Metrics such as postoperative mortality and complications have traditionally been used to gauge hospital quality across the nation, as prolonged hospitalisations and intensive therapies have been identified to be major drivers of perioperative expenditures.[1 3] More recently, postoperative readmissions have garnered increasing attention as a performance measure.[4 5] This shift in focus is, in part, based on the premise that high-value systems are better equipped to coordinate post-discharge care and mitigate the development of complications following discharge.[5–8]

However, the reliability of readmission rates as a marker of quality following major inpatient surgery has been questioned.[9–14] While prediction models for mortality and complications have demonstrated excellent discrimination and calibration in the surgical setting, readmissions appear to be more sporadic and are not readily explained by current risk adjustment methods.[9 13] Moreover, a study by Shih and Dimick[13] in national Medicare beneficiaries undergoing coronary artery bypass highlighted a low signal-to-noise ratio for readmissions, rendering hospital-level analyses of readmission

rates as a measure of hospital quality in cardiac surgery unreliable. Since the CMS Hospital Readmissions Reduction Program (HRRP) is thought to be systemic and translate across service lines at each hospital, unreliable measurement of readmissions performance can misclassify hospitals. This notion is especially relevant in the setting of cardiac surgery, where quality metrics, including readmissions, are reported to the Society of Thoracic Surgeons (STS) and publicly available in several states.[3]

In the present study, we examined interhospital variation in rates of non-elective 30-day readmissions following three major cardiac operations and evaluated whether such rates are correlated with inpatient mortality or perioperative complications. We hypothesised a poor correlation between readmissions across various operative categories and no association between risk-adjusted rates of readmission and adverse clinical events.

DATA AND METHODS

Data source and timeframe

This was a retrospective cohort study using the 2019 Nationwide Readmissions Database (NRD).[15] As the largest all-payer readmissions database, the NRD contains discharge data from 28 geographically diverse states and provides estimates for approximately 59% of hospitalisations in the USA using a validated survey weighting methodology.[15] The NRD uses unique patient and hospital identifiers to track admissions across participating centres within each calendar year.

Study population

All elective adult (≥18 years) hospitalisations for isolated coronary artery bypass grafting (CABG), surgical aortic valve replacement/repair (SAVR) or mitral valve replacement/repair (MVR) were identified using *International Classification of Diseases, 10th Revision* (ICD-10) procedures codes (online supplemental table S1). Patients not surviving to index discharge, undergoing transcatheter valve procedures or carotid revascularisation, and those with endocarditis, were excluded from further analysis. To enhance the reliability of hospital-level analyses, only centres performing >10 CABG, 10 SAVR and 10 MVR in 2019, were included. Discharges in the month of December were excluded to ensure sufficient follow-up (30 days). Furthermore, records with missing data for in-hospital mortality, age and costs were excluded (n=70, <0.1%).

Variable definitions and outcomes

Baseline patient and hospital characteristics were defined in accordance with the NRD data dictionary.[15] The burden of chronic conditions was captured using the Van Walraven modification of the Elixhauser Comorbidity Index, a validated composite of 30 comorbidities.[16] Additional comorbidities were tabulated using ICD-10 codes (online supplemental table S1). Major adverse events (MAEs) were defined as a composite of several in-hospital events, including mortality and cardiac, respiratory, infectious, gastrointestinal, neurological, renal and thromboembolic complications (online supplemental table S1). These conditions were selected due to their inclusion in CMS and STS performance measures and are used as an established control in our analyses. Overall hospital volume was calculated as the total number of isolated, elective CABG, SAVR and MVR performed at each hospital. Hospitals were further categorised into low-volume, medium-volume and high-volume tertiles based on the 33rd and 66th percentiles of overall cardiac surgical volume in 2019. Hospitalisation costs were calculated through application of hospital-specific cost-to-charge ratios to overall charges and adjusted for inflation using 2019 Personal Health Index.[15]

Statistical analysis

Individual multi-level, mixed-effects logistic regressions were developed to model the likelihood of non-elective 30-day readmissions following CABG, SAVR and MVR. In addition, three multi-level models were fit to predict MAE within each operative category. Patient factors, including age, sex, income quartile, insurance status and comorbidities, were treated as fixed effects and selected for inclusion in the model using elastic net regularisation.[15] Unique hospital identifiers were incorporated into the second level as random effects. Patients who did not survive to discharge were only included within models predicting MAE. We calculated the interclass correlation (ICC) for each model to quantify the variation attributable to center-level differences. Random intercepts from each multi-level model were estimated using Bayesian methodology and considered to be the center-level risk-adjusted rates of MAE and 30-day readmissions.[17] We utilised Bayesian hierarchical models to account for increased variability in MAE and readmissions at centres with smaller sample size and shrink estimates towards the population average. Additionally, we correlated center-specific risk-adjusted rates of readmission and MAE across operative categories using Pearson correlation coefficient.

Categorical variables are reported as percentages and compared using the Pearson χ^2 test. Normally distributed variables are reported as means with SD, while those with skewed distribution are presented as medians with IQR. The Mann-Whitney U and adjusted Wald test were employed to compare medians and means, respectively. Statistical significance was set at $\alpha=0.05$. All regression outputs are presented as adjusted ORs with 95% CIs. Stata V.16.1 was used to perform all statistical analysis (StataCorp).

RESULTS

Cohort characteristics and unadjusted outcomes

Of an estimated 86 024 patients who met study criteria across 298 hospitals, 62.6% underwent isolated CABG, 22.5% SAVR and 14.9% MVR. Patient characteristics stratified by operations are shown in table 1. The majority of patients in all three cohorts were male and insured by Medicare; 8.4% of patients who underwent CABG, 9.3% SAVR and 11.8% MVR were readmitted within 30 days of discharge and 35.1% of those who underwent CABG, 32.3% SAVR and 37.0% MVR experienced an MAE during the index hospitalisation. The median observed hospital-level rates of 30-day readmissions following CABG, SAVR and MVR were 8.3% (IQR: 5.9%–11.1%), 9.1% (IQR: 5.0%–13.2%) and 9.6% (IQR: 4.5%–15.4%), respectively. Furthermore, median center-level rates of MAE following CABG, SAVR and MVR were 35.3% (IQR: 27.0%–43.8%), 30.0% (IQR: 22.2%–42.3%) and 37.5% (IQR: 27.0%–50.0%), respectively. A comparison of patient and operative characteristics stratified by 30-day readmission and MAE is shown in online supplemental tables S2 and S3.

Hospital variation in risk-adjusted rates of 30-day readmission and MAE

The results for mixed-effect models for readmissions following CABG, SAVR and MVR are summarised in online supplemental table S4. The median hospital-specific, risk-adjusted readmission rates for CABG, SAVR and MVR were 4.2% (IQR: 3.6%–5.0%), 4.1% (IQR: 3.3%–4.9%) and 5.4% (IQR: 4.4%–7.3%),

Table 1 Patient-level demographics, hospital and operative characteristics of patients undergoing CABG, SAVR and MVR

Parameter	CABG (n=53 893)	SAVR (n=19 350)	MVR (n=12 781)	P value
Age (years, mean±SD)	66.5±9.3	63.2±12.1	62.9±12.7	<0.001
Female (%)	21.1	32.7	45.4	<0.001
Income quartile (%, percentile)				<0.001
76–100th	21.2	26.3	29.2	
51–75th	27.1	28.1	27.5	
26–50th	26.7	26.2	23.2	
0–25th	25.0	19.4	20.1	
Insurance type (%)				<0.001
Private	33.0	40.8	41.8	
Medicare	58.0	50.0	48.6	
Medicaid	5.0	5.4	6.2	
Other payer	4.0	3.8	3.4	
Elixhauser comorbidity index (mean±SD)	4.1±1.9	5.0±1.9	4.9±2.0	<0.001
Comorbidities (%)				
Congestive heart failure	27.0	34.0	46.3	<0.001
Arrhythmia	42.5	51.9	66.0	<0.001
Peripheral vascular disorder	12.0	33.8	6.9	<0.001
Chronic lung disease	17.8	16.0	15.7	<0.001
Hypothyroidism	10.0	11.2	11.0	0.01
Late-stage chronic kidney disease	2.8	1.0	1.4	<0.001
Liver disease	2.4	2.0	2.3	0.15
Coagulopathy	18.4	30.5	30.5	<0.001
Anaemia	2.8	2.8	2.7	0.9
Hospital characteristics (%)				
Hospital bed size				0.04
Small	6.4	4.5	4.4	
Medium	20.5	21.4	21.6	
Large	73.1	74.1	74.0	
Location/teaching status				0.1
Non-metropolitan	1.4	0.9	0.9	
Metropolitan non-teaching	9.4	7.6	7.9	
Metropolitan Teaching	89.2	91.5	91.1	
Cardiac operative volume tertiles				<0.001
Lowest	17.4	18.2	18.1	
Middle	42.5	37.9	34.1	
Highest	40.1	43.9	47.8	

CABG, coronary artery bypass grafting; MVR, mitral valve replacement/repair; SAVR, surgical aortic valve replacement/repair.

respectively. Of note, interhospital differences measured by ICC accounted for 3.8% of explained variance in unplanned readmissions for CABG, 7.6% for SAVR and 10.0% for MVR (figure 1).

A complete list of covariates and associated OR values derived from multivariable models of MAE is reported in online supplemental table S5. The median hospital-specific, risk-adjusted rates of MAE for CABG, SAVR and MVR were 10.2% (IQR: 7.5%–12.6%), 6.0% (IQR: 4.2%–8.7%) and 11.1% (IQR: 8.2%–14.6%), respectively. Modest variation in MAE was noted by ICC analysis, with center-level differences accounting for 6.0% of variance in MAE rates for CABG, 12.8% for SAVR and 10.2% for MVR (figure 1).

Correlation between risk-adjusted rates of 30-day readmission and MAE

The Pearson correlation coefficient between hospital-specific rates of readmission for CABG and SAVR was 0.10 (p=0.09), indicating no significant correlation (figure 2A). Similarly, hospital-specific readmission rates for SAVR and MVR exhibited no significant association (r=0.09, p=0.10, figure 2B). However, there was a statistically significant, although weak, correlation between readmission rates for CABG and MVR (r=0.20, p<0.001, figure 2C). In contrast, we noted statistically significant and moderate correlations between hospital-specific adjusted rates of MAE for CABG and SAVR (r=0.45, p<0.001, figure 2D), SAVR and MVR (r=0.41, p<0.001, figure 2E), and CABG and MVR (r=0.49, p<0.001, figure 2F).

The relationship between hospital-specific adjusted rates of readmission and MAE was also assessed within each operative category. Hospital-specific adjusted rates of readmission and MAE for CABG exhibited no significant association (r=0.06, p=0.26, figure 3A). A similar negative finding was noted in the case of SAVR (r=0.04, p=0.43, figure 3B) and MVR (r=−0.03, p=0.65, figure 3C).

DISCUSSION

In this nationally representative cohort study of adults undergoing isolated CABG, SAVR or MVR, we found negligible interhospital variation in risk-adjusted rates of 30-day readmissions. On the contrary, significant center-level variation for MAE across all operative categories was present. Of note, hospital-specific readmission rates across the three surgical procedures exhibited minimal association with MAE. Our findings suggest that unplanned readmission following adult cardiac surgery may not be an ideal hospital quality measure as systemic factors do not appear to influence readmissions.

When assessing the utility of a benchmarking quality measure, it is necessary to first define the attributes of a reliable hospital quality metric. The ideal measure would be impervious to variations in case mix and disease severity across institutions, and yet be able to detect the collective impact of hospital protocols, policies and procedures that influence patient outcomes.[1 8] Thus, a candidate metric to assess the quality of surgical care should ideally exhibit interhospital variation among the predominant case mix of operations performed and correlate with other clinical endpoints. While an analysis of all perioperative outcomes should be undertaken to ensure optimal surgical care, measures that fall short of these fundamental qualities may be ineffective targets for quality improvement.[12]

The present study found minimal variation in risk-adjusted 30-day readmissions attributable to center-level differences across CABG, SAVR and MVR. This finding is consistent with prior work across different surgical service lines reporting that patient factors almost entirely account for the observed variation in readmissions, while hospital factors play a minor role.[10 18 19] Although measurement of readmission performance is generally thought to indicate a hospital's capacity to limit complications and coordinate post-discharge care, these rehospitalisations may, in fact, be influenced by non-modifiable patient factors.[9–11 20] Among patient factors, a growing body of work has demonstrated social determinants of health (SDoH), such as poor access to care and lower socioeconomic status, to increase the likelihood of early readmission.[9–11 20] In a national cohort of community-dwelling Medicare beneficiaries, Arbaje and colleagues[20] noted that patients who lived alone, lacked self-management abilities or those with lower levels of education

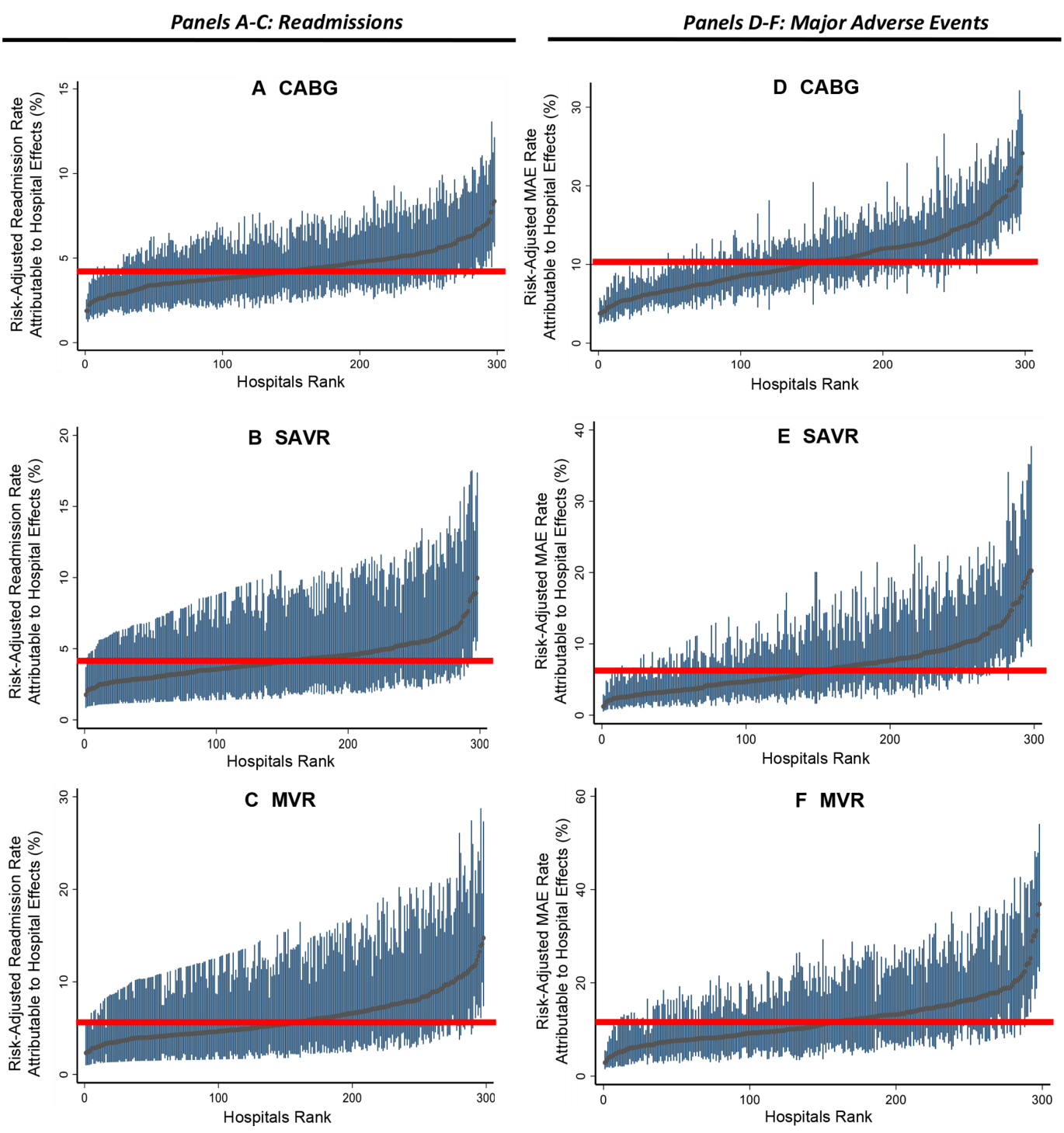

Figure 1 Interhospital variation in risk-adjusted rates of unplanned 30-day readmission (panel A: CABG; panel B: SAVR; panel C: MVR) and MAEs (panel D: CABG; panel E: SAVR; panel F: MVR). Author's analysis of 2019 Nationwide Readmission Database. Using multi-level modelling and Bayesian estimation of random intercepts, we found negligible interhospital variation in risk-adjusted readmissions rates (panels A–C) while a significant center-level variation was noted in risk-adjusted MAE rates (panels D–F). Hospitals are ranked by hospital-attributable readmission or MAE rates. Error bars represent 95% CIs. Red line indicates group median. CABG, coronary artery bypass grafting; MAE, major adverse events (mortality or cardiac, respiratory, infectious, gastrointestinal, neurological, renal or thromboembolic complications); MVR, mitral valve replacement /repair; SAVR, surgical aortic valve replacement/repair.

had higher risk-adjusted readmission rates. The contribution of SDoH is further supported by studies reporting racial disparities in postoperative readmissions.[10 21 22] Our findings reinforce rising concerns for penalising hospitals while a growing body of literature suggests that patient factors and adverse SDoH predominately influence postoperative readmissions.

The goal of measurement and benchmarking hospital outcome characteristics is to ultimately effect change and improve the quality of care for the entire service line. If readmission rates truly reflect the innate ability of a facility to deliver optimal care, they should ideally correlate across surgical procedures within a hospital or at least within individual care teams. However, we

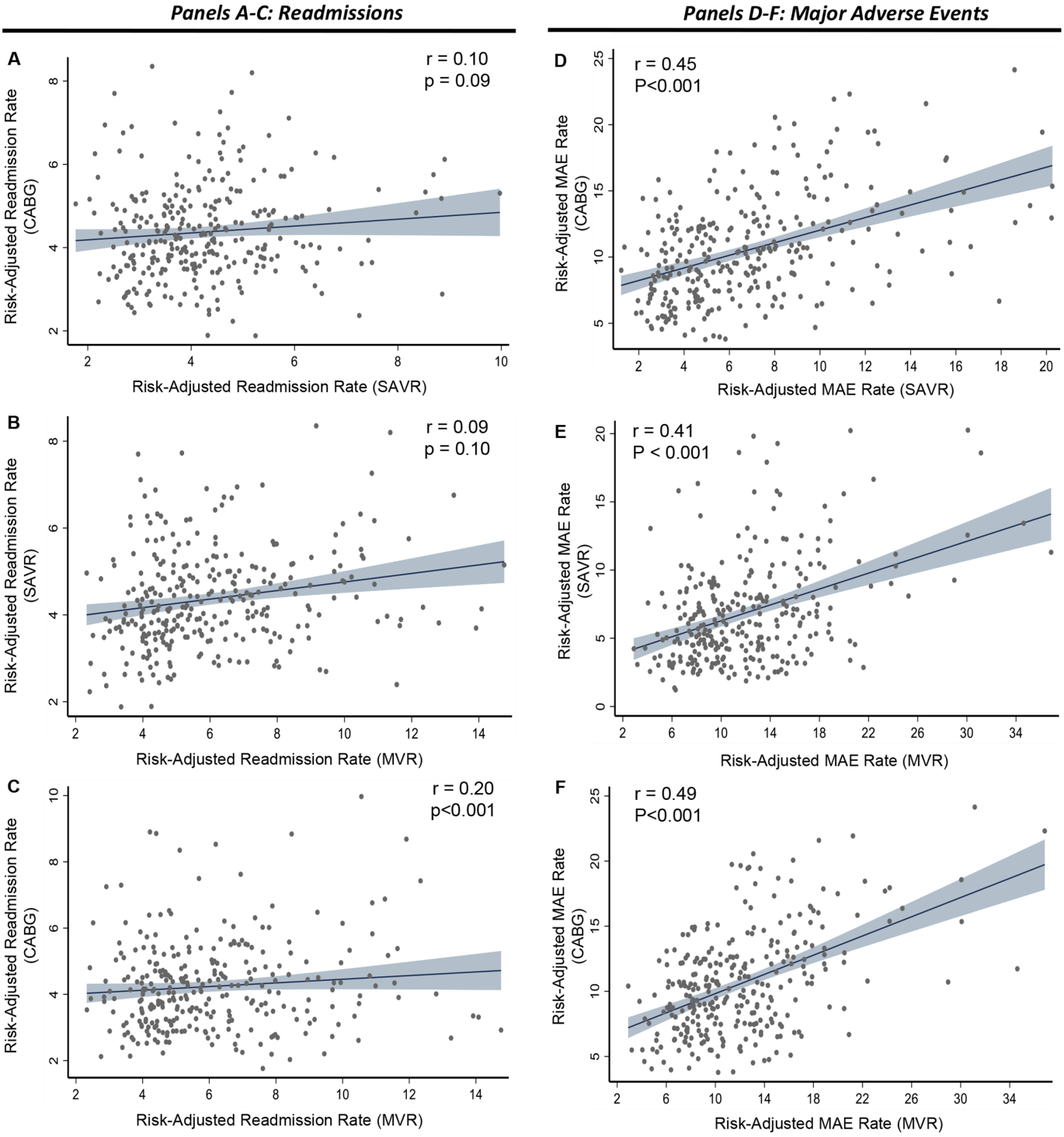

Figure 2 Scatterplots of the relationship between center-level risk-adjusted rates of readmission across operative categories (panels A–C) and center-level risk-adjusted rates of MAEs across operative categories (panels D–F). Author's analysis of 2019 Nationwide Readmission Database. Hospital-specific readmission rates for CABG and SAVR (panel A) as well as SAVR and MVR (panel B) exhibited no significant association. There was a weak but statistically significant correlation between hospital-specific readmission rates for CABG and MVR (panel C). A statistically significant, moderate correlation between hospital-specific MAE rates for CABG and SAVR (panel D), SAVR and MVR (panel E), and CABG and MVR (panel E) were noted. r indicates Pearson correlation coefficient. CABG, coronary artery bypass grafting; MAE, major adverse events (mortality or cardiac, respiratory, infectious, gastrointestinal, neurological, renal or thromboembolic complications); MVR, mitral valve replacement /repair; SAVR, surgical aortic valve replacement/repair.

found weak correlations between risk-adjusted 30-day readmissions across CABG, SAVR and MVR. To ensure the validity of our analysis, we used MAE as an established control and noted statistically significant and moderate correlations between hospital-specific adjusted rates of MAE across the three procedures. The utility of readmissions as a quality endpoint has similarly been questioned by Cram *et al*[14] who recommended targeting patient safety and quality practices rather than rehospitalisation

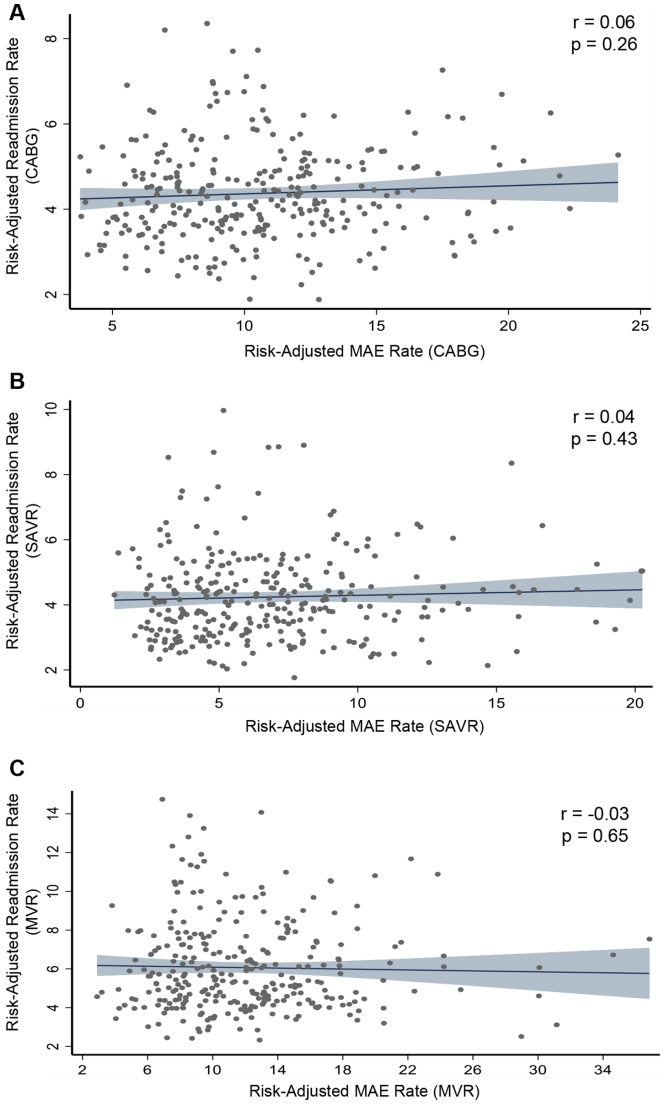

Figure 3 Scatterplots of the relationship between center-level risk-adjusted rates of readmission and MAEs (panel A: CABG, panel B: SAVR, panel C: MVR). Author's analysis of 2019 Nationwide Readmission Database. Hospital-specific adjusted rates of readmission and MAE for CABG (A), SAVR (B) and MVR (C) exhibited no significant association. r indicates Pearson correlation coefficient. CABG, coronary artery bypass grafting; MAE, major adverse events (mortality or cardiac, respiratory, infectious, gastrointestinal, neurological, renal or thromboembolic complications); MVR, mitral valve replacement/repair; SAVR, surgical aortic valve replacement/repair.

rates. Indeed, if financial penalties associated with HRRP were to be reduced or eliminated, hospitals may be better suited to direct their quality improvement resources towards evidence-based practices. Moreover, studies assessing quality metrics in other surgical populations have reported that poor reliability of outcome measures may substantially increase the risk of misclassifying hospitals, impacting hospital finances and public perception.[23 24] Importantly, the use of unreliable quality metrics may result in disproportional penalisation of large academic institutions and safety net hospitals serving vulnerable populations.[19 25]

The emphasis on 30-day readmission as a hospital quality metric may shift the narrative away from the goal of providing patient-centred care. In an era of comprehensive preoperative planning, meticulous perioperative management and use of standardised recovery pathways, postoperative length of stay continues to shorten across the spectrum of major inpatient operations.[26–28] As such, readmission may be necessary for managing delayed surgical complications that arise later in the post-discharge period.[12 29] In a prospective study of patients undergoing pancreatic resection, Kent and colleagues[29] concluded that rehospitalisation was significantly associated with procedure-specific complications. Prior to using readmission as a quality measure, there may need to be a greater focus on understanding the postoperative course and procedure-specific outcomes.[29] Indeed, the increased risk of readmissions following certain procedures may be inherent to the surgical or patient factors and not so much a reflection of poor provision of care.[12] Given our finding of institutional variation in MAE rates, the incidence of these events may serve as a superior quality metric compared with readmission rates alone.

Limitations

The present study has several important limitations inherent to its retrospective design and the administrative structure of NRD. Although the NRD is the largest all-payer readmission database, it is subject to variation in billing practices due to its coding nature. Furthermore, the readmission rates reported in the present study may be underestimated as rehospitalisation across states is not tracked in the NRD. Granular clinical parameters, such as STS-predicted risk of mortality score and left ventricular ejection fraction, are not captured in the NRD and thus could not be accounted for in risk adjustments. Moreover, surgeon experience and granular hospital characteristics, such as the use of streamlined postoperative pathways, were not available for analysis. Notably, as outpatient mortality data are unavailable in the NRD, we were unable to account for the competing risk between mortality and readmission. Nonetheless, the present study captured a nationally representative sample and adhered to robust statistical methodology to minimise the impact of these limitations.

CONCLUSION

The present study found negligible interhospital variation in risk-adjusted readmission rates following three major isolated cardiac operations. Hospital-specific risk-adjusted readmission rates across the three surgical procedures exhibited no to minimal association across operations and MAE. Our findings suggest that readmissions following adult cardiac surgery may not be an ideal quality measure as hospital factors do not appear to influence this outcome. A critical appraisal of HRRP-related penalisation of hospitals based on readmissions following adult cardiac surgery is warranted.

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Contributors SE, SSB and PB designed the study. SE, SB, AV, CW, SS and YS analysed and interpreted data. SE, SB, NLC, KA and PB wrote the manuscript and all authors revised it. PB serves as the overall guarantor responsible for overall content.

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Competing interests PB received proctor fees from AtriCure as a surgical proctor. This manuscript does not discuss any AtriCure products or services. Other authors report no conflicts or disclosures. The authors have no funding sources to declare.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval The present study was deemed exempt from full review by the Institutional Review Board (IRB) at the University of California, Los Angeles (IRB# 17-0 01 112).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. The data that support the findings of this study are publicly available from Healthcare Cost and Utilization Project (HCUP) upon completion of Data Use Agreement for researchers who meet the criteria for access to confidential data. Data cannot be provided directly by the authors due to specific approval required by HCUP. The authors had no special access privileges to the data that others would not have. As such, requests for data acquisition should be forwarded to the HCUP.

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