The 30-Year Influence of a Regional Consortium on Quality Improvement in Cardiac Surgery

Alexander Iribarne, MD, MS, Bruce J. Leavitt, MD, Benjamin M. Westbrook, MD, Reed Quinn, MD, John D. Klemperer, MD, Gerald L. Sardella, MD, Robert S. Kramer, MD, Daniel J. Gelb, MD, MS, David C. Charlesworth, MD, Jeremy Morton, MD, Charles A. S. Marrin, MBBS, Anthony DiScipio, MD, Jock McCullough, MD, Cathy S. Ross, MS, and David J. Malenka, MD, for the Northern New England Cardiovascular Disease Study Group

Section of Cardiac Surgery, Department of Surgery, Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire; Section of Cardiac Surgery, Department of Surgery, University of Vermont Medical Center, Burlington, Vermont; Section of Cardiac Surgery, Department of Surgery, Catholic Medical Center, Manchester, New Hampshire; Section of Cardiac Surgery, Department of Surgery, Maine Medical Center, Portland, Maine; Section of Cardiac Surgery, Department of Surgery, Eastern Maine Medical Center, Bangor, Maine; Section of Cardiac Surgery, Department of Surgery, Concord Hospital, Concord, New Hampshire; Section of Cardiology, Department of Medicine, Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire

Background. **The Northern New England Cardiovascular Disease Study Group (NNECDSG) was founded in 1987 as a regional consortium to improve cardiovascular quality in Maine, New Hampshire, and Vermont. We sought to assess the longitudinal impact of the NNECDSG on quality and cost of coronary artery bypass grafting (CABG) during the past 30 years.**

Methods. **Patients undergoing isolated CABG at 5 medical centers from 1987-2017 were retrospectively reviewed (n = 67,942). They were divided into 4 time periods: 1987-1999 (n = 36,885), 2000-2005 (n = 14,606), 2006-2011(n = 8470), and 2012-2017 (n = 7981). The first period was the time the NNECDSG initiated a series of quality improvement initiatives including data feedback, quality improvement training, process mapping, and site visits.**

Results. **Throughout the 4 time intervals, there was a consistent decline in in-hospital mortality, from 3.4% to 1.8% despite an increase in predicted risk of mortality (*P* < .001), and a significant decline in in-hospital morbidity, including return to the operating room for bleeding, acute kidney injury, mediastinitis, and low output failure (*P* < .001). Median length of stay decreased from 7 to 5 days (*P* < .001), which translated into potential savings of $82,722,023. There was a decrease in use of red blood cells from 3.1 units to 2.6 units per patient in the most current time, which translated into potential savings of $1,985,456.**

Conclusions. **By using collaborative quality improvement initiatives, the NNECDSG has succeeded in significant, sustained improvements in quality and cost for CABG during the past 30 years. These data support the utility of a regional consortium in improving quality.**

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Regional consortia have been used across cardiovascular subspecialties to improve quality and patient outcomes.[1-3] The Northern New England Cardiovascular Disease Study Group (NNECDSG) was the first regional consortium focused on quality improvement in cardiac surgery. For 30 years, the NNECDSG has used registry data across hospitals in Maine, New Hampshire, and Vermont to study regional variation in outcomes after surgery.

The NNECDSG was created in 1987 in response to data published by the Health Care Financing Authority on in-hospital mortality rates among Medicare beneficiaries.[4] At the time, contemporary methods for database maintenance and analysis using risk adjustment did not exist, and the decision was made to collect data on consecutive isolated coronary artery bypass grafting (CABG) in Northern New England hospitals, which ultimately formed the NNECDSG.[5] After 2 years, data on approximately 3000 CABG operations were collected and demonstrated risked-adjusted mortality rates by center ranging from 2.3% to 5.7% and mortality rates by surgeon ranging from 2.2% to 9.3%.[6]

Over time, regional quality improvement initiatives were performed using benchmarking site visits, quality improvement training, process mapping, and direct data feedback.[7] CABG mortality rates began to decline, and by

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Address correspondence to Dr Iribarne, Section of Cardiac Surgery, Dartmouth-Hitchcock Medical Center, 1 Medical Center Drive, Lebanon, NH 03756; email: alexander.iribarne@hitchcock.org.

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9 months, the regional CABG mortality rate decreased by 24%.[7] Since this time, our collaborative has evolved to pursue quality improvement initiatives in areas such as blood conservation, low output heart failure, and early extubation. In addition, regional consortia have been developed in other regions of the United States and have demonstrated improvements in patient outcomes through effective collaboration.[8-10]

With any quality improvement initiative, questions always surround the long-term sustainability of such interventions. In this analysis, we examine the longitudinal influence of the NNECDSG on quality improvement over the past 30 years.

Patients and Methods

Data Source

Data were obtained from the NNECDSG Registry from 1987-2017. Registry data are validated against hospital billing data every 2 years for complete capture of cases and to ensure the accuracy of vital status at discharge. Institutional Review Boards at all participating medical centers have designated the NNECDSG as quality improvement, and therefore, patient consent for data collection and analysis was waived.

Patients and Time Periods

There were 67,942 patients who underwent isolated CABG from 1987-2017 across 5 medical centers in Maine, New Hampshire, and Vermont. Data were divided into 4 time periods: 1987-1999 (n = 36,885), 2000-2005 (n = 14,606), 2006-2011 (n = 8470), and 2012-2017 (n = 7981). The time from 1987-1999 was referred to as the preintervention and intervention period, noted as the time when the NNECDSG was started, implemented a data collection tool, and engaged in focused continuous quality improvement initiatives to reduce mortality. During this time, there were also efforts on reducing low-output heart failure, which was the major cause of death after CABG in the region. The later years were divided into 3 equal 6-year periods to examine the sustained influence of quality improvement.

Study End Points

The primary end point was in-hospital mortality. In addition, we examined length of stay (LOS), packed red blood cell (PRBC) transfusion during the intraoperative and postoperative period, and in-hospital morbidity, including return to the operating room for bleeding, renal failure, acute kidney injury, mediastinitis or sternal dehiscence, prolonged intubation ($\geq$24 hours), low-output heart failure, stroke, and pneumonia. Low-output heart failure was defined as the use of an intraoperative or postoperative intraaortic balloon pump, the need to return to cardiopulmonary bypass, or continuous use of 2 or more inotropes at 48 hours postoperatively. Acute kidney injury was defined as an increase in serum creatinine level 3.0-times greater than baseline, or a serum creatinine level of 4 mg/dL or more, acute rise must be at least 0.5 mg/dL, or new requirement for hemodialysis. Renal failure was defined as the need for new hemodialysis.

Cost Information

Given that the analysis included 5 hospitals across 3 states and across 3 decades, direct hospital cost data were unavailable. LOS was used as a proxy for inpatient cost savings. We started with the per day average cost for inpatient care using data from the American Hospital Association Annual Survey.[11] These data were compiled by year and state into State Health Facts, a project of the Henry J. Kaiser Foundation, which we used to adjust for inflation.[11] Cost savings for LOS were calculated as median days saved, per patient, as a multiplier over the total patients for each subsequent time period, compared with the previous time period.

For costing blood transfusion, we assumed that all patients underwent blood typing and cross-match, and these costs were not considered in the analysis. We focused specifically on patients who received PRBCs intraoperatively or postoperatively and analyzed the costs associated with the unit of blood as well as the cost of PRBC administration. Using 2017 hospital costing data from 1 center, we estimated the cost of administering 1 unit of PBRC at $87.84 and the cost of the unit itself at $120. We used the United States Bureau of Economic Analysis Gross Domestic Product: Chain-type Price Index to adjust costs of PBRC for inflation.[12] Cost savings for blood transfusion were calculated as average units saved, per patient, as a multiplier over the total patients for each subsequent time period, compared with the previous time period.

Statistical Analysis

Univariate comparisons of patient characteristics, by time category, are summarized using percentages for categorical variables and means or medians for continuous variables, using Pearson χ^2 test and the Student *t* test (or Wilcoxon rank sum test for nonparametric data), respectively. We used a test for trend to compare outcomes over time periods. Multivariable logistic regression was used to adjust in-hospital mortality; our risk adjustment model has been published previously.[13] All analyses were performed using Stata 14.0 software (StataCorp, College Station, TX).

Results

Patient Characteristics

Between 1987 and 2017, 67,942 patients underwent isolated CABG. Patient and disease characteristics are summarized in Table 1. Over time, fewer isolated CABGs were performed in the region. Compared with the earliest time, patients during the most recent time period were older, included fewer women, and had a larger body mass index. Patients in the most current time period also had

Table 1. Patient and Disease Characteristics

Characteristics	Time Period				P Value[a]
	1987-1999	2000-2005	2006-2011	2012-2017	
Number of procedures	36,885	14,606	8470	7981	...
Age, y	64.7 ± 10.4	65.6 ± 10.7	65.3 ± 10.4	66.0 ± 9.8	<.001
<60	11,570 (31.4)	4467 (30.6)	2602 (30.7)	2086 (26.1)	<.001
60-69	12767 (34.6)	4569 (31.3)	2909 (34.3)	2993 (37.5)	
70-79	10,748 (29.2)	4450 (30.5)	2318 (27.4)	2345 (29.4)	
≥80	1771 (4.8)	1118 (7.6)	641 (7.6)	557 (7.0)	
Female sex	10,258 (27.8)	3820 (26.2)	1990 (23.5)	1749 (21.9)	<.001
Body surface area, m^2	1.96 ± 0.23	2.01 ± 0.24	2.04 ± 0.25	2.06 ± 0.25	<.001
<1.70	4087 (12.9)	1399 (9.6)	743 (8.8)	553 (6.9)	<.001
1.70-1.99	14,443 (45.5)	5765 (39.5)	2983 (35.3)	2739 (34.3)	
≥2.00	13,214 (41.6)	7423 (50.9)	4737 (56.0)	4689 (58.8)	
Body mass index, kg/m^2	28.4 ± 5.1	29.3 ± 5.6	29.9 ± 6.0	30.3 ± 5.9	<0.001
<18.5	172 (0.7)	101 (0.7)	51 (0.6)	27 (0.3)	<0.001
18.5-24.9	6265 (24.2)	3042 (20.9)	1580 (18.8)	1309 (16.5)	
25.0-29.9	11,138 (43.1)	5697 (39.1)	3134 (37.2)	2886 (36.3)	
≥30	8267 (32)	5736 (39.4)	3653 (43.4)	3729 (46.9)	
Prior coronary artery bypass grafting	2272 (6.9)	620 (4.3)	212 (2.5)	153 (1.9)	<0.001
Prior percutaneous coronary intervention	4640 (16.2)	2425 (16.6)	1957 (23.1)	2219 (27.8)	<.001
Comorbid disease					
Diabetes	9008 (24.4)	4976 (34.1)	3145 (37.1)	3426 (42.9)	<.001
Vascular disease	4819 (13.1)	3318 (22.7)	2079 (24.6)	2283 (28.6)	<.001
Chronic obstructive pulmonary disease	3206 (8.7)	1457 (10.0)	1263 (14.9)	1580 (19.8)	<.001
Congestive heart failure	4019 (10.9)	1835 (12.6)	1123 (13.3)	1603 (20.1)	<.001
Dialysis or creatinine ≥2 mg/dL	827 (2.8)	528 (3.6)	385 (4.6)	264 (3.3)	<.001
New York Heart Association, class IV or V	346 (18.86)	1693 (19.9)	1381 (22.68)	498 (20.6)	<.001
Ejection fraction	0.54 ± 0.138	0.535 ± 0.135	0.535 ± 0.128	0.538 ± 0.121	.37
<0.40	4380 (13.7)	1892 (14.7)	1070 (13.6)	1005 (13.0)	<.001
0.40-0.49	5465 (17.1)	1971 (15.4)	1170 (14.9)	1098 (14.2)	
0.50-0.59	7822 (24.5)	3172 (24.7)	2048 (26.1)	2248 (29.2)	
≥0.60	14,212 (44.6)	5808 (45.2)	3549 (45.3)	3362 (43.6)	
Coronary artery disease					
Left main stenosis ≥50%	8601 (23.3)	4532 (31.0)	3174 (37.5)	3079 (38.6)	<.001
3-vessel disease	15,712 (50.8)	7497 (52.1)	4457 (53.0)	4591 (57.7)	<.001
Myocardial infarction ≤7 days	3106 (8.4)	3148 (21.6)	2271 (26.8)	2370 (29.7)	<.001
Priority at surgery					
Elective	13,513 (36.7)	3922 (26.9)	2372 (28.0)	2522 (31.6)	<.001
Urgent	20,756 (56.4)	9597 (65.8)	5472 (64.6)	5087 (63.7)	
Emergency	2521 (6.9)	1076 (7.4)	623 (7.4)	372 (4.7)	

[a]P value for the χ^2 test or nonparametric test of trend.

Data are presented as number (%) or mean ± SD.

higher frequencies of comorbidities, including diabetes, peripheral vascular disease, chronic obstructive pulmonary disease, congestive heart failure, and renal insufficiency. In addition, patients presented to surgery more urgently and more frequently within 7 days of a myocardial infarction.

Primary and Secondary Outcomes

Throughout the study, there was a consistent decline in unadjusted in-hospital mortality from 3.4% in the earliest time to 1.8% in the present ($P < .001$l; Table 2). Moreover, while the expected mortality increased over time, there was a consistent decline in the observed-to-expected ratio of mortality, with observed mortality rates for approximately the past 10 years generally at or below 2% (Figure 1). In addition to improvements in in-hospital mortality, in-hospital morbidity also significantly declined. Specifically, there were continuous reductions in return to the operating room for bleeding, acute kidney injury, mediastinitis, and low-output heart failure ($P < .001$; Table 2).

Table 2. Primary and Secondary Crude Outcomes

In-hospital Outcomes	1987-1999	2000-2005	2006-2011	2012-2017	*P* Value[a]
Mortality [b]	1246 (3.4)	362 (2.5)	187 (2.2)	143 (1.8)	<.001
Stroke[c]	386 (1.5)	213 (1.5)	137 (1.6)	102 (1.3)	.434
Return to operating room for bleeding[c]	1362 (5.2)	375 (2.6)	169 (2.0)	137 (1.7)	<.001
Acute kidney injury	...	280 (3.0)	205 (2.5)	120 (1.5)	<.001
Renal failure	...	95 (0.65)	85 (1.00)	52 (0.65)	.037
Mediastinitis/sternal dehiscence[c]	313 (1.2)	100 (0.7)	48 (0.6)	29 (0.4)	<.001
Pneumonia	...	285 (2.2)	201 (2.4)	166 (2.1)	.438
Prolonged intubation (>24 h) and/or reintubation[d]	898 (8.4)	1304 (9.3)	911 (11.1)	704 (8.9)	<.001
Low-output heart failure[d]	1132 (9.1)	818 (5.7)	487 (5.9)	362 (4.7)	<.001

[a]*P* value for the χ^2 test or nonparametric test of trend; [b]Data first available on consecutive patients in 1987; [c]Data first available on consecutive patients in 1992; [d]Data first available on consecutive patients in 1996.

Data are presented as the rate number (%).

Hospital Costs

The median LOS significantly declined from 7 days in 1987-1999 to 5 days in the most recent time period ($P <$ .001). When cumulative reductions in LOS were analyzed, there was an estimated total potential cost savings of $82,722,023 for the study duration ($P < .001$; Table 3). Use of PRBCs also decreased significantly, from a mean of 3.1 units per patient to a mean of 2.8 units per patient ($P <$ .001). This reduction in PRBC use represents a cumulative potential cost savings of $1,985,456 for the study duration (Table 4).

Comment

While the NNECDSG has been in existence for the past 30 years, the central goal of the consortium—to foster a multidisciplinary, voluntary collaborative dedicated to improving cardiovascular quality— has remained unchanged. In this longitudinal, multicenter analysis, we demonstrate that a regional collaborative resulted in significant and sustained improvements in patient outcomes as well as significant cost savings. These data demonstrate an important role for regional collaboration in cardiac surgery quality improvement.

In 1987, when the NNECDSG was first developed, the concept of using registry data to study outcomes after cardiac surgery was novel. Prompted by early published data on Medicare mortality rates after CABG, original members of the NNECDSG noted significant variation in mortality throughout the region by hospital and surgeon. Even after risk adjustment and review of catheterization data for complexity of coronary anatomy, the observed variation in mortality persisted.[14]

In response, the NNECDSG developed a quality improvement program that included data feedback to medical centers and surgeons, quality improvement training, process mapping, and a series of benchmarking

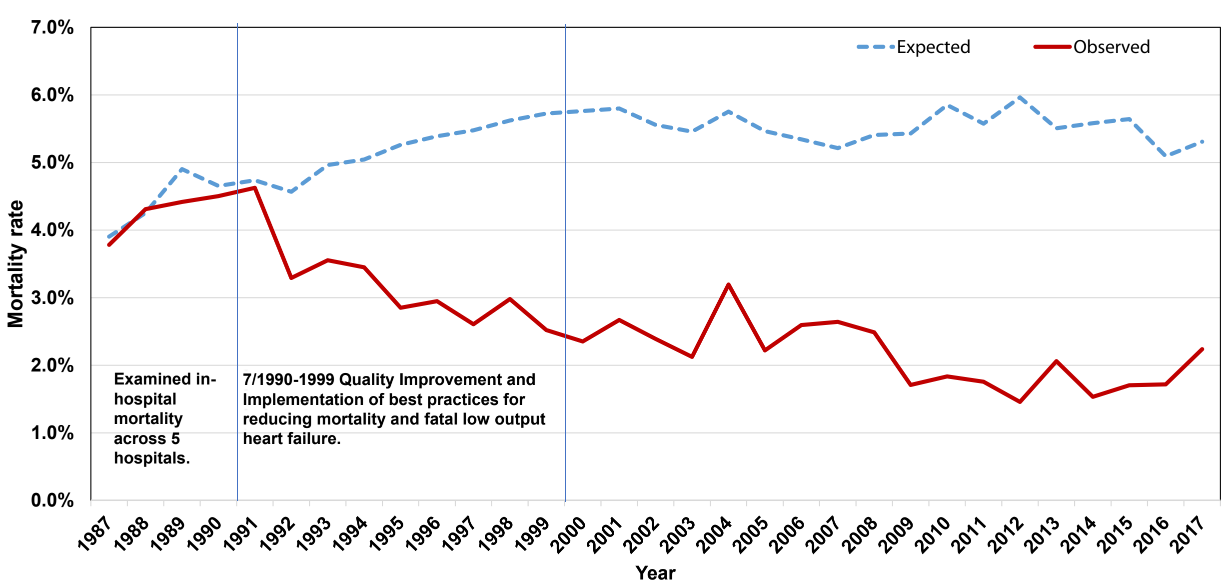

Figure 1. Observed and expected in-hospital mortality after coronary artery bypass grafting.

Table 3. Length of Stay for Patients Discharged Alive Estimated Cost Savings

	Isolated CABG				
Variable	1987-1999	2000-2005	2006-2011	2012-2017	1987-2017
Median length of stay, days	7	5	6	5	6
Patients, No.	35,621	14,244	8283	7838	65,986
Average daily inpatient cost, $		1210	1637	2213	
Potential savings, $	…	34,469,074	13,555,163	34,697,787	
Total potential savings 1987-2017					82,722,023

CABG, coronary artery bypass grafting; No., number.

site visits.[14-16] These techniques were developed based on the works of Deming[17] and Berwick,[18] who were among the first to call for the adoption of the methods of continuous quality improvement in health care. In addition, a feedback report was distributed to each center 3 times a year that included regional outcomes, center outcomes, and deidentified individual surgeon outcomes. In-person meetings were also conducted 3 times per year and focused on review of regional trends in outcomes data and quality improvement.

Within 6 months of our consortium, there was a decline in CABG mortality, and within 9 months, the regional mortality declined by 24%, with no change in patient risk.[7] In an analysis by Peterson and colleagues[19] in 1998, equivalently low mortality rates for CABG among Medicare beneficiaries were observed in the NNECDSG and the New York State Cardiac Surgery Reporting System. Now, after 30 years, we demonstrate that the NNECDSG has had a significant and sustained decline in morbidity and mortality after CABG despite persistently rising expected mortality. In the present, the regional unadjusted mortality rate for CABG was 1.8%, which is similar to the 2017 in-hospital mortality in The Society of Thoracic Surgeons (STS) national database for isolated CABG of 1.8%.[20] Morbidity has also declined in the region, with significant and sustained improvements in return to the operating room for bleeding, acute kidney injury, mediastinitis, and low-output heart failure. Importantly, major complications such as stroke and renal failure have remained low, and LOS in the present is below the national median of 6 days.[20] We attribute our regional outcomes to continuous quality improvement initiatives that still include benchmarking, regional meetings, and outcomes reports conducted 3 times per year.

Our analysis lacks the granularity to distinguish which early interventions, described in detail previously,[7] resulted in the observed improvements in mortality. However, it is likely that a multifaceted approach, tailored to the needs of individual hospitals, provides the greatest benefit. In addition, with advances in perioperative management, we have shifted quality improvement efforts to best practices in the areas of perioperative readiness for surgery, reduction of PRBC transfusion, and development of prediction models for low-output heart failure.[21,22] We have maintained momentum for the NNECDSG by continuously evolving our quality improvement initiatives, data collection methods, and surgeon-specific quality reports.

The positive influence of regional collaboration on quality is strengthened by the fact that other areas in the United States have used a similar approach to improve outcomes. The Virginia Cardiac Surgery Quality Initiative (VCSQI) is a voluntary consortium that covers 99% of the state's cardiac surgery operations and has been in existence for approximately 20 years.[8] The collaboration has resulted in numerous quality improvement initiatives, including transfusion reduction, perioperative glucose management, early extubation, and atrial fibrillation

Table 4. Red Blood Cell Transfusion Estimated Cost Savings

	Isolated CABG			
Variable	2000-2005	2006-2011	2012-2017	*P* Value
No. patients	14,606	8470	7981	
No. patients with RBC data[a]	11,844	8457	7969	
No. patients receiving RBCs	5,689	2525	1820	
Patients receiving RBCs, % (No.)	48.0	29.9	22.8	<.001
Average units per patient	3.1	3.1	2.8	<.001
Total units given	17,572	7802	5074	
Savings, $		863,528	1,121,928	
Total potential savings 2000-2017, $			1,985,456	

[a]RBC data became available in 2001.

CABG, coronary artery bypass grafting; No., number; RBC, red blood cell.

prophylaxis.[23-25] The VCSQI meets quarterly, and the collaborative focuses on establishing clinical priorities, periodic reporting, and identifying best practices and underperformance. Through linkage of clinical data to UB-04 cost data, the VCSQI collaborative has also studied resource utilization.[3] Unlike our study, which uses estimated cost savings, UB-04 data allow for true all-payor cost analyses, such as the incremental cost of postoperative complications.[3]

Rich and colleagues[26] recently demonstrated cost savings of $10,212,637 and $8,519,630 secondary to avoidance of prolonged ventilation and acute renal failure, respectively. In our analysis, we estimated total cost savings $82,722,023 during the study period secondary to reductions in LOS as well as $1,985,456 in cost savings secondary to reductions in PRBC use. Of note, the importance of PRBC reduction extends beyond cost and also reduces transfusion-related complications.[24] We note, however, that LOS was used in our analysis as a proxy for costs and that this measure is only one component of actual payor costs.

Prager and colleagues[10] have similarly reported the success of regional collaboration through the Michigan Society of Thoracic and Cardiovascular Surgeons (MSTCVS). Through a unique collaboration with Blue Cross/Blue Shield, the MSTCVS has pursued numerous quality improvement initiatives in areas such as internal mammary artery use, preoperative intraaortic balloon pump use, and CABG risk-adjusted mortality.[27] Like the techniques used by the NNECDSG, the MSTCVS continuously analyzes data for outliers and conducts in-person site visits for centers with adjusted mortality consistently higher than the state or STS average. Like the results observed with the NNECDSG, these efforts have resulted in financial savings while maintaining mortality rates below the national average. Although not specifically quantified in this report, regional consortia also provide a forum for discussing new ideas and reviewing data to advance quality outcomes research.

With a continued focus on public reporting of health quality data, a natural question of regional collaborations is how the publication of such data influences quality.[28] Recently, Shahian and colleagues[29] reported on the influence of mandatory public reporting in Massachusetts. The authors demonstrate that during the 12 years of public reporting, risk-adjusted mortality after CABG was consistently lower than the national average. It is important to note, however, that static reporting of data alone is unlikely to improve quality. As the authors conclude, surgeon involvement in the measure development process, peer adjudication, and efforts for improvement at outlier hospitals is an important component of quality improvement. The authors also note that surgeons in public reporting states may benefit from formal peer organizations that are most easily operationalized at the state or regional level.

All centers in the NNECDSG participate in the STS Adult Cardiac Surgery database, and we see our regional efforts as supplementary to and concordant with national quality initiatives. The NNECDSG is a voluntary collaborative and does not publicly report data but does provide regional reports that include individual center outcomes as well as deidentified surgeon outcomes. Each surgeon is provided with a confidential unique identifier to allow for benchmarking among peers, and these reports are reviewed 3 times a year at regional meetings to address outlying trends and provide rapid feedback for improvement. Thus, regional consortia with direct surgeon involvement and peer-to-peer quality improvement represent an alternative model to mandatory state reporting that can achieve a similar end goal of improving patient outcomes.

Study Limitations

This analysis has several limitations. First, all centers in the analysis were participants in the NNECDSG. Although the introduction of the NNECDSG correlated with sustained improvements in quality over the study, this does not imply a causal relationship.

Second, the NNECDSG data collection forms evolved during the study. Major outcomes, such as mortality, were collected throughout the study; however, other outcome measures, such as renal insufficiency and pneumonia, were not collected in the earliest time period.

Lastly, the cost savings from the NNECDSG were based on state cost estimates of hospitalization, and the PRBC cost was based on costs from a single participant center. Given that the study spanned 30 years and 5 medical centers, direct cost could not be reported. Nevertheless, the intention of cost data was to demonstrate an estimate of potential cost savings associated with regional collaboration rather than costs associated with specific outcome measures. Because cost data were derived from acute care hospitalization data rather than cardiac service line cost data, actual point estimates of cost may vary.

Conclusion

The NNECDSG was the first regional consortium in the United States to leverage clinical registry data to improve regional outcomes with cardiac surgery. Over the past 30 years, despite a rising predicted risk of mortality, there have been sustained regional improvements in morbidity and mortality after CABG in Northern New England. Regional consortia provide opportunities for continuous quality improvement and enhance national efforts by providing a forum for evaluation and engagement on a local level.

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