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ORIGINAL ARTICLE



Determinants of Value in Coronary Artery Bypass Grafting

BACKGROUND: Over 180 000 coronary artery bypass grafting (CABG) procedures are performed annually, accounting for \$7 to \$10 billion in episode expenditures. Assessing tradeoffs between spending and quality contributing to value during 90-day episodes has not been conducted but is essential for success in bundled reimbursement models. We, therefore, identified determinants of variability in hospital 90-day episode value for CABG.

METHODS: Medicare and private payor admissions for isolated CABG from 2014 to 2016 were retrospectively linked to clinical registry data for 33 nonfederal hospitals in Michigan. Hospital composite risk-adjusted complication rates (≥ 1 National Quality Forum-endorsed, Society of Thoracic Surgeons measure: deep sternal wound infection, renal failure, prolonged ventilation >24 hours, stroke, re-exploration, and operative mortality) and 90-day risk-adjusted, price-standardized episode payments were used to categorize hospitals by value by defining the intersection between complications and spending.

RESULTS: Among 2573 total patients, those at low- versus high-value hospitals had a higher percentage of prolonged length of stay >14 days (9.3% versus 2.4%, $P=0.006$), prolonged ventilation (17.6% versus 4.8%, $P<0.001$), and operative mortality (4.8% versus 0.6%, $P=0.001$). Mean total episode payments were \$51 509 at low-compared with \$45 526 at high-value hospitals ($P<0.001$), driven by higher readmission (\$3675 versus \$2177, $P=0.005$), professional (\$7462 versus \$6090, $P<0.001$), postacute care (\$7315 versus \$5947, $P=0.031$), and index hospitalization payments (\$33 474 versus \$30 800, $P<0.001$). Among patients not experiencing a complication or 30-day readmission (1923/2573, 74.7%), low-value hospitals had higher inpatient evaluation and management payments (\$1405 versus \$752, $P<0.001$) and higher utilization of inpatient rehabilitation (7% versus 2%, $P<0.001$), but lower utilization of home health (66% versus 73%, $P=0.016$) and emergency department services (13% versus 17%, $P=0.034$).

CONCLUSIONS: To succeed in emerging bundled reimbursement programs for CABG, hospitals and physicians should identify strategies to minimize complications while optimizing inpatient evaluation and management spending and use of inpatient rehabilitation, home health, and emergency department services.

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Key Words: coronary artery bypass ■ hospitalization ■ inpatient ■ length of stay ■ pneumonia

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WHAT IS KNOWN

- Extensive variation in the quality of coronary artery bypass grafting care has prompted the establishment of quality measures through the Society of Thoracic Surgeons and National Quality Forum.
- Sources of variation in 90-day episode payments for isolated coronary artery bypass grafting include readmission, professional, and postacute care payments.

WHAT THE STUDY ADDS

- This study adds specific targets for succeeding in bundled care reimbursement models by incorporating both risk-adjusted clinical outcomes and risk-adjusted, price-standardized 90-day episode payments to assess value (ie, quality/spending).
- High-value hospitals' performance in Michigan was driven by avoiding prolonged length of stay, prolonged intubation, and operative mortality, in conjunction with achieving lower episode spending in all areas.
- Patients who avoided complications or readmissions at high-value hospitals had lower inpatient evaluation and management spending and lower utilization of inpatient rehabilitation, but higher utilization of home health and emergency department services.

Approximately 300 000 adults undergo cardiac surgery annually, and over half include coronary artery bypass grafting (CABG), accounting for ≈\$7 to 10 billion in episode expenditures.¹⁻³ As a result, CABG is one of the most widely studied inpatient surgical procedures and has become a target for bundled payment models. Extensive work has been performed describing hospital variation in the quality of CABG care,⁴⁻⁹ prompting the establishment of quality measures through the Society of Thoracic Surgeons (STS) and National Quality Forum.¹⁰ Despite these efforts, less attention has been paid to the relationship between quality and spending.

The Bundled Payments for Care Improvement-Advanced (BPCI-A) program was initiated on October 1, 2018 by the Center for Medicare & Medicaid Services to implement voluntary episode payment models¹¹ and hold providers accountable for the quality and expenditures throughout an episode of care. A number of investigators have identified hospital variation in clinical outcomes after CABG, including mortality,^{4,12} complications,^{5-7,12} and failure to rescue,^{4,8,9,12} but have not assessed spending. Other investigators have reported wide hospital variation in episode payments after cardiac surgery but have not assessed clinical outcomes.^{3,13} While health care reform efforts such as the BPCI have focused on optimizing value (defined as quality divided

by expenditures), few studies have examined the relationship between clinical outcomes and episode payments to identify how high-value hospitals achieve their performance, whether through increasing quality, decreasing payments, or both. The few studies that have characterized value in performing CABG have either been performed at a single center,¹⁴ limited to one outcome (pneumonia),² or used hospital costs and charge-to-cost ratios, which may not accurately reflect real-world spending.¹⁴⁻¹⁶ In contrast, an analysis linking established measures of clinical outcomes (eg, complications and mortality) with episode payments could help hospitals identify targets to increase value and succeed in the BPCI or other similar programs.

To help hospitals, payors, and providers better navigate value-based reimbursement models, clinical outcomes data were linked to 90-day episode payments housed within 2 statewide quality improvement collaboratives. These data were used to assess determinants of high-value episodes for CABG surgery.

METHODS

The University of Michigan Institutional Review Board deemed this study to be exempt from review. These data cannot be made available due to data use restrictions. Additional details pertaining to analytic methods are available from the corresponding author upon reasonable request.

Data Sources

Episode payments were collected from the Michigan Value Collaborative (MVC), a group of 87 Michigan acute care hospitals and 31 physician organizations that seeks to achieve the best possible patient outcomes at the lowest reasonable cost. The MVC Coordinating Center uses Medicare fee-for-service claims data and Blue Cross Blue Shield of Michigan preferred provider organization claims to create a validated registry of comprehensive 90-day episodes of care among Michigan patients.¹⁷

Clinical data were collected through the Michigan Society of Thoracic and Cardiovascular Surgeons Quality Collaborative (MSTCVS-QC), developed in 2001 as a cardiac surgeon-led quality collaborative embedded in the MSTCVS. In 2005, the MSTCVS-QC became partially funded by the Blue Cross/Blue Shield of Michigan insurance company. The collaborative meets quarterly to review hospital-specific processes and outcomes, and to facilitate and evaluate quality improvement studies to improve the outcomes of cardiac and general thoracic surgical patients in Michigan. The MSTCVS-QC gathers data from all 33 nonfederal hospitals in Michigan that provide cardiac surgery. On a quarterly basis, each of the 33 nonfederal adult cardiac surgical hospitals in Michigan send the MSTCVS-QC data coordinating center a copy of their STS national harvest file through a certified STS vendor.

Hospital characteristics were collected through the American Hospital Association Annual Survey and included the following reported variables: number of beds, teaching status, and urban designation.

Patient Population

Isolated CABG 90-day episodes were identified within the MVC based on admission date ranges (June 1, 2014 through June 1, 2016) for Blue Cross Blue Shield of Michigan and Medicare beneficiaries residing in Michigan (n=2782). Procedures from both data warehouses were successfully probabilistically matched (match rate 92.5%, n=2573) using an algorithm that included hospital, surgeon, patient date of birth, gender, admit date, and discharge date (Appendix in the [Data Supplement](#)).

Defining Hospital Value

A centered mean complication rate and centered mean total episode payment was defined empirically for each of the 33 hospitals. For clinical risk-adjustment, observed/expected ratios were created by dividing the patient-level observed complication rate by the expected morbidity and operative mortality according to the National Quality Forum-endorsed STS CABG composite measure risk-adjustment model.¹⁰ The observed/expected ratio for each hospital was then multiplied by the crude complication rate to form a risk-adjusted mean complication rate. Each hospital was added to a scatter plot of risk-adjusted centered means, with each dot representing one hospital and weighted in size by its overall isolated CABG volume (Figure 1). Hospitals were subsequently defined as low or high value based on their risk-adjusted complication rates and spending as compared with the centered means. While analyses were primarily focused on the comparison between low- versus high-value hospitals (Tables 1 through 3), a more complete analysis of all hospital value strata was also conducted (Tables I and II in the [Data Supplement](#)).

To distinguish between the quality and spending determinants of hospital value, a subset analysis was additionally performed among patients who did not experience a complication or 30-day readmission (n=1923/2573, 74.7%). This analysis focused on identifying differences in episode payments between low- and high-value hospitals for uncomplicated isolated CABG.

Clinical Data

All processes of care and clinical outcomes measures were selected based on their inclusion in either the STS CABG performance measures¹⁰ or as part of the Merit-Based Incentive Payment System under Center for Medicare & Medicaid Services.¹⁸

Processes of care measures included preoperative β blocker, appropriate antibiotic selection and discontinuation, use of internal mammary artery, and aspirin, β blockers, and lipid-lowering statins at discharge. In accordance with the STS and the National Quality Forum,¹⁰ the composite postoperative outcomes measure included any of the following: deep sternal wound infection, renal failure, prolonged ventilation (>24 hours), stroke, surgical re-exploration, and operative mortality. Prolonged length of stay was defined as >14 days. Operative mortality was defined as death during hospitalization in which CABG was performed or within 30 days after surgery. Risk-adjusted 30-day readmission was derived from an STS model of Medicare fee-for-service beneficiaries only¹⁰ and thus could not be included in the composite complication

rate observed/expected ratio calculation. Instead, a regression of unadjusted 30-day readmission with morbidity and operative mortality was conducted to determine a risk-adjusted readmission rate. The distribution of hospitals by centered mean readmission rate and 90-day episode payments is displayed in Figure I in the [Data Supplement](#).

Ninety-Day Price-Standardized Episode Payments

The primary outcome was total 90-day price-standardized episode payments. Payments were quantified for 90-day episodes of care and were disaggregated into index hospitalization, professional, readmission, and postacute care components and further subcomponents.¹⁹ Patient clinical demographic data for these episodes were collected using *International Classification of Diseases-Ninth Revision* codes. Payments were price-standardized using average Medicare payments in the state of Michigan to account for payer-type, inflation, regional variation, and contractual differences.²⁰ Price standardization ensures that variation in payments reflects differences in health care utilization rather than differences in geographic reimbursement.

Readmission and postacute care payments were reported as mean component payments and as conditional on use, which restricted payments to patients who were readmitted, received postacute care, or both. Postdischarge payments were restricted to patients known to be alive at hospital discharge (low-value hospitals: 568/587, 96.8% and high-value hospitals: 1023/1027, 99.6%).

Statistical Analyses

Total and component payments were risk-adjusted using a 2-step regression model, adjusting for patient characteristics, comorbidities, and payments in the 6 months before the index procedure. Risk adjustment was performed using observed/expected ratios as previously described.¹³ Among component and subcomponent payments, percent attributed to the total difference in payments between groups was reported. Since total and component episode payments were risk-adjusted separately, component percentages attributed to the total difference may not equal 100%. A sensitivity analysis was performed to compare mean inpatient evaluation and management (E&M) payments indexed per hospital day between low- versus high-value hospitals in both the primary and subset analyses to evaluate differences not attributed to the number of days spent in the hospital. Hospital days used to index these payments consisted of the total length of stay during the 90-day episode, including any readmissions.

A Pearson weighted product-moment correlation coefficient was calculated for Figure 1 and Figure I in the [Data Supplement](#) to incorporate hospital procedural volume. Categorical variables were presented as percentages, continuous variables as mean (SD), and payments as mean (SE). Mann-Whitney *U* or Kruskal-Wallis tests were used to test continuous hospital-level variables and aggregated patient-level characteristics among low- versus high-value and all 4 hospital categories, respectively. χ^2 tests were used for hospital-level variables. Payment data were tested using a generalized estimating equation treating hospital as a cluster unit.

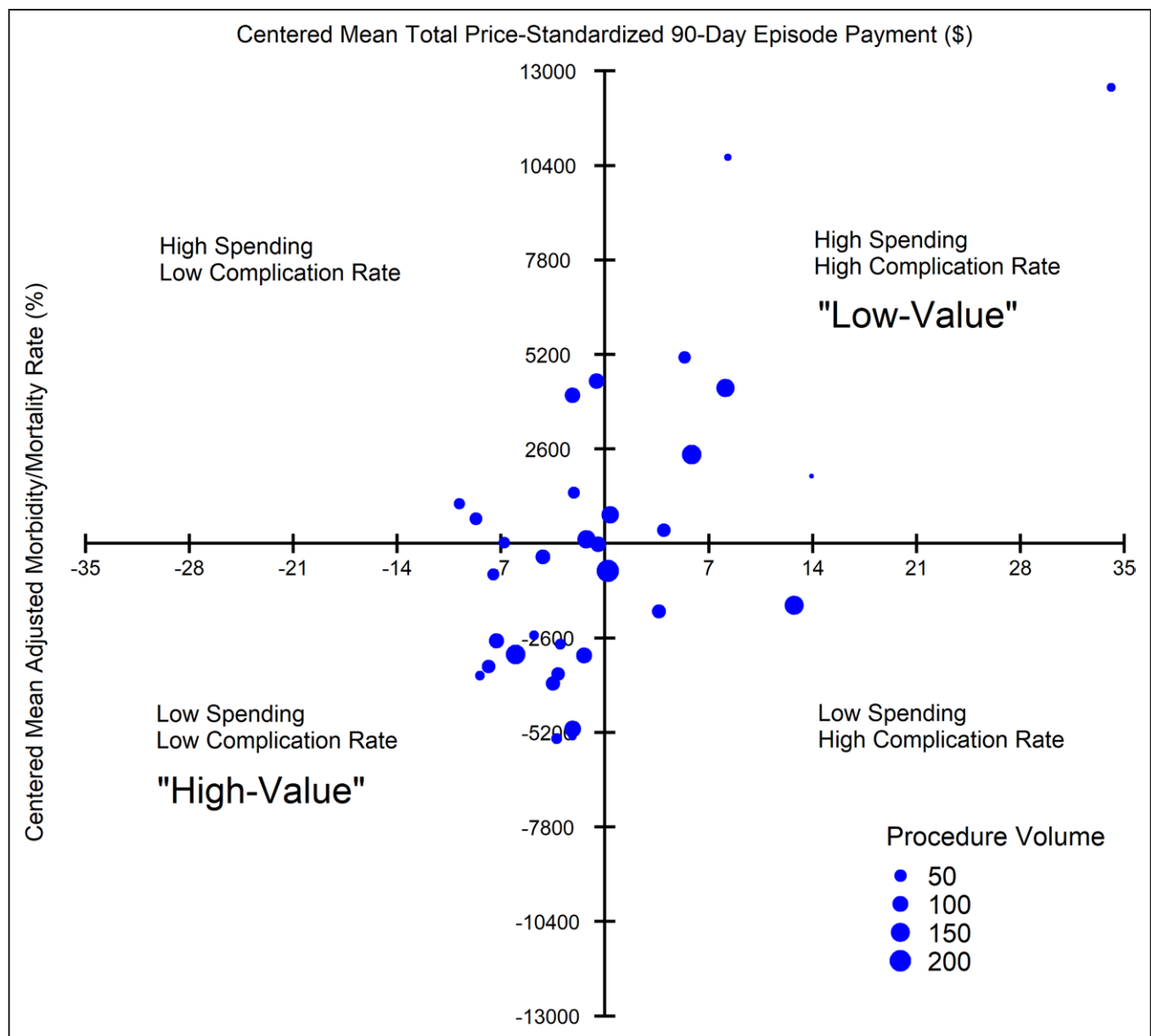


Figure 1. Deviation from centered mean in complication rate (x axis) and total episode payments (y axis).

Plotted dots are weighted by hospital volume of isolated coronary artery bypass grafting procedures. Quadrants are labeled as high or low spending and complication rates. Complications included any of the following: deep sternal wound infection, renal failure, prolonged ventilation (>24 h), stroke, surgical re-exploration, and operative mortality. Centers in the high spending and high complication rate quadrant are considered low-value, while those in the low spending and low complication rate quadrant are considered high-value. Pearson-weighted correlation coefficient=0.51.

P values of <0.05 (2-tailed) were considered statistically significant. All analyses were conducted using SAS 9.4 (SAS Institute, Cary, NC).

RESULTS

Hospital Value Distribution

Eight hospitals (n=587) had high spending and a high complication rate (low-value hospitals), 15 hospitals (n=1027) had low spending and a low complication rate (high-value hospitals), 3 hospitals (n=448) had low spending and a high complication rate, and 7 hospitals (n=511) had high spending and a low complication rate (Figure 1).

Hospital Structure and Processes

The distribution of Medicare patients, hospital structural characteristics, and compliance with performance processes did not differ between high- and low-value hospitals (Table 1). Patients in low-value hospitals had a higher mean number of hierarchical condition categories (5.7 [1.2] versus 4.6 [0.6], *P*=0.012), longer mean intensive care unit length of stay (123 [78] versus 63 [20] hours, *P*=0.008) and overall postoperative length of stay (8.9 [2.8] versus 6.4 [0.8] days, *P*=0.002), and a higher rate of unplanned readmission within 30 days (20.6% versus 13.4%, *P*=0.005).

Table 1. Hospital Characteristics Stratified by Low-Value and High-Value Hospitals Defined by Spending and Complication Rate Category

	Overall	High spending and high complication rate (low-value)	Low spending and low complication rate (high-value)	P value
Hospitals, n	33	8	15	
Total patients, n	2573	587	1027	
Percent medicare CABG patients, mean % per hospital	77	76	78	0.52
Hospital structure				
Mean beds, n (SD)	464 (241)	460 (266)	411 (219)	0.52
Teaching, %	97	88	100	0.36
Urban, %	90	100	86	0.52
Hospital processes, % compliance				
Compliance with all processes	93.5	93.3	93.9	0.70
Aspirin at discharge	99.2	99.9	98.8	0.21
β-blockers at discharge	99.6	99.9	99.4	0.21
Lipid-lowering statin at discharge	98.7	99.6	98.6	0.24
Preoperative β-blockers	97.3	95.8	97.8	0.42
Use of internal mammary artery	99.1	99.5	99.4	0.62
Appropriate antibiotic selection	99.9	100	100	1.00
Appropriate antibiotic discontinuation	99.5	99.5	99.4	0.50
Clinical characteristics				
Mean HCCs, n (SD)	4.9 (0.9)	5.7 (1.2)	4.6 (0.6)	0.012
Mean admission to discharge LOS, d (SD)	9.6 (2.1)	11.6 (3.4)	8.6 (0.9)	0.006
Mean surgery to discharge LOS, d (SD)	7.2 (1.8)	8.9 (2.8)	6.4 (0.8)	0.002
Mean ICU LOS, h (SD)	80 (49)	123 (78)	63 (20)	0.008
Emergency department visit, %	19.3	16.9	18.8	0.35
Unplanned readmission rate, %	17.2	20.6	13.4	0.005
Overall complication rate, %	11.1	20.8	6.7	<0.001
Surgery status, %				
Elective	50.0	45.3	54.3	0.11
Emergent	1.7	2.0	1.8	0.57
Emergent salvage	0.2	0.9	0.0	0.13
Urgent	48.1	51.9	43.9	0.19

CABG indicates coronary artery bypass grafting; HCC, hierarchical condition category; ICU, intensive care unit; and LOS, length of stay.

Risk-Adjusted Clinical Outcomes

Risk-adjusted rates of prolonged hospital length of stay (low-value: 9.3% versus high-value: 2.4%, $P=0.006$), prolonged ventilation (low-value: 17.6% versus high-value: 4.8%, $P<0.001$), and operative mortality (low-value: 4.8% versus high-value: 0.6%, $P<0.001$) were higher at low- compared with high-value hospitals, while adjusted rates of deep sternal wound infection, renal failure, stroke, surgical re-exploration, and 30-day readmission did not statistically differ (Table 2).

Ninety-Day Price-Standardized Episode Payments

Mean total episode payments were higher at low-value hospitals (\$51 509 [\$1024] versus \$45 526 [\$402],

$P<0.001$). Nearly half (45%, \$2674) of the difference in spending between low- and high-value hospitals was accounted for by higher index hospitalization spending (Figure 2).

Eighty-one percent of the difference in professional payments at low- and high-value hospitals were driven by inpatient E&M payments (low: \$2109 [\$96] versus high: \$1004 [\$35], $P<0.001$). Inpatient E&M payments remained higher at low- compared with high-value hospitals when indexed by hospital days (\$183 [\$5] versus \$108 [\$4] per hospital day, $P=0.002$). Sixty-eight percent of the difference in postacute care payments was driven by inpatient rehabilitation payments (low: \$1419 [\$230] versus \$489 [\$94], $P=0.005$). A higher proportion of patients at low-value hospitals were readmitted (20% versus 15%, $P=0.006$) and used postdischarge inpatient rehabilitation (10% versus 4%, $P<0.001$),

Table 2. Risk-Adjusted Composite and Individual Outcomes Stratified by Low-Value (High Spending and High Complication Rate) and High-Value (Low Spending and Low Complication Rate) Hospitals

	Overall	Low-value	High-value	P value
Hospitals, n	33	8	15	
Total patients, n	2573	587	1027	
Risk-adjusted composite major morbidity and mortality, %	11.0	21.0	6.6	<0.001
Prolonged length of hospital stay (>14 d)	4.4	9.3	2.4	0.006
Deep sternal wound infection	0.2	0.1	0.2	0.63
Postoperative renal failure	1.5	2.2	1.0	0.16
Prolonged intubation/ventilation	8.5	17.6	4.8	<0.001
Stroke/cerebrovascular accident	1.3	1.1	1.7	0.88
Operative mortality	1.8	4.8	0.6	<0.001
Surgical re-exploration	2.5	4.5	1.3	0.26
30-day risk-adjusted readmission rate	11.3	11.7	10.8	0.25

while a smaller proportion used home health (66% versus 74%, $P=0.001$) and emergency department services (15% versus 19%, $P=0.024$). Patients in the low complications/high spending hospital group had similar mean inpatient E&M payments (\$1727 [\$79]) as low-value hospitals (\$2109 [\$96]) but had a similar proportion of patients using emergency department services (20%) as high-value hospitals (19%; Table III in the [Data Supplement](#)). Among patients with any payments, overall postacute care payments were higher at low-value hospitals (\$7908 [\$576] versus \$6247 [\$223], $P=0.013$; Table 3).

Payment Variation Among Patients Without Complications

Among patients who did not experience a complication or readmission ($n=1923/2573$, 74.7%), total episode payments no longer statistically differed between low-value versus high-value hospitals (\$42 489 [\$552] versus \$41 380 [\$325], $P=0.11$). Low-value hospitals had higher professional payments (\$6160 [\$88] versus \$5596 [\$57], $P<0.001$), especially higher inpatient E&M payments (\$1405 versus \$752, $P<0.001$), which remained higher at low- compared with high-value hospitals when indexed by hospital days (\$171 [\$6] versus \$95 [\$4] per hospital day, $P=0.002$). In contrast, index hospitalization and postacute care payments were not statistically different between low- and high-value hospitals. In addition, a higher proportion of patients at low-value hospitals used inpatient rehabilitation (7% versus 2%, $P<0.001$), while a smaller proportion used home health (66% versus 73%, $P=0.016$) and the emergency department (13% versus 17%, $P=0.034$; Table IV in the [Data Supplement](#)).

DISCUSSION

In this large, multi-center, statewide experience, variability existed both in health care quality and spending

across hospitals in a 90-day episode following isolated CABG. Specifically, low-value hospitals had higher rates of prolonged hospital stay (9.3% versus 2.4%), more patients with prolonged ventilation (17.6% versus 4.8%), and a higher operative mortality (4.8% versus 0.6%). Additionally, low-value hospitals had higher total and component 90-day episode payments. Patients not experiencing a complication or rehospitalization at low- compared with high-value hospitals had higher professional payments and a higher rate of inpatient rehabilitation utilization, but lower rates of home health and emergency department utilization.

This study has several limitations. First, while representing the predominant health care payors in Michigan (Medicare, Blue Cross Blue Shield of Michigan), the MVC does not capture other important payors (eg, Medicaid) and the distribution of payors may differ by hospital. Second, although the present study represents the experience of all 33 nonfederal hospitals performing cardiac surgery in Michigan, these findings may not be generalizable outside of Michigan or to procedures other than isolated CABG. Third, while the results from this study were risk-adjusted and price-standardized, all important confounding factors may not be accounted for. Last, while the MVC collects the majority of expenses reimbursed during a 90-day episode, not all relevant expenditures may be captured from both a payor (eg, pharmaceutical) and patient (eg, out of pocket expenses) standpoint.

These data indicate that high-value hospitals succeeded in part by minimizing complications, but also had lower professional services spending and differences in component postacute care utilization among patients without postoperative complications or readmissions. Hospitals engaged in bundled care models may succeed by investing in home health and emergency department services in efforts to avoid readmissions and inpatient rehabilitation. Although not statistically significant ($P=0.19$), low-value hospitals had a higher

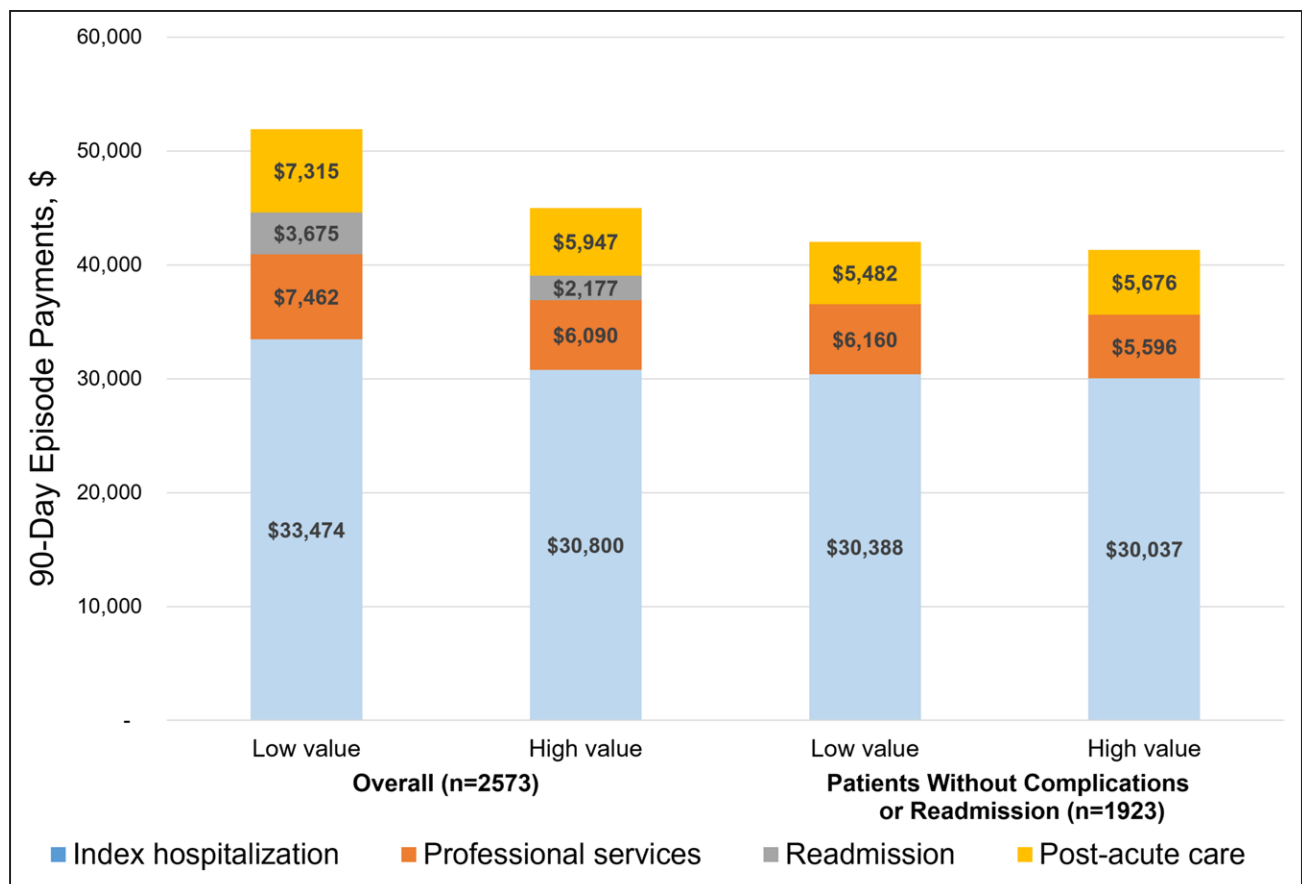


Figure 2. Variation in total and component 90-day episode payments after coronary artery bypass grafting in low- and high-value hospitals among the overall population (n=2573) and only patients who did not experience a complication or get readmitted within 30 days (n=1923).

Complications included any of the following: deep sternal wound infection, renal failure, prolonged ventilation (>24 h), stroke, surgical re-exploration, and operative mortality. Postacute care payments include inpatient and outpatient rehabilitation, home health, skilled nursing facility, emergency department, and other outpatient facility payments.

proportion of nonelective operations. While this difference may reflect differences in disease severity, clinical risk-adjustment was performed, and it may alternatively indicate better patient selection and preoperative optimization at high-value hospitals. Succeeding in preoperative preparation and appropriate patient selection may not only result in decreased rates of prolonged hospital stay, prolonged ventilation, and operative mortality, but could also decrease spending for inpatient E&M through fewer postoperative consultations. Additionally, low-value hospitals may have higher E&M payments due likely in part to poor care coordination²¹ or evaluating patients on a more frequent basis, as has been reported with increased laboratory testing at low-compared with high-ranked medical centers.²²

Prior investigators have evaluated value for cardiac surgical patients. The Virginia Cardiac Services Quality Initiative leveraged clinical data along with risk-adjusted cost-to-charge ratios to identify targets for advancing value. The authors reported a strong positive correlation between risk-adjusted quality (eg, morbidity and mortality) and risk-adjusted length of stay, but not between risk-adjusted quality and cost measures.¹⁵

Similarly, the current study found a higher incidence of prolonged length of stay at low-value hospitals and a mean 2.5-day longer length of stay compared with high-value hospitals. In contrast to the Virginia Cardiac Services Quality Initiative analysis, the current study includes specific National Quality Forum-defined quality metrics included as part of STS national CABG hospital performance ratings. Additionally, the Virginia Cardiac Services Quality Initiative authors did not find a significant association between quality and cost, potentially because they reported cost-to-charge ratios rather than spending. Authors of another recent study used a proprietary accounting tool in conjunction with 10 clinical outcome metrics used to define perfect care.¹⁴ Similar to the current study, the authors used STS performance metrics, as well as additional metrics deemed more closely tied to cost. However, the analysis was limited to a single center, with uncertain application at other hospitals, whereas the current data were collected from 33 diverse hospitals and as episode payments are more generalizable in assessing reimbursement. In further contrast to the current analysis and similar to the Virginia Cardiac Services Quality Initiative analysis,¹⁵ the

Table 3. Mean (SE) Risk-Adjusted, Price-Standardized 90-Day Total and Component Episode Payments in Low-Value (High Spending and High Complication Rate) and High-Value (Low Spending and Low Complication Rate) Hospitals

	Overall	Low-value	High-value	P value
Hospitals, n	33	8	15	
Total patients, n	2573	587	1027	
Patients, mean n (SD) per hospital	78 (51)	73 (59)	68 (38)	0.85
Total payments, \$	48099 (375)	51509 (1024)	45526 (402)	<0.001
Index hospitalization, \$	31928 (186)	33474 (546)	30800 (213)	<0.001
Professional services, \$	6511 (56)	7462 (157)	6090 (67)	<0.001
Surgical procedures	3244 (22)	3273 (50)	3195 (30)	0.25
Inpatient E&M services	1372 (33)	2109 (96)	1004 (35)	<0.001
Outpatient E&M services	248 (4)	286 (8)	238 (5)	0.010
E&M consult (inpatient and outpatient)	115 (7)	161 (18)	107 (11)	0.027
Anesthesia	925 (7)	980 (15)	935 (11)	0.43
Imaging	274 (4)	330 (10)	269 (6)	0.038
Labs and tests	93 (3)	118 (7)	86 (5)	0.017
Other professional	231 (14)	266 (32)	181 (17)	0.003
Overall readmission, \$	3115 (213)	3675 (485)	2177 (246)	0.005
n patients with any \$	471 [19%]*	116 [20%]*	149 [15%]*	0.006
\$, when present	23746 (1285)	25955 (2671)	20939 (1763)	0.07
Overall postacute care, \$	6614 (194)	7315 (539)	5947 (216)	0.031
n patients with any \$	2457 [97%]*	546 [93%]*	983 [96%]*	0.020
\$, when present	6964 (202)	7908 (576)	6247 (223)	0.013
Inpatient rehabilitation	927 (97)	1419 (230)	489 (94)	0.005
n patients with any \$	163 [6%]*	61 [10%]*	40 [4%]*	<0.001
\$, when present	29109 (2093)	28874 (2929)	24982 (2900)	0.65
Outpatient rehabilitation	489 (19)	466 (31)	496 (26)	0.67
n patients with any \$	1396 [55%]*	300 [51%]*	571 [56%]*	0.08
\$, when present	938 (33)	847 (49)	929 (41)	0.86
Skilled nursing facility	1585 (115)	1862 (278)	1668 (184)	0.58
n patients with any \$	433 [17%]*	113 [19%]*	181 [18%]*	0.42
\$, when present	16860 (974)	22666 (2132)	16939 (1485)	0.88
Home health	2373 (40)	2100 (97)	2368 (65)	0.25
n patients with any \$	1947 [77%]*	386 [66%]*	755 [74%]*	0.001
\$, when present	3199 (41)	3258 (114)	3286 (66)	0.89
Facility emergency department	316 (20)	205 (28)	276 (24)	0.021
n patients with any \$	510 [20%]*	88 [15%]*	200 [19%]*	0.024
\$, when present	1788 (85)	1537 (151)	1590 (92)	0.77
Other outpatient facility	698 (48)	834 (144)	706 (71)	0.33
n patients with any \$	2007 [79%]*	383 [65%]*	855 [83%]*	<0.001
\$, when present	912 (62)	1302 (222)	864 (86)	0.033

Conditional-on-use payments only include patients alive at discharge (overall: 2542/2573, 98.8%; low-value: 568/587, 96.8%; high-value: 1023/1027, 99.6%) who used readmission payments, postacute care payments, or both. E&M indicates evaluation and management.

* Percentages in brackets were calculated by number of patients using each post-discharge category divided by the number of patients alive at discharge in each column.

authors quantified actual costs to the hospital.¹⁴ While cost-to-charge ratios and other measures of hospital cost are informative for hospital operations, incorporating spending by payors is essential to be competitive in value-based bundled reimbursement models, since

measures from the BPCI-A and similar models are based on payments received.

Avedis Donabedian defined a hospital's performance as the byproduct of processes of care, outcomes, and a hospital's structure.²³ Since metrics of process and struc-

ture are conceptually important,²³ but largely unmeasured,⁷ most prior assessments of hospital performance have consisted of measuring variation in outcomes,^{5,7,8} finances (eg, charges, hospital costs, payments),^{3,13,24} or both (eg, value).^{2,14–16,25} In this study, existing metrics reflecting both hospital structure (from the American Heart Association survey) and processes of care (from the STS) were largely similar across categories of hospital value (Table 1), but may inadequately capture these aspects of quality. Important differences were identified in outcomes, with higher rates of prolonged hospital stay, prolonged intubation, and operative mortality at low-value hospitals. In the context of bundled payment models, traditional conceptual models for assessing institutional quality should be broadened to capture the application of learning health system principles to quality improvement cycles in routine practice.^{26–28} While Donabedian provides a commonly cited framework for quality, efforts focusing on value will require modifications to Donabedian's model to include spending. Accordingly, the current study also included analyses of risk-adjusted, price-standardized episode payments rather than hospital charges, cost-to-charge ratios, or other estimates of cost.^{15,16,24} Episode payments are a better reflection of payers' and society's perspective on cost, since they reflect the actual realized cost of the episode of care and are thus more relevant to bundled payments and value-based reimbursement.

Given the importance of spending, one prior analysis of MVC data assessed reimbursement by evaluating variation in episode payments after isolated CABG.³ Sources of variation between the highest and lowest hospital payment quartiles were readmission (35.1% higher), professional (33.9% higher), and postacute care (29.6%) payments. Subcomponent drivers of payment differences included diagnosis related group distribution, inpatient E&M services, higher utilization of inpatient rehabilitation, and patients with multiple readmissions.³ Similarly, the current study identified inpatient E&M professional payments and postdischarge inpatient rehabilitation payments to be the main drivers of payment variation between hospitals. Importantly, inpatient E&M payments are driven by the duration of a patient's hospital stay, while inpatient rehabilitation payments are driven by utilization (yes versus no), since the latter's payments are based on diagnosis-related group pricing rather than care intensity. However, when indexed by hospital day, inpatient E&M payments were still higher at low-value hospitals both overall and among patients avoiding complications or readmission. These findings may suggest that high-value hospitals are more protocolized in standard care resulting in lower inpatient E&M payments, independent of time spent in the hospital. The present analysis further advances these prior findings by incorporating risk-adjusted clinical outcomes to evaluate value and defining specific targets for succeeding in bundled care reimbursement models, especially among patients without complication or readmission.

After initially introducing mandatory bundled payment models in 2016, Center for Medicare & Medicaid Services announced the voluntary BPCI-A model and enrolled its first cohort in October of 2018.¹¹ Michigan quality improvement collaboratives are uniquely situated to evaluate the BPCI-A in future analyses by linking MSTCVS-QC risk-adjusted clinical data to MVC 90-day episode payments to compare the performance of BPCI-A participants to nonparticipants. While Michigan includes a diverse set of geographies and practice environments to analyze, a similar nationwide analysis of Medicare patients could be performed by linking STS clinical data to Medicare claims. These future data could further highlight specific strategies for success in BPCI-A and other value-based payment models.

CONCLUSIONS

In conclusion, high-value hospitals' performance was driven by avoiding prolonged length of stay, prolonged intubation, and operative mortality, in conjunction with achieving lower episode spending in all areas. Among patients who avoided complications or readmissions at high-value hospitals, lower spending was driven by professional payments, but not index hospitalization, post-acute care, or readmission payments. These findings may reflect a higher proportion of elective operations performed at high-value centers, with improved post-operative care leading to fewer complications and lower spending. These data identify specific clinical outcomes and sources of modifiable payment variation which may inform approaches to bundled payments and value-based reimbursement for hospitals and payors.

ARTICLE INFORMATION

Received November 21, 2019; accepted September 8, 2020.

This article was sent to Karen E. Joynt Maddox, MD, MPH, Guest Editor, for review by expert referees, editorial decision, and final disposition.

Current address for Dr Li: Department of Public Administration and International Affairs, The Maxwell School of Citizenship and Public Affairs, Syracuse University, Syracuse, NY.

The Data Supplement is available at <https://www.ahajournals.org/doi/suppl/10.1161/CIRCOUTCOMES.119.006374>.

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Sources of Funding

Dr Brescia is supported by the National Research Service Award postdoctoral fellowship (No. 5T32HL076123). Support for the Michigan Society of Thoracic and Cardiovascular Surgeons Quality Collaborative (MSTCVS-QC) and the Michigan Value Collaborative (MVC) is provided by the Blue Cross Blue Shield of Michigan (BCBSM) and Blue Care Network as part of the BCBSM Value Partnerships program. Although BCBSM works collaboratively with MSTCVS-QC and MVC, the opinions, beliefs and viewpoints expressed by the author do not necessarily reflect the opinions, beliefs and viewpoints of BCBSM or any of its employees.

Disclosures

Dr Likosky, Dr Norton, J.D. Syrjamaki, Dr Thompson, and Dr Regenbogen receive partial salary support from Blue Cross Blue Shield of Michigan (BCBSM). Data from the Michigan Value Collaborative was obtained through data use agreement RSCH-2014-26142. Dr Likosky receives research funding from the Agency for Healthcare Research and Quality (R01HS026003 AHRQ) and National Institutes of Health (1R01HL146619-01A1 REVISED) and serves as a consultant for the American Society of Extracorporeal Technology. The content of this article is solely the responsibility of the authors and does not necessarily represent the views of the National Institutes of Health or the Agency for Healthcare Research and Quality. The other authors report no conflicts.

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