Value-driven cardiac surgery: Achieving “perfect care” after coronary artery bypass grafting

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ABSTRACT

Objective: The objective of this study was to determine if the implementation of a value-driven outcomes tool comprising modifiable quality and utilization metrics lowers cost and improves value of coronary artery bypass grafting (CABG) postoperative care.

Methods: Ten metrics were defined for CABG patients in 2 temporally separated phases. Clinical care protocols were designed and implemented to increase compliance with these metrics. Clinical outcomes and cost data were harvested from the electronic medical record using a proprietary value-driven outcomes tool and verified by a data management team. “Perfect care” was defined as achieving all 10 metrics per patient episode.

Results: Over a 45-month period, data of 467 consecutive patients who underwent isolated CABG were analyzed. “Perfect care” was successfully achieved in 304 patients (65.1%). There were no observed differences in mortality between patient groups. Linear regression analysis showed a negative correlation between percent compliance with “perfect care” and mean cost. When multivariate analysis was used to adjust for preoperative risk score, mean cost for patients with “perfect care” was 37.0% less than for those without “perfect care.”

Conclusions: In the context of focused institution-specific interventions to target quality and utilization metrics for CABG care, clinical care pathways and protocols informed by innovative tools that link automated tracking of these metrics to cost data might simultaneously promote quality and decrease costs, thereby enhancing value. This descriptive study provides preliminary support for a systematic approach to define, measure, and modulate the drivers of value for cardiothoracic surgery patients. (J Thorac Cardiovasc Surg 2018;156:1436-48)

Multivariate analysis of difference in cost with “perfect care” adjusted for preoperative STS risk score.

Central Message

Value in cardiothoracic surgery care can be increased by defining and achieving relevant quality and utilization metrics that help to reduce cost while maintaining excellent clinical outcomes.

Perspective

Because of the robust tradition of outcomes reporting and strict adherence to quality standards across the specialty, cardiothoracic surgeons are uniquely poised to deliver value, defined as quality and service divided by cost. It is crucial to deliberately develop systems and processes to measure and promote value in modern cardiothoracic surgery practice.

See Editorial Commentary page 1449.

Established in 1989 as a quality improvement initiative among cardiothoracic surgeons, the Society of Thoracic Surgeons (STS) database is used to collect data on

compliance with quality and process metrics to track clinical outcomes of common cardiac surgery procedures. The outcomes of coronary artery bypass grafting (CABG) surgery are considered the principal performance metric for surgeons and programs.¹ Since implementing STS database-facilitated outcomes tracking, the specialty has consistently improved outcomes for CABG to the point

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Abbreviations and Acronyms

CABG	= coronary artery bypass grafting
CMS	= Centers for Medicare and Medicaid Services
ICU	= intensive care unit
STS	= Society of Thoracic Surgeons
VDO	= Value-Driven Outcomes

that achieving a 30-day mortality rate <1% has been articulated as an achievable benchmark goal.²⁻⁴ Although these quality and outcomes improvements are laudable, there has been a simultaneous increase in costs.⁵ There has been little motivation to decrease cost while maintaining high quality and good outcomes because treatments have historically been reimbursed in a fee-for-service model, which does not incentivize or reward cost-effective care.^{6,7} As health care reimbursement moves from fee-for-service to bundled disease-specific payments, minimizing care costs on the individual patient and institutional levels will become increasingly more important.^{8,9}

In response to this changing environment, the concept of “value-driven” care has recently gained traction. Value is defined as the quality of patient care and service divided by total cost of care (Figure 1).¹⁰⁻¹² In this model, if quality and clinical outcomes remain stable, value increases as costs decrease. Although treatment approaches and outcomes for coronary artery disease have become standardized (the numerator of the value equation), cost of care remains widely variable across different health systems and among different physicians (the denominator of the value equation).^{5,7,13} It can be quite difficult to accurately measure the costs of health care, because hospital and system charges are significantly distinct from actual cost of care delivery.¹⁴ To objectively measure value, the full cost of care for treatment of a patient’s disease process must be known.¹⁵ The University of Utah Value-Driven Outcomes (VDO) program was created specifically to address these concerns.^{15,16} Using the VDO framework, the current study was designed to determine the effect on value of achieving “perfect” postoperative care in patients who

undergo CABG. In this study, “perfect care” is narrowly defined as achieving the 10 quality and utilization metrics that the authors identified as highly relevant to the cardiac surgery practice at the University of Utah. Clinical protocols were designed to increase compliance with these metrics and test the hypothesis that achieving these metrics would decrease costs and thereby increase value. We report the results of this iterative process to improve the value of CABG care by defining and achieving “perfect care” coupled with the measurement of patient direct care cost.

METHODS

The study is a retrospective observational analysis of the change in value (clinical quality divided by costs) of care before and after an institutional effort to define and achieve CABG-specific quality and utilization metrics. The development and implementation of protocols to increase compliance with these metrics was divided into 2 phases, each with a unique set of parameters derived in an iterative process driven by clinically relevant outcomes and institution-specific utilization data. In this study we compiled the relative total hospitalization costs associated with all patients during and after protocol implementation, grouped according to whether or not all metrics were achieved. Data were extracted from both phases of protocol implementation. This study protocol was reviewed by the University of Utah institutional review board and was judged not to constitute human subjects research. Informed consent was not required.

Data Source and Study Population

Cost data were collected using the previously described University of Utah VDO methodology.^{15,16} This validated proprietary accounting approach links the commercial electronic health record (Epic, Verona, Wis) with clinical outcome data and direct costs. Previously validated against actual cost or time, the VDO tool is designed to capture 98% of total direct costs, including percent attributable facility, professional, personnel, plus actual usage costs (medications, supplies). All data were collected directly from our institution’s electronic medical record using automated systems and by a dedicated data entry team that verified all data entries as accurate. The VDO tool synthesized and analyzed data as previously described, including all patient-specific costs.¹⁵ The express goal of this approach is to tabulate actual cost from the health care system perspective to identify and quantify costs that are directly attributable to direct patient care. To that end, certain large groups of cost such as facility space, labor, equipment, and professional time were calculated on the basis of a patient’s estimated use of these resources, whereas supplies, medications, and contracted services are directly tabulated on the basis of the health care system’s actual acquisition costs.¹⁵ Professional fees were not included in the analysis to allow a focus on health system direct costs. Because costs are individually negotiated with payers, we are institutionally prohibited from reporting actual cost dollar amounts in the results, but instead report percent change.

Metric Identification, Protocol Development, and Implementation

Metric identification. In phase I of the study (May 2014 to December 2016), 7 quality metrics were identified on the basis of the STS CABG Composite Score and National Quality Forum measures. The metrics included 4 CABG Composite Score components (selected on the basis of the ability to be modified through compliance with care protocols and pathways), and 3 additional related quality metrics, determined by stakeholders. For example, mortality is the major component of the STS CABG score, but cannot be directly modified via clinical care protocols,

$$V = \frac{Q + S}{\$}$$

FIGURE 1. The value equation.

and so was not chosen. Final metrics included: (1) antibiotics delivered within 1 hour before surgery, (2) antibiotics discontinued between 24 and 48 hours postoperatively, (3) antiplatelet medication prescribed at hospital discharge, (4) antilipid medication prescribed at discharge, (5) use of an internal mammary artery, (6) absence of reintubation, and (7) β -blockers prescribed at hospital discharge.¹ Discharge medications were started during the acute hospitalization, so they were thought to be relevant to the index hospitalization costs.

In phase II of the study (January 2017 to September 2017), 3 additional utilization metrics were identified, including: (8) discontinuation of inotrope medication use within 24 hours, (9) discontinuation of mechanical ventilation within 24 hours, and (10) use of ≤ 500 mL of albumin for postoperative resuscitation. Inotrope medications were defined as epinephrine, dobutamine, milrinone, isoproterenol, and dopamine. The rationale for including these additional utilization metrics was to more directly affect total cost of care for each patient. Because of extremely high compliance with the phase I metrics, the total cost of care was disassociated with achievement of these metrics. Therefore, the study designers identified care parameters with high variability and that also directly influenced cost. Although these 3 utilization metrics are not strictly considered quality metrics, we sought to identify inefficiencies in clinical care that contributed to increased costs. This would further support the hypothesis that by achieving compliance with utilization metrics (ie, decreasing resource utilization), total cost of care would be reduced and therefore value would be increased. Specifically, there are few patient outcome data to support the use of albumin versus crystalloid after cardiac surgery,^{17,18} although albumin use remained prevalent in our unit. Duration of mechanical ventilation is known to be shorter with protocolized weaning.¹⁹ Last, similar to mechanical ventilation, we believe that focusing attention on iterative reassessment for readiness to wean from inotropes had the potential to reduce the intensive care unit (ICU) length of stay.

Protocol development. Clinical care protocols and pathways designed to achieve the identified metrics were drafted by stakeholders. Stakeholders included cardiothoracic surgeons, anesthesiologists, intensive care physicians, cardiovascular ICU nurses, cardiothoracic surgery advanced practice clinicians, and VDO consultants. The protocols were designed to increase compliance with the identified metrics. Our hypothesis was that increased compliance would directly decrease costs, assessed using the VDO tool.

Protocol implementation. A 6-month wash-in period followed metric identification for phase I, during which the protocols were widely circulated to nursing staff, cardiothoracic surgeons, surgical and ICU fellows, intensivists, and advanced practice clinicians, and then brought into clinical practice. The wash-in period for phase II was shortened to 1 month because of the familiarity of the staff with the VDO concept. These wash-in periods included silent observation by VDO project staff to assess implementation rates. VDO project staff also conducted interviews with nurses on perceived barriers to facilitate ongoing implementation of the clinical protocols. Compliance with the clinical protocols was tracked on physician and nursing levels to maximize achievement of each metric.

Protocol Compliance and the Concept of “Perfect Care”

Compliance with the 7 STS quality metrics identified in phase I were tracked prospectively throughout the study period. Compliance with the phase II utilization metrics were tracked prospectively from the time of their implementation and retrospectively for phase I of the study using the automatic data collection process inherent to the VDO tool and verified by the study data collection team. Direct patient costs were measured using the VDO tool and were associated with metric compliance. Total costs were calculated for each patient encounter. “Perfect care” was tightly defined in the context of this study as achieving all 10 metrics per patient episode.

Statistical Analysis

Demographic characteristics were stratified according to compliance with “perfect care.” Counts and column percentages are reported for binary variables whereas means and SDs are included for numeric variables. We used *t* tests to compare means for continuous variables, whereas χ^2 tests of independence were used for categorical variables. Cost data were not normally distributed. Inspection of the cost data versus the theoretical density of the flexible gamma distribution¹⁹ indicated that the data were approximately gamma distributed, as shown in Figures E1 and E2. Thus, as has been recommended for analysis of cost data,^{20,21} generalized gamma regression²² with a log link was used to compare means for patients who did and did not receive “perfect care” adjusted for preoperative STS risk score. STS score was treated as a categorical variable with 3 groups: low, intermediate, and high with preoperative STS of $<1.0\%$, $1.0\%-3.0\%$, and $>3.0\%$, respectively. Linear regression was used to evaluate the relationship of monthly mean costs and “perfect care” compliance rates. Significance was defined as a *P* value $< .05$.

RESULTS

Patient Characteristics and Outcomes

Over a 45-month period, data of 467 consecutive patients who underwent isolated CABG were analyzed. Demographic characteristics and comorbidities for the 304 patients who received “perfect care” and 163 patients who did not are shown in Table 1. There were no significant differences in age, body mass index, marital status, or ethnicity between groups. More patients in the group that received “perfect care” had commercial insurance (47.4% vs 31.9%; *P* = .012) and were male (85.2% vs 68.7%; *P* $< .001$), respectively, versus the group that did not receive “perfect care.”

Preoperative STS risk of mortality was higher in the patients who did not receive “perfect care” compared with the patients who did receive “perfect care” ($3\% \pm 0.04$ vs $1\% \pm 0.01$; *P* $< .001$). Preoperative myocardial infarction was diagnosed in 26.3% of all patients and was not significantly different between the 2 groups. History of diabetes was not different between the 2 groups. Hypertension was more common in the group that received “perfect care” (90.1% vs 83.4%; *P* = .023), whereas previous cerebrovascular accident was more common in the group that did not receive “perfect care” (17.2% vs 8.9%; *P* = .012), as was the incidence of preoperative heart failure (57.7% vs 26.0%; *P* $< .001$), the rate of preoperative pulmonary hypertension (18.4% vs 7.6%; *P* = .001), a history of chronic obstructive pulmonary disease (25.2% vs 11.5%; *P* $< .001$), and the incidence of reduced preoperative left ventricular ejection fraction (35.3% vs 12.8%; *P* $< .001$). Elective surgical priority was more common in the group that received “perfect care” (85.2% vs 78.5%; *P* = .041).

Differences in unadjusted 30-day mortality did not reach statistical significance between patients who did and did not receive “perfect care” (1.6% vs 4.9%; *P* = .080). The overall incidence of postoperative permanent stroke was not different between groups (1.8% vs 1.0%; *P* = .726),

TABLE 1. Demographic characteristics and outcomes

Characteristic	Without “perfect care”	With “perfect care”	P value
n	163 (34.9)	304 (65.1)	
Age group, y			.516
31 to 40	2 (1.2)	5 (1.6)	
41 to 50	8 (4.9)	15 (4.9)	
51 to 60	28 (17.2)	69 (22.7)	
61 to 70	63 (38.6)	125 (41.1)	
71 to 80	50 (30.7)	71 (23.4)	
≥81	12 (7.4)	19 (6.2)	
Male sex	112 (68.7)	259 (85.2)	< .001
Body mass index	31.29 (±16.99)	29.77 (±5.93)	.159
Marital status			.155
Divorced	23 (14.1)	25 (8.2)	
Married	104 (63.8)	211 (69.4)	
Other	4 (2.8)	16 (5.3)	
Single	22 (13.5)	33 (10.8)	
Widowed	10 (6.1)	19 (6.2)	
Ethnicity			.197
Hispanic/Latino	10 (6.1)	27 (8.9)	
Not Hispanic/Latino	145 (89.0)	270 (88.8)	
Other/unknown	8 (4.9)	7 (2.3)	
White/Caucasian	138 (84.7)	247 (81.2)	.426
Payer			.012
Utah Commercial	52 (31.9)	144 (47.4)	
Utah Medicaid	13 (8.0)	23 (7.6)	
Utah Medicare	83 (50.9)	117 (38.5)	
Other	15 (9.2)	20 (6.6)	
Medical history			
Diabetes	131 (80.4)	225 (74.0)	.154
Hypertension	136 (83.4)	274 (90.1)	.050
Heart failure	94 (57.7)	79 (26.0)	< .001
Pulmonary hypertension	30 (18.4)	23 (7.6)	.001
Previous CVA	28 (17.2)	27 (8.9)	.008
Previous MI	45 (27.6)	78 (25.7)	.730
COPD	41 (25.2)	35 (11.5)	< .001
Preoperative STS Score	3% (±0.04)	1% (±0.01)	< .001
Preoperative LVEF			< .001
<30%	11 (±16.2)	2 (±2.0)	
31% to 45%	13 (±19.1)	11 (±10.8)	
>45%	44 (±64.7)	89 (±87.3)	
Surgical priority			.041
Elective	128 (78.5)	259 (85.2)	
Urgent	31 (19.0)	44 (14.5)	
Emergency	4 (2.5)	1 (0.3)	
Outcomes			
30-Day mortality	8 (4.9)	5 (1.6)	.080
Permanent stroke	3 (1.8)	3 (1.0)	.726
Myocardial infarction	10 (6.1)	20 (6.6)	1
Atrial fibrillation	89 (54.6)	85 (28.0)	< .001

Total N = 467. Binary variables are presented as counts and percentages, numeric variables are presented as mean ± SD. CVA, Cerebrovascular accident; MI, myocardial infarction; COPD, chronic obstructive pulmonary disease; STS, Society of Thoracic Surgeons; LVEF, left ventricular ejection fraction.

nor was the incidence of postoperative myocardial infarction (6.1% vs 6.6%; $P = 1.0$). The incidence of atrial fibrillation was higher in the patient group that did not receive “perfect care” compared with the group that did receive “perfect care” (54.6% vs 28.0%; $P < .001$).

Compliance With “Perfect Care” Metrics

“Perfect care” was achieved for all metrics in 304 patients (65.1%). Figure 2 shows the compliance rate for each metric of perfect care grouped according to phase I and phase II metrics. Perfect care was successfully achieved for the 7 phase I STS database-derived metrics in 421 patients (90.1%). An additional 44 patients (9.4%) achieved 6 of 7 STS metrics. Perfect care was achieved for all 3 of the phase II metrics in 319 patients (68.3%). An additional 97 patients achieved 2 of 3 metrics (20.8%). Table 2 shows a summary of the cost categories tracked according to the VDO tool. Among the phase I STS database-derived metrics, the most common cause of failure was reintubation (16 patients; 4.0%) followed by lack of antiplatelet medication prescribed at discharge (14 patients; 3.0%). Antibiotic delivery and discontinuation, as well as internal mammary artery use, was achieved in 100% of patients. For the phase II metrics, postoperative albumin use ≤500 mL was achieved in 397 patients (84.5%). Inotropes were successfully weaned off within 24 hours in 393 patients (83.6%). Mechanical ventilation was successfully discontinued within 24 hours in 391 patients (83.2%).

Cost Comparisons

A comparison of mean total cost between the group that received “perfect care” (phase I + phase II) and the group that did not is shown in Figure 3, A. There was considerably more variability in mean total cost of care across the group that did not receive “perfect care.” In addition to the increased consistency of cost in the “perfect care” group, overall cost of care for patients achieving “perfect care” across all metrics was 45.0% lower than for patients not achieving “perfect care.” Figure 3, B, elucidates the cost savings observed across multiple categories for patients that received “perfect care” and those that did not. Values are presented as relative percentage differences between “perfect care” and non-“perfect care.” The costliest aspect of care was facility fees, which includes cardiovascular ICU, cardiovascular ward, and operating room fees. Facility fees were 42.6% lower in the patient group that received “perfect care.” Supply costs were the second most costly item in total patient care costs and were 41.1% lower in the “perfect care” group. Ancillary services such as technicians and respiratory therapists, in addition to pharmacy, laboratory, and imaging fees were also less costly in the “perfect care” group (53.7% lower, 51.0% lower, 45.6% lower, and 40.6% lower, respectively).

FIGURE 2. Frequency of study metrics achieved in (A) phase I and (B) phase II. Presented as number of patient care episodes for which the quality and utilization metrics were achieved.

Figure 4, A, shows the correlation between the rate of “perfect care” delivery and the total cost over the time frame of the study. The rate of “perfect care” immediately after implementation of the phase II protocols (dashed line) increased, along with a decrease in mean total cost. During the final 4 months of the study, rates of “perfect care” began to decline, and mean total cost increased. After efforts to increase compliance with the clinical care protocols, the “perfect care” success rate increased and mean total cost decreased. A linear regression analysis confirmed an inverse relationship between “perfect care” success rate and total patient care cost across the entire study period (slope = 2.3; $r^2 = 0.29$; $P = .038$; Figure 5).

To assess cost differences adjusted for preoperative comorbidities and risk of surgery, a multivariate analysis

was performed. Figure 6 shows the risk-stratified cost differences. Patients who were low risk for CABG (STS score <1.0%) and those who were intermediate risk (STS score 1.0%–3.0%) did not have a difference in mean total costs ($P = .1$). However, high-risk patients (STS score >3.0%) had an associated 155% increase in mean total cost compared with the low-risk patient group (95% confidence interval, 1.32–1.82; $P < .001$). As presented in Figure 6, even after adjusting for preoperative risk, mean total cost for patients with “perfect care” was 37% lower than for those without (95% confidence interval, 0.56–0.70; $P < .001$).

DISCUSSION

Outcomes for coronary artery disease care have dramatically improved in the past 4 decades, with low mortality and morbidity seen across many different health centers and practice structures.²³ As a fundamental procedure of modern adult cardiac surgery, CABG has become an agreed-upon benchmark with which to measure quality and outcomes.²⁴ Recently, the Centers for Medicare and Medicaid Services (CMS) have announced their intention to implement a bundled payment model for coronary artery disease that will emphasize quality of care instead of quantity of care.²⁵ This is a significant departure from the traditional volume-based reimbursement strategies that have been historically used in the United States health care system.²⁶ Value of care, defined as quality or outcomes divided by cost has been increasingly used as a conceptual framework to evaluate the performance of health systems.¹⁵ Because of this impending change in the regulatory environment, cardiothoracic surgeons must develop systems and methods to define achievable clinical metrics that are correlated with costs of care. This will allow surgeons to measure, track, and improve value of care to successfully build and maintain a practice within the new CMS payment structure.

This study represents an iterative process aimed at increasing value of care within a single institution’s

TABLE 2. “Perfect care” metric pass rates

Metric	Frequency achieved (%)	Frequency of lone failure (%)
Antibiotics delivered 1 h preoperatively	467 (100)	0 (0)
Antibiotics discontinued within 24 to 48 h	467 (100)	0 (0)
Antiplatelet medication prescribed at discharge	453 (97.0)	4 (0.9)
Antilipid medication prescribed at discharge	459 (98.3)	10 (2.1)
Use of internal mammary artery	467 (100)	0 (0)
No reintubation	451 (96.6)	2 (0.4)
β -Blocker medication prescribed at discharge	463 (99.1)	2 (0.4)
Use of <500 mL of albumin	397 (85.0)	28 (6.0)
Off ventilator within 24 h	391 (83.7)	50 (10.7)
Off inotropes within 24 h	393 (84.2)	28 (6.0)

The frequency that each metric was achieved is presented as well as how often that metric was the only metric not achieved for a given patient encounter.

FIGURE 3. Total cost of patient care with and without achievement of “perfect care.” A, Mean total cost per patient care episode comparing “perfect care” (blue) with not “perfect care” (red). B, Cost differences according to category when “perfect care” was achieved, presented as percentage change versus not “perfect care.”

CABG practice. Mean total cost was significantly less in patients who achieved the postoperative quality and utilization metrics identified in this study, even after adjusting for preoperative risk. In phase I, protocols were designed and implemented in the operating room, ICU, and wards to encourage compliance with 7 STS-database derived quality and process metrics. Mortality rates were not different between the 2 groups and we observed only a modest decrease in cost despite achieving high rates of “perfect care” across the phase I metrics. This suggests that the STS database metrics, although closely related to improved outcomes over the past decade, might have limited effect on total cost of care in the modern era.

With the addition of phase II protocols and metrics, the total cost of care showed a more consistent inverse relationship with achievement of “perfect care.” This result

suggests that the phase II utilization metrics have more influence on cost of care and therefore represent a target for improving value. This iterative process highlights the importance of determining appropriate institution-specific metrics to define “perfect care” to maximize value. An important point is that achieving “perfect care” does not necessarily have to influence patient outcomes to influence value. By preserving outcomes but reducing cost, value is increased. These data show that these interventions have increased value for CABG patients treated within the University of Utah Health System, but identical interventions might not influence costs across other systems, because the drivers of cost for a given procedure or disease might or might not be generalizable to other patient populations. Rather than focusing on the specific metrics tracked in this study, it is crucial to emphasize the framework for

FIGURE 4. Timeline of “perfect care” success rate and total cost. A, Combined success rate for all 10 metrics. *Dashed line* represents the initial roll-out of the phase II protocols. B, Success rate for the single metric of inotrope weaning by 24 hours. C, Success rate for the single metric of ventilator weaned within 24 hours. D, Success rate for albumin use ≤ 500 mL. *Dashed line* represents the start point of the phase II clinical protocols.

intervention as the take-home point from this study. The iterative process of defining “perfect care” metrics and then measuring the cost implications of achieving those metrics allows for analysis of value. Although the specific

metrics might not be transferrable, this concept and iterative process have potential applicability to any health care environment if applied systematically. If achievement of specific “perfect care” metrics do not change the result of

FIGURE 5. Linear regression trend model for mean total cost given the percent “perfect care” achieved. Shaded area represents 95% confidence interval.

the value equation for a given institution or health care system, then different metrics must be sought and implemented until cost (and therefore value) is affected.

Limitations

This observational study relied on software algorithms that scour the electronic medical record to collect clinical data. Although the VDO system has been validated and manually confirmed for this study, automated data collection represents a real-world challenge. This study represents a single institution’s experience in developing a value-based outcomes metric and applying it to CABG surgery practices. Although the current study shows significant cost savings and value improvements by

FIGURE 6. Multivariate analysis of differences in mean total costs. Patients were stratified according to preoperative Society of Thoracic Surgeons (STS) risk of mortality. Low risk was defined as STS score <1.0%, intermediate risk was defined as an STS score of 1% to 3%, and high risk was defined as STS score >3%. Comparisons in mean total cost were adjusted for preoperative risk score and analyzed between groups who received “perfect care” and those who did not receive “perfect care.” CI, Confidence interval.

VIDEO 1. Dr Glotzbach discusses the main hypothesis, results, conclusions, and context of the study. Video available at: [https://www.jtcvs.org/article/S0022-5223\(18\)31470-3/fulltext](https://www.jtcvs.org/article/S0022-5223(18)31470-3/fulltext).

focusing on these 10 metrics, these results might not be generalizable to other centers. A specific factor in this lack of generalizability is the potential for differences in pricing and direct costs among different institutions and health care systems. In addition, this study focused on total cost of the index hospitalization after CABG surgery, but was not designed to evaluate postdischarge or long-term costs incurred after the acute hospitalization.

CONCLUSIONS

When “perfect care”—defined by institution- and patient population-specific metrics—is achieved in patients who undergo CABG, significant cost reductions can be obtained. Innovative tools linking automated tracking of quality metrics to costing data provide significant opportunities for focused interventions (eg, ventilator weaning protocols) that increase quality, decrease costs, and thereby enhance the value of CABG for individual patients and the health care system. This study provides evidence for the effectiveness of a systematic approach to define, measure, and modulate the drivers of value for cardiothoracic surgery patients. We present our findings as a model for cardiothoracic surgeons to adapt individual practices and health care systems to flourish in this new environment (Video 1).

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

References

- Jin R, Furnary AP, Fine SC, Blackstone EH, Grunkemeier GL. Using Society of Thoracic Surgeons risk models for risk-adjusting cardiac surgery results. *Ann Thorac Surg*. 2010;89:677-82.
- LaPar DJ, Filardo G, Crosby IK, Speir AM, Rich JB, Kron IL, et al. The challenge of achieving 1% operative mortality for coronary artery bypass grafting: a multi-institution Society of Thoracic Surgeons database analysis. *J Thorac Cardiovasc Surg*. 2014;148:2686-96.
- Mack MJ. If this were my last speech, what would I say? *Ann Thorac Surg*. 2012;94:1044-52.
- Kimmaliardjuk DM, Toeg H, Glineur D, Sohmer B, Ruel M. Operative mortality with coronary artery bypass graft: where do we stand in 2015? *Curr Opin Cardiol*. 2015;30:611-8.
- Osnabrugge RL, Speir AM, Head SJ, Jones PG, Ailawadi G, Fonner CE, et al. Prediction of costs and length of stay in coronary artery bypass grafting. *Ann Thorac Surg*. 2014;98:1286-93.
- Scudeler TL, Rezende PC, Hueb W. The cost-effectiveness of strategies in coronary artery disease. *Expert Rev Pharmacoecon Outcomes Res*. 2014;14:805-13.
- Osnabrugge RL, Speir AM, Head SJ, Jones PG, Ailawadi G, Fonner CE, et al. Cost, quality, and value in coronary artery bypass grafting. *J Thorac Cardiovasc Surg*. 2014;148:2729-35.e2721.
- Porter ME, Teisberg EO. Redefining competition in health care. *Harv Bus Rev*. 2004;82:64-76.136.
- Hawkins RB, Mehaffey JH, Yount KW, Yarbboro LT, Fonner C, Kron IL, et al. Coronary artery bypass grafting bundled payment proposal will have significant financial impact on hospitals. *J Thorac Cardiovasc Surg*. 2018;155:182-8.
- Porter ME. What is value in health care? *N Engl J Med*. 2010;363:2477-81.
- Bradley SM, Strauss CE, Ho PM. Value in cardiovascular care. *Heart*. 2017;103:1238-43.
- Ken Lee KH, Matthew Austin J, Pronovost PJ. Developing a measure of value in health care. *Value Health*. 2016;19:323-5.
- Kilic A, Shah AS, Conte JV, Mandal K, Baumgartner WA, Cameron DE, et al. Understanding variability in hospital-specific costs of coronary artery bypass grafting represents an opportunity for standardizing care and improving resource use. *J Thorac Cardiovasc Surg*. 2014;147:109-15.
- Mandigo M, O'Neill K, Mistry B, Mundy B, Millien C, Nazaire Y, et al. A time-driven activity-based costing model to improve health-care resource use in Mirbalais, Haiti. *Lancet*. 2015;385(Suppl 2):S22.
- Lee VS, Kawamoto K, Hess R, Park C, Young J, Hunter C, et al. Implementation of a value-driven outcomes program to identify high variability in clinical costs and outcomes and association with reduced cost and improved quality. *JAMA*. 2016;316:1061-72.
- Kawamoto K, Martin CJ, Williams K, Tu MC, Park CG, Hunter C, et al. Value driven outcomes (VDO): a pragmatic, modular, and extensible software framework for understanding and improving health care costs and outcomes. *J Am Med Inform Assoc*. 2015;22:223-35.
- Verheij J, van Lingen A, Raijmakers PG, Rijnsburger ER, Veerman DP, Wisselink W, et al. Effect of fluid loading with saline or colloids on pulmonary permeability, oedema and lung injury score after cardiac and major vascular surgery. *Br J Anaesth*. 2006;96:21-30.
- Gondos T, Marjanek Z, Ulaksai Z, Szabó Z, Bogár L, Károlyi M, et al. Short-term effectiveness of different volume replacement therapies in postoperative hypovolaemic patients. *Eur J Anaesthesiol*. 2010;27:794-800.
- Lellouche F, Mancebo J, Joliet P, Roeseler J, Schortgen F, Dojat M, et al. A multicenter randomized trial of computer-driven protocolized weaning from mechanical ventilation. *Am J Respir Crit Care Med*. 2006;174:894-900.
- Barber J, Thompson S. Multiple regression of cost data: use of generalised linear models. *J Health Serv Res Policy*. 2004;9:197-204.
- Mani K, Lundkvist J, Holmberg L, Wanhainen A. Challenges in analysis and interpretation of cost data in vascular surgery. *J Vasc Surg*. 2010;51:148-54.
- Manning WG, Basu A, Mullahy J. Generalized modeling approaches to risk adjustment of skewed outcomes data. *J Health Econ*. 2005;24:465-88.
- Benjamin EJ, Blaha MJ, Chiuve SE, Cushman M, Das SR, Deo R, et al. Heart disease and stroke statistics-2017 update: a report from the American Heart Association. *Circulation*. 2017;135:e146-603.
- Epstein AJ, Polsky D, Yang F, Yang L, Groeneveld PW. Coronary revascularization trends in the United States, 2001-2008. *JAMA*. 2011;305:1769-76.
- Center for Medicare and Medicaid Services: CMS-5519. Medicare Program; Advancing Care Coordination through Episode Payment Models (EPMs). Washington, DC: Department of Health and Human Services; 2016.
- Institute of Medicine (IOM), Smith M, Saunders R, Stuckhardt L, McGinnis JM, eds. *Best Care at Lower Cost: The Path to Continuously Learning Health Care in America*. Washington, DC: The National Academies Press; 2013:239-47.

Key Words: value-driven outcomes, CABG, value, cost effectiveness

Discussion

Moderator: David T. Cooke

Moderator: Murray G. Kwon

Moderator. This is Dr Jason Glotzbach with “The new paradigm of value-driven care in cardiothoracic surgery: defining and achieving “perfect care” for patients after coronary artery bypass surgery to promote cost-effectiveness.”

Dr Jason P. Glotzbach (Salt Lake City, Utah). Thank you. Good morning. And thank you to the Association for allowing us to present our data here today. We have nothing to disclose. First, I will provide a little background for this study. I think most of us have heard that CMS has announced they are going to start bundling reimbursement for CABG care in the United States. This represents a deliberate move away from the fee for service model that we’ve all been traditionally operating under for decades, the first phase is rolling out July 1, so this is coming and we all have to learn how to deal with it. Basically the concept is an episode-based or episode payment model, looking at the entire episode of care for a given patient with a given disease. For coronary disease, this includes primary care physicians, cardiologists, interventional cardiologists, cardiac surgeons, all sharing the care of a certain patient in an episode model. The key with this is that it’s all one big pool of payment, of bundled reimbursement for this one disease in one

patient, and so we have to work within this to provide a procedure for these patients, or we're taking care of these patients, we need to work within this larger framework, and then... sorry if this doesn't project well... but down on the bottom, they mention that value-based decisions are going to be key for this effort so this brings up the concept of value. Value as we're talking about it in this setting has a very specific definition. This is not just a kind of fluffy term.

Michael Porter, who is a Harvard Business School economist, is one of the thought leaders in this area. In the *New England Journal* of 2010, he defines value as neither an abstract ideal nor a code word for cost reduction, so this is a very specifically defined term in this setting. At the University of Utah we've done a lot of work on this. This is a paper published from our institution last year in *JAMA*, looking at value and describing our value-driven outcomes program which we've been developing has an institution-specific proprietary system to try to effect value, defined by this equation. On the top is quality, which is what we would traditionally think of as outcomes and service, divided by cost. Defined in this very specific way, we sought to design a study to look at modifiable clinical metrics in CABG patients at our institution that could be modified to improve value in the postoperative period. This is an observational study. We used our value-driven outcome tool, which I'll be talking more about as we go along, which allowed us to collect data prospectively and retrospectively throughout this study. We looked at just isolated CABG patients, all comers over the period, at our institution. Our goal was to define metrics that might affect value or cost. We started with the 7 process measures that we're all very familiar with in the STS database, and we defined successful achievement of these 7 metrics as achieving perfect care. Perfect care is a term we're using very specifically in this context to mean achieving these arbitrary metrics that we've designated, so this is not meant to be a global term. To improve compliance with the metrics we chose, we implemented clinical protocols in our practice in the ICU and the wards, and then we looked at prospectively collected data linking cost to clinical outcomes using our VDO tool. Here are the metrics, these are all familiar to us, antibiotics given, antiplatelet, antilipid, β -blocker at discharge, use of a mammary, and avoiding reintubation. So, using these 7 metrics we started looking at our compliance and we saw that we actually were doing pretty well, and I think that most programs in the modern era are something like this where we're basically hitting all of these milestones most of the time.

You can see on the bar graph on the left, 90% of patients had 7 of 7 metrics, so 100% compliance, and then another 9% only missed 1, so 99% of patients were getting most of these accomplished and then if you look on the right side, you see over time our compliance rate, there's very minimal variability in cost, in this graph the cost is the

red line and the blue line is the percentage of perfect care with these 7 metrics. So even with a little bit of variability in the rate of achieving perfect care, we're still not seeing that much variability in cost. Frankly, we were a little bit disappointed that applying these metrics didn't really do anything with cost in this patient population, so we thought, okay, we need to add something else. We need to find some more metrics, so going back to this, one signal we noticed here was in the reintubation rates, which is in the middle column there on the right. There is some variability there so we focused on mechanical ventilation and tried to drill down on that as a driver of costs. We added another metric to track discontinuation of mechanical ventilation within 24 hours. We also looked at length of stay in our ICU and saw that some patients were lingering on inotropes for 24-48 hours, which would keep them in the ICU and so another metric we added was to focus on discontinuing inotrope use within 24 hours. Finally, we noticed that we were using a lot of albumin for routine resuscitation, which is, of course, more expensive than crystalloid, so we added albumin usage as a third metric. So at that point, we added more protocols, focusing on these 3 additional metrics, trying to increase compliance. This probably doesn't project well, but this is just an example of one of our protocols and these are designed to empower the nurses, the respiratory therapists, the overnight house staff to function autonomously within these protocols to move care along for these patients, so trying to get people extubated and wean the inotropes and do that without having to run it all the way up the chain to the attending physician. When we looked at these metrics, the dashed line represents the implementation of these protocols. This is when we started focusing on these 3 additional metrics, and then we retrospectively collected data from the electronic medical record (EPIC), going back to the beginning of the study. Before we started really focusing on this, there was quite a lot of variability and then after we implemented the protocols, we tended to get a little bit better compliance with these 3 metrics, and you see some more variability on the left hand with the bar graphs that we actually have some room to improve compared with the STS metrics where we were doing very well. So, here's our results.

We looked at 400 patients total. There was no difference in age. There was an interesting, higher percentage of male patients in the group that did get perfect care. The rest of the demographic characteristics were not different. Ethnicity and insurance status were the same, notably. In terms of comorbidities or medical history, the group that ended up without perfect care had a higher incidence of heart failure, pulmonary hypertension, previous stroke, and COPD preoperatively. That was significant, in addition to a higher STS score as you would predict from all those comorbidities, and a lower percentage of patients with a normal EF. So, all those things were real differences between the 2

populations. We'll talk more about that a little later. There was no difference in the surgical priority of the 2 groups. In terms of outcomes there was no difference in 30-day mortality, stroke, or postoperative MI and there was a significant difference in atrial fibrillation rates with the perfect care group lower.

So now looking at all metrics put together... these are all 10 metrics over the entire study, again cost is in red, the percent compliance is in blue. We see that after our phase II protocol, we start to see some variation where cost is going down as our compliance with these metrics goes up. This is the cost savings, so on the left is total cost, we observed a 45% reduction in mean total cost per patient care episode when we achieved perfect care versus when we didn't. And remember, perfect care is defined by these 10 metrics in our institution. Other categories: facilities, fees, supplies, etc. The facilities fee is a surrogate for length of stay. And then finally, we did a univariate linear regression analysis, trying to look at the correlation between the rate of perfect care and the mean total cost, and we see a significant result of an inverse relationship between those 2 things. So, as compliance with perfect care goes up, our cost goes down.

We were encouraged by these results; however, our study does have several limitations. We used an automatic data collection system that's linked to the electronic medical record, so we're dependent on the fidelity of the EMR. So, if it's not in EPIC, we didn't capture it in this study. So that's certainly a limitation. Also, the preoperative risk is clearly different between these 2 groups of patients, so are we just showing a sicker higher-risk patient population costs more to care for? As it stands now we can't account for that in our data and we're currently working on a multivariate analysis to try to account for the STS score, and correct for the preoperative risk. As of now I can't really comment on that. I think that this is a limitation, but I do think from the data that we have a suggestion that we're on to something although we need to do more work to prove this point out. Finally, this is a single-institution process that was our deliberate design, but also a weakness in that we cannot apply our metrics to other practices or other institutions because we made these metrics specific for our practice at our institution. We also limited it to our index hospitalization so we're not looking at long-term cost here.

So, in conclusion, I think that using a tool that links cost data to clinical metrics will allow you to measure and then therefore influence value. This is going to be a crucial concept that we're all going to have to be looking at, and I think this paradigm represents a way to accomplish this goal. At our institution, we measure perfect care with these 10 metrics that we've chosen and then when we achieve that care, we see significant cost reductions within our patients post-CABG and so I think this process represents a model or framework that we can use collectively going forward,

as we try to deal with this changing regulatory and reimbursement environment. In conclusion, I would like to thank my co-authors and partners as well as our IT and statistical support from the VDO team at University of Utah. Thank you.

Dr Ben Taylor (*Boise, Idaho*). Jason, thank you for your presentation. Thank you for my colleagues at Utah for tackling a difficult topic here. This is something we're all faced with and value outcomes and clinical outcomes often aren't on the same trajectory... don't even intersect, and so a lot of us have issues with focusing on value outcomes when we really as surgeons want to concentrate on clinical outcomes.

You already alluded to the topic of my first question which is related to how your 2 populations are risk-unadjusted. So, you had 400 patients that were consecutive. They were risk-unadjusted, so you had 255 that were let's say much better operative candidates, so they all got perfect care. They lived happily ever after, they got all your 8 or 10 metrics, and you saved 45% on their care and that's great. The other 145 patients had worse EF, they had more heart failure, they had a higher history of stroke, more COPD, and a much higher STS score, 3% versus 1%. So, they were always going to cost more. So, I'm sure you've looked into how you could risk-adjust these 2 groups and maybe it's not possible on the basis of statistics, but what... if you can't do that, what would your next intervention be, and have you thought about for those high-risk patients that you could incorporate into your model in terms of saving costs, on the basis of your video?

Dr Glotzbach. Thanks, Dr Taylor. I appreciate your comments. So, this is clearly a limitation that we're struggling with and I would like to make 2 points on this. I think, number 1, there's clearly going to be a group of patients that you can't fast-track through in this kind of approach. I think that what we're focusing on here, is that we can identify a group of patients that should be fast-tracked, and that we can maximize value by limiting all these things that increase costs. So, I think highlighting that preoperatively or when the patient hits the ICU we can sort patients into groups where this is a routine fast-track patient and these are not, and I think going forward, we're starting to stratify patients a little bit more. In terms of these data themselves, it's difficult because we are not powered to risk-adjust very well. So, we're trying to get to a multivariate analysis but where this is an ongoing project so I think as we collect more data over the next 12 months, we'll be able to do that a little bit more effectively. I think the overall point I would make is I think we should be working to achieve value when you have equivalent clinical outcomes. I think doing something that's cheaper but that's going to provide lesser clinical outcome, obviously none of us are interested in that and so I think the

goal of this kind of effort is to identify things that are clinically equivalent, but influence cost differently. Albumin I think is a good example where there's a lot of good data on routine resuscitation, there's probably no clinical difference between crystalloid and albumin, but albumin costs more at most institutions, if we find the right metrics, we can reduce cost for everybody regardless of risk.

Discussant. That's great. And then the second question was can you drill down a little bit more on this VDO and your whole process. Who does the legwork and how do you set that up?

Dr Glotzbach. Absolutely. You probably noticed there are no dollar signs in this presentation, so this is a closely guarded state secret at the University of Utah, that this VDO process is a proprietary software that links with EPIC, which is our electronic medical record, and so it's kind of a black box in terms of how it works. The concept is that it's built to be a real-time data analysis tool, so we're getting monthly reports from the VDO team saying this was your cost of CABG last month and they drill down on all these different costs, and not looking at billing or kind of traditional cost analysis of how much we're billing the insurance company but actually what we're spending in the hospital and so that's the key difference that I think sets this process apart and gives the institution an advantage while we're trying to figure out cost.

Dr Robert Cerfolio (New York, NY). My main point is, and I guess you've got to say something 8 times before it gets delivered, so this would be my 4th at this meeting. This is not value. You are looking at 10 metrics that are myopic. Richard Whyte got mad at me, I called him myopic, but this is really myopic. When you buy a car, bro, you don't ask if it's good at 30 or 90 days... you ask what is it at 5 and 10 years?

Dr Glotzbach. Right.

Dr Cerfolio. We've got to stop pigeonholing ourselves to 30- and 90-day value. What makes you better than a cardiologist is your reintervention rate, your patency rate, your decreased cost. A recurrent cancer costs \$110,000. That's why an operation is better than SRS. Value is quality divided by cost, not 30- or 90-day metrics, but 3, 5, 7, 10 years... durability. We do it for orthopedic surgeons, quality of life, return to work, that's what we should be looking at. So, I would argue we have got to start writing articles that show our worth of value at real-time intervals which ain't 30 and 90 days.

Dr Glotzbach. Absolutely. Thanks, Dr Cerfolio. That's a really good point, and I think this represents the very beginning of our process and we have a chronic phase that we're starting where we're looking at patient follow-up and

starting at 90 days and pushing farther out. I think our goal is to build this into a longitudinal process where eventually it would look at 5, 10 years, if we can show value at that level, then that's the...

Dr Cerfolio. And you will. And finally, costs come down when very... any system's cost comes down when you limit variations. The problem with surgeons is we all have variables, this staple or that staple or this needle driver is too heavy, I want the green one. Ridiculous. Cut out all the variations, take your surgical tray from 200 instruments and make it 12. Watch what happens to your costs.

Dr Glotzbach. Right. Thank you.

Dr Eugene Grossi (New York NY). Nice presentation. Quick question. Of those patients receiving nonperfect care, how many were due to system failure and how many were due to patient disease?

Dr Glotzbach. That's a great question. Unfortunately, I can't answer that for these data. I think that depending on the metric, certainly patient disease would play into ventilator use, inotrope use, that kind of thing, and we're starting to try to stratify these patients so we can identify the ones that need more care, the sicker patients, for example, a patient with a low EF coming out of CABG obviously will need more ICU time than a patient with normal function, so I think that the system's interventions are the easy part. Dealing with the sicker patients or the kind of variability among different patient courses is much more difficult in this kind of an endeavor, but we're definitely working on that.

Moderator. One last question, Dr Shemin.

Dr Richard Shemin. You know, I compliment you on all the efforts and I think all of us continue to look at what we can control in the postoperative care and hospitalization, but the real challenge for us is controlling costs throughout the 90-day bundle. And what of the data sets that we will

have, how will we organize our patients so that we maintain the control and the decision-making, as opposed to the decisions that might be out of our control in the community and I wonder what your thoughts are in trying to do that well.

Dr Glotzbach. Absolutely, I agree that's critical, and I think every institution and every practice is going to have to come up with something that works locally. This is very difficult to generalize but for us at our institution, what we're doing as an extension of this VDO project, is we're now pushing this out to 90 days where we have phone calls going out to patients at home and clinic visits and all that is being incorporated into this data collection model where we're looking at costs longitudinally and so

there's the acute hospitalization and then there's the 2 and a half months after. For example, we're looking at whether the patient is enrolling in cardiac rehab within 2 weeks or are they taking their medications, and what's their weight doing? All those things we are now collecting as the chronic phase of this project and so I think going forward

we'll be reporting these results where we try to intervene in the kind of intermediate term of this process, and then hopefully we can continue to push out to the long-term and so I think this is an ongoing process that we're all going to have to be working with going forward.

Dr Shemin. Thank you very much.

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Adult: Coronary

ORIGINAL SUBMISSION: Remote Ischemic Preconditioning in High Risk Cardiovascular Surgery Patients: A Randomized-Controlled Trial. Nicole S. Coverdale. *Semin Thoracic Surg* 2018: 26-33

Editorial Commentary: Remote Ischemic Preconditioning: A Complex Question with an Even More Complex Answer. Irving L. Kron. *Semin Thoracic Surg* 2018: 34-35

FIGURE E1. Histogram data of distribution of cost data. Mean cost for each treatment group is marked by the *solid line* (not “perfect care”) and *dashed line* (“perfect care”). The data fit a gamma distribution.

Cullen, A. and Frey, H. (1999). Probabilistic Techniques in Exposure Assessment. Plenum Publishing Co., 1st edition.

- Bootstrapped skewness and kurtosis values (Efron and Tibshirani, 1994) are included on the plot to account for inherent uncertainty/"lack of robustness" of skewness and kurtosis measures.
- It was determined that the Gamma was a reasonable fit for the data (see also the plots below)

FIGURE E2. Additional evidence for gamma distribution of cost data. Probabilistic modeling of data using multiple bootstrapped iterations to account for the inherent uncertainty in the data. *CDFs*, Cumulative distribution function.