Advancing cardiotomy suction practices for coronary surgery via multidisciplinary collaborative learning

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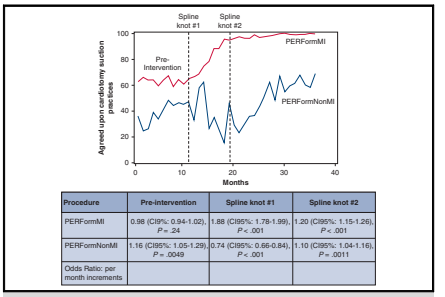
ABSTRACT

Objective: Professional standards recommend stopping cardiotomy suction at the termination of cardiopulmonary bypass before protamine administration based on perceived safety concerns. This study evaluated a multidisciplinary collaborative quality-improvement intervention promoting this agreed-upon cardiotomy suction practice during coronary artery bypass grafting (CABG).

Methods: A statewide intervention (eg, unblinded surgeon and perfusionist feedback, evidence-based lectures, evaluating barriers to change) involved 32 centers participating in the PERForm (ie, Perfusion Measures and Outcomes) Registry to standardize cardiotomy suction practices at cardiopulmonary bypass termination during CABG. Four non-Michigan registry participating centers were not exposed to collaborative learning. Cardiotomy suction practice was defined as the absence of or stopping cardiotomy suction before protamine administration. The practice changes attributed to the intervention, including Michigan and non-Michigan comparisons, were evaluated with the change of time effect modeled using splines. Multivariable regression was used to evaluate the intervention's associated impact (eg, mortality, reoperation, transfusion).

Results: Among 10,394 patients undergoing CABG at Michigan centers, 80.7% achieved agreed-upon cardiotomy suction practices. The Michigan centers had nonsignificant changes in agreed-upon cardiotomy suction practices during the preintervention period ($P = .24$), with significant increased monthly change in practice thereafter, absent adjusted morbidity and mortality increases. The Michigan centers achieved a significantly greater adjusted monthly improvement in agreed-upon practices relative to non-Michigan centers within 7 months after the intervention (adjusted odds ratio for change of trends: 2.53, $P < .001$).

Conclusions: This initiative demonstrates the effectiveness of multidisciplinary collaborative quality improvement in advancing agreed-upon cardiotomy suction practices without negatively impacting clinical outcomes. (JTCVS Open 2024;17:121-44)



Procedure	Pre-intervention	Spline knot #1	Spline knot #2
PERFormMI	0.98 (CI95%: 0.94-1.02), $P = .24$	1.88 (CI95%: 1.78-1.99), $P < .001$	1.20 (CI95%: 1.15-1.26), $P < .001$
PERFormNonMI	1.16 (CI95%: 1.05-1.29), $P = .0049$	0.74 (CI95%: 0.66-0.84), $P < .001$	1.10 (CI95%: 1.04-1.16), $P = .0011$
Odds Ratio: per month increments			

Agreed-upon cardiotomy suction practice use within Michigan versus non-Michigan centers.

CENTRAL MESSAGE

Use of agreed-upon cardiotomy suction practices was advanced via a statewide quality learning intervention without negatively impacting risk-adjusted clinical outcomes.

PERSPECTIVE

This statewide study evaluated the role of a multidisciplinary collaborative learning intervention to implement professional consensus-based cardiotomy suction practices. Collaborative centers in Michigan increased agreed-upon cardiotomy suction practice use during isolated CABG surgery, whereas centers outside of Michigan had lower adoption. Adjusted outcomes were not negatively impacted.

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Abbreviations and Acronyms

AmSECT	= American Society for Extracorporeal Technology
CABG	= coronary artery bypass grafting
CI	= confidence interval
CPB	= cardiopulmonary bypass
MSTCVS-QC	= Michigan Society of Thoracic and Cardiovascular Surgeons Quality Collaborative
OR_{adj}	= adjusted odds ratio
PERForm	= Perfusion Measures and Outcomes
VBR	= value-based reimbursement

Patient care during cardiac surgical procedures using cardiopulmonary bypass (CPB) requires a multidisciplinary effort to safely advance the initiation and termination of bypass. The American Society for Extracorporeal Technology (AmSECT) was created with the goal of improving patient care and safety through continued research and education of safe extracorporeal circulation practices.[1] AmSECT has developed professionally based consensus standards and guidelines ("Standards and Guidelines") that reflect recommended practices to advance safe and effective perfusion practices.[2] These Standards and Guidelines, which are grounded predominantly in perceived safety concerns, have been endorsed by both perfusion (eg, The American Academy of Cardiovascular Perfusion) and surgical societies (The Society of Thoracic Surgeons, The American Association for Thoracic Surgery).

The termination of cardiotomy suction following protamine administration may theoretically increase the risk of clot formation within the CPB circuit. This risk has been theorized based on the lack of predictable response of a patient's activated clotting time to protamine test dosing.[3] In the event of early hemodynamic instability following termination of CPB, such a clot may in turn render the circuit unavailable for urgent return to CPB. Center-specific surveillance data additionally suggest considerable interhospital variability in the timing of cardiotomy suction cessation relative to protamine administration.[4] Based on these perceived safety concerns, AmSECT's membership voted to include a conservative practice guideline for the termination of cardiotomy suction before protamine administration as a standard in its 2017 Standards and Guidelines document.[5]

Collaborative learning, involving performance feedback and benchmarking, has been leveraged predominantly by cardiac surgeons to advance evidence-based practices and postoperative outcomes.[6-8] This multicenter study evaluated the role of collaborative learning in standardizing the practice of cardiotomy suction termination before the administration of protamine during isolated coronary artery bypass grafting (CABG).

METHODS

Patients and Methods

This quality improvement study leveraged data from the Perfusion Measures and Outcomes (PERForm) Registry, which is maintained through the Michigan Society of Thoracic and Cardiovascular Surgeons Quality Collaborative (MSTCVS-QC) and is the official registry of the American Society of Extracorporeal Technology. Participating centers provide the PERForm registry's Data Coordinating Center with its institutional surgical (Society of Thoracic Surgeons Adult Cardiac Surgery Database) and detailed perfusion data, both of which are subject to audit. The study cohort included adults (≥18 years) undergoing isolated CABG between October 1, 2018, and September 30, 2021. The dataset included 32 centers (of the 36 PERForm registry participants) involved in a statewide, multidisciplinary collaborative learning initiative. The MSTCVS-QC partnered with The Michigan Perfusion Society[9] to advance perfusion representation and involvement (in and outside of MSTCVS-QC quarterly meetings) in this initiative.

Data-use agreements restrict the distribution of raw study−related data files. Requests for summary statistics will be reviewed and may be approved by the study team.

The analysis focused on patients undergoing isolated CABG (Figure E1). This study was designated as "Not Regulated" by the University of Michigan Medical School Institutional Review Board: HUM00198261 (approval: June 8, 2021); the need for informed consent was waived.

Data Elements and Outcome Measures

This study evaluated pre-, intra-, and postoperative variables contained in the surgical and perfusion datasets. Preoperative characteristics included patient demographics, comorbidities, laboratory data, as well as Society of Thoracic Surgeons Adult Cardiac Surgery Database predicted mortality and major morbidity. Intraoperative treatment characteristics included procedure type, CPB and crossclamp durations, intra-aortic balloon pump, static extracorporeal circuit prime volume, conventional ultrafiltration, autotransfusion, and ultrafiltration indexed to the patient's weight, nadir hematocrit on CPB, anticoagulation management, protamine dosing (milligrams) and method, and blood-management practices. The primary outcome was the MSTCVS-QC's agreed-upon cardiotomy suction practice following CPB termination, defined as either not using cardiotomy suction or terminating its use before any protamine administration. By consensus, the timing of protamine administration was considered to begin with the administration of a test dose. Secondary outcomes included red blood cell transfusions, visible evidence of a clot within the heart−lung machine (eg, oxygenator, venous and/or cardiotomy reservoirs, filters, pump tubing) at any point in the operation, intensive care unit hours, total ventilation time (hours), reoperation for bleeding, renal failure, stroke, and operative death.

Multidisciplinary Collaborative Learning Intervention

The PERForm registry began collecting data concerning the timing of cardiotomy suction termination on October 1, 2018 (start of the baseline, preintervention period). An in-depth description of the collaborative learning approach is provided in Appendix E1. Discussions surrounding this collaborative learning intervention began at the 2019 Summer MSTCVS-QC's quarterly conference, with attendance from each Michigan cardiac surgical center (eg, thoracic surgeons, perfusionists, anesthesiologists, database managers), Table E1. Representatives from the MSTCVS-QC presented data, with surgeons and perfusionists presenting their local

practice patterns, data supporting their decisions, and benefits and drawbacks for alternative cardiotomy suction practices. Subsequent presentations occurred at the Fall 2019 MSTCVS-QC quarterly conference (also attended by similar center representatives), with the goal of developing a performance benchmark for isolated CABG.

MSTCVS-QC Timing of Protamine Administration Benchmark

The MSTCVS-QC Quality Committee, the executive arm of the MSTCVS-QC, establishes performance benchmarks for its participating centers. These benchmarks serve as part of the Blue Cross Blue Shield of Michigan value-based reimbursement (VBR) incentive program. Participating centers receive financial incentives if they achieve or exceed the established MSTCVS-QC's performance benchmark.

The MSTCVS-QC has undertaken previous collaborative learning initiatives among its centers, albeit traditionally focused on performance measures involving a single intraoperative specialty (eg, increasing internal mammary artery use among surgeons).[6-8] The MSTCVS-QC's Quality Committee achieved its first perfusion statewide VBR in 2019 that defined cardiotomy suction practices according to the following: (1) AmSECT's Standard 12.1 ("Cardiotomy suction shall be discontinued at the onset of protamine administration to avoid clotting within the CPB circuit"[5]) and (2) emerging suggestive safety data.[3] Specifically, the VBR stipulated that 65% of all isolated CABG operations would use this agreed-upon cardiotomy suction practice entailing either (1) no cardiotomy suction use on initiation of protamine or (2) terminating cardiotomy suction before protamine administration (including a test dose). All statewide centers would receive (1) a financial incentive if the MSTCVS-QC achieved its target performance or (2) no incentive if the target was not achieved. This statewide, multidisciplinary collaborative learning intervention was based on perceived safety concerns regarding the timing of cardiotomy suction termination, rather than a strong foundation of evidence within the literature. The intervention officially began between January 1, 2020, through September 30, 2020.

Statistical Analyses

Categorical and continuous variables were compared using χ^2 and Wilcoxon rank-sum tests, respectively. A generalized linear mixed effect model was performed to evaluate the impact of the quality-improvement intervention on the agreed-upon cardiotomy suction practice among the 32 Michigan centers that were subject to collaborative learning relative to the 4 non-Michigan PERForm centers. The change of time effect was modeled using 2 spline terms, with the knots at the time of intervention (August 2019) and an empirically defined changing trend (March 2020). This model adjusted for patient characteristics and risk factors as the fixed effect, and surgeon as the random effect. The fixed effects included age, body surface area, sex, race, ejection fraction, creatinine, white blood count, cardiogenic shock, atrial fibrillation, cardiac symptom at the time of admission (eg, unstable angina), cerebrovascular disease, previous stroke, diabetes, New York Heart Association class, home oxygen therapy, pneumonia, current smoke status, hypertension, immunosuppression, left main disease, number of diseased vessels, liver disease, myocardial infarction less than 7 days from the operation, previous cardiovascular intervention, percutaneous coronary intervention in less than 6 hours, intra-aortic balloon pump, peripheral arterial disease, dialysis, admission status, and anticoagulant medication.

Several analyses were conducted. First, comparisons in blood management and anticoagulation practices were compared between low- and high-performing Michigan centers as well as the 2 lowest- and 2 highest-performing non-Michigan centers. Second, the intervention was assessed related to clinical outcomes (ie, reoperation due to bleeding, intraoperative and postoperative transfusion, renal failure, stroke, operative mortality) with multivariable logistic regression models.

Variance inflation factor values were calculated based on both CABG and aortic valve replacement cohorts, with no evidence of concern regarding colinearity.[10] Analyses were performed using SAS 9.4 (SAS Institute).

RESULTS

A total of 10,394 patients underwent isolated CABG at Michigan centers between October 1, 2018, and September 30, 2021. Of these, 3491 (33.6%) procedures were performed before and 6903 (66.4%) following the start (August 2019) of the collaborative learning intervention. The agreed-upon cardiotomy suction practices were used in 62.8% (n = 2194) of patients in the preintervention period, with 27.8% (n = 609) of those patients having no cardiotomy suction and 72.2% (n = 1585) having cardiotomy suction terminated before protamine administration. In the postintervention period, the agreed-upon cardiotomy practice was used in 89.7% (n = 6192) of patients, with 5.6% (n = 346) having no cardiotomy suction and 94.4% (n = 5846) having cardiotomy suction terminated before protamine administration ($P < .001$ for the comparison of pre- and postintervention). The non-Michigan centers, which did not receive the intervention, used the agreed-upon practices in 77.5% (620/800) of procedures. Average (standard deviation) agreed-upon practice use among surgeons increased between the preintervention (n = 86, 65.2% [42.5%]) and postintervention (n = 98, 88.8% [18.8%]) periods, $P < .001$.

Patients receiving versus not receiving the agreed-upon cardiotomy suction practices were qualitatively similar with respect to patient demographics and baseline comorbidities, Table 1. A full listing of characteristics stratified by the 2 cardiotomy suction practices and time periods is provided in Table E2.

Intra- and Postoperative Characteristics Among Michigan Centers

Patients in whom cardiotomy suction was terminated before protamine administration had significantly longer median crossclamp times (77 minutes vs 71 minutes, $P < .001$), similar ($P > .05$) median CPB duration and use of red blood cell transfusion, and were more likely to receive an autotransfusion device (99.4% vs 91.3%, $P < .001$), while less likely to undergo retrograde autologous priming (84.1% vs 94.9%, $P < .001$). Clot within the heart−lung machine was visible among 0.48% of procedures and was lower in the group receiving the agreed-upon cardiotomy suction practices (0.4 vs 0.9, $P < .001$). Unadjusted rates of operative mortality (0.6% vs 0.4%, $P = .61$), renal failure (1.9% vs 2.0%, $P = .81$), stroke (1.4% vs 0.9%, $P = .11$), and reoperation for bleeding (1.8% vs 1.4%, $P = .26$) were similar between the 2 groups, whereas patients in whom the pump suckers were turned off before protamine had a significantly greater

TABLE 1. Preoperative characteristics for patients undergoing CABG among Michigan centers stratified by use of agreed-upon cardiotomy suction practices during the whole study period

Variables	Overall (n = 10,394)	Nonadoption of agreed-upon practices (n = 2008)	Adoption of agreed-upon practices (n = 8386)	*P* value
Age, y	67.0 [60.0, 73.0]	67.0 [60.0, 73.0]	67.0 [60.0, 73.0]	.40
Body surface area, m^2	2.1 [1.9, 2.2]	2.1 [1.9, 2.3]	2.1 [1.9, 2.2]	.56
Female	2385 (22.9)	458 (22.8)	1927 (23.0)	.89
Race				.03
Black	531 (5.1)	126 (6.3)	405 (4.8)	
Asian	92 (0.9)	20 (1.0)	72 (0.9)	
White and other	9771 (94.0)	1862 (92.7)	7909 (94.3)	
Ejection fraction	57.0 [48.0, 61.0]	58.0 [48.0, 62.5]	57.0 [48.0, 61.0]	.49
Creatinine, mg/dL	1.0 [0.83, 1.2]	1.00 [0.86, 1.20]	0.99 [0.83, 1.18]	.02
Hematocrit	40.4 [36.9, 43.7]	40.4 [37.1, 43.7]	40.4 [36.8, 43.7]	.85
White blood cell count, thousands	8.00 (3.10)	7.93 (3.28)	8.01 (3.05)	.30
Shock	194 (1.9)	24 (1.2)	170 (2.0)	.02
Atrial fibrillation	613 (5.9)	139 (6.9)	474 (5.7)	.03
Cardiac presentation at admission				<.001
No symptom	437 (4.2)	72 (3.6)	365 (4.4)	
Stable angina	1289 (12.4)	184 (9.2)	1105 (13.2)	
Unstable angina	3847 (37.0)	867 (43.2)	2980 (35.5)	
Non-STEMI	2964 (28.5)	508 (25.3)	2456 (29.3)	
Other (includes STEMI)	1857 (17.9)	377 (18.8)	1480 (17.6)	
Cerebrovascular disease	2805 (27.0)	555 (27.6)	2250 (26.8)	.48
Stroke	856 (8.2)	152 (7.6)	704 (8.4)	.25
Diabetes and control method				.56
Insulin diabetes	1993 (19.2)	368 (18.3)	1625 (19.4)	
Noninsulin diabetes	3095 (29.8)	605 (30.1)	2490 (29.7)	
Other or no diabetes	5306 (51.0)	1035 (51.5)	4271 (50.9)	
New York Heart Association class III/IV	1023 (9.8)	169 (8.4)	854 (10.2)	.02
Home oxygen	161 (1.5)	45 (2.2)	116 (1.4)	.01
Recent pneumonia	207 (2.0)	39 (1.9)	168 (2.0)	.93
Recent smoker	2282 (22.0)	441 (22.0)	1841 (22.0)	1.00
Hypertension	9507 (91.5)	1873 (93.3)	7634 (91.0)	.00
Immunosuppressive therapy	430 (4.1)	88 (4.4)	342 (4.1)	.58
Left main disease	2334 (22.5)	656 (32.7)	1678 (20.0)	<.001
Liver disease	317 (3.0)	70 (3.5)	247 (2.9)	.23
Myocardial infarction within 7 d	3016 (29.0)	492 (24.5)	2524 (30.1)	<.001
Number of diseased vessels				.11
One or fewer	253 (2.4)	46 (2.3)	207 (2.5)	
Two	1870 (18.0)	330 (16.4)	1540 (18.4)	
Three	8271 (79.6)	1632 (81.3)	6639 (79.2)	
Previous cardiac intervention	3620 (34.8)	692 (34.5)	2928 (34.9)	.72
Percutaneous coronary intervention within 6 h	63 (0.6)	16 (0.8)	47 (0.6)	.29
Preoperative intra-aortic balloon pump or inotropes	717 (6.9)	94 (4.7)	623 (7.4)	<.001
Peripheral arterial disease	1581 (15.2)	332 (16.5)	1249 (14.9)	.071
Dialysis	257 (2.5)	44 (2.2)	213 (2.5)	.41

(Continued)

TABLE 1. Continued

Variables	Overall (n = 10,394)	Nonadoption of agreed-upon practices (n = 2008)	Adoption of agreed-upon practices (n = 8386)	*P* value
Status				.03
Elective	4032 (38.8)	832 (41.4)	3200 (38.2)	
Urgent	6128 (59.0)	1133 (56.4)	4995 (59.6)	
Emergent	232 (2.2)	43 (2.1)	189 (2.3)	
Anticoagulants within 48 h	5144 (49.5)	879 (43.8)	4265 (50.9)	<.001

Values are median (interquartile range) or n (%). *STEMI*, ST-Elevation myocardial infarction; *CABG*, coronary artery bypass grafting.

rate of postoperative red cell transfusion (24.0% vs 20.2%, $P < .001$). Both groups had a qualitatively similar need to return to CPB (2.2% vs 1.7%, $P = .17$), median ventilation hours (5.1 vs 5.5, $P < .001$), and intensive care unit hours (48.0 vs 52.9, $P < .001$), Table 2. Risk-adjusted outcomes among patients undergoing CABG within Michigan centers are displayed in Table 3. Risk-adjusted outcomes were similar between the 2 cardiotomy suction practice groups, including intra- (adjusted odds ratio [OR_{adj}], 0.93; 95% confidence interval [CI], 0.78-1.1) or postoperative (OR_{adj}, 1.15; 0.97-1.36) red cell transfusion, renal failure (OR_{adj}, 0.73; 0.48-1.13), stroke (OR_{adj}, 1.39; 0.80-2.41), reoperation due to bleeding (OR_{adj}, 1.29; 0.84-1.98), and operative mortality (OR_{adj}, 1.05; 0.48-2.29).

There was no significant change in clot formation between the groups ($P = .75$) following the intervention, whereas median intensive care unit (47.5 vs 53.0, $P < .001$) and total ventilation (5.1 vs 5.4, $P = .008$) duration were lower among those receiving the agreed-upon cardiotomy suction practice. A full listing of intra- (including protamine dosing and method) and postoperative characteristics stratified by adoption (or not) of agreed-upon cardiotomy suction practices and time periods is provided in Table E3.

Changes of Trends in Cardiotomy Suction Practices due to the Collaborative Learning Intervention

There was no significant monthly change in cardiotomy suction practices during the preintervention period among Michigan centers (OR_{adj}, 0.98; 95% CI, 0.94-1.02). There was a (1) progressive increase in the monthly use of agreed-upon cardiotomy suction practice within 7 months after initiating the intervention (OR_{adj}, 1.89; 95% CI; 1.78-1.99) and (2) sustained increased monthly use of these practices thereafter (OR_{adj}, 1.20; 95% CI. 1.15-1.26), Table 4.

Univariate Comparisons of Michigan and Non-Michigan Centers

Detailed characteristics of patients cared for at non-Michigan centers are provided in Table E4. Anticoagulation and blood management practices among CABG operations were compared between the low and high tercile performing Michigan centers, as well as the 2 lowest- and highest-performing non-Michigan centers, Table E5. In addition, comparisons of pre-, intra-, and postoperative characteristics between Michigan and non-Michigan centers are displayed in Table E6.

Evaluation of Trends Among Non-Michigan Centers Not Subject to the Multidisciplinary Collaborative Learning Intervention

Among non-Michigan hospitals, there was a significant monthly increase in use of agreed-upon cardiotomy suction practices in the preintervention period (OR_{adj}, 1.16; 95% CI, 1.05-1.29; $P = .0049$), whereas there was a significant monthly decrease within 7 months after initiating the intervention (OR_{adj}, 0.74; 95% CI, 0.66-0.84), and then a significant monthly increase thereafter (OR_{adj}, 1.10; 95% CI, 1.04-1.16). The Michigan centers achieved a significantly greater adjusted monthly improvement in use of these practices relative to non-Michigan centers within 7 months after the intervention (OR_{adj} for change of trends: 2.53, $P < .001$), Table 4 and Figure 1.

DISCUSSION

This large, multicenter study evaluated the role of a multidisciplinary statewide collaborative learning intervention in advancing the adoption of agreed-upon cardiotomy suction practices that included terminating cardiotomy pump suction before the administration of protamine during isolated CABG surgery (Figure 2). Michigan centers involved in collaborative learning had an increase in the adoption of these agreed-upon cardiotomy suction practices within the setting of isolated CABG, whereas non-Michigan centers had lower adoption levels. This result was achieved without an associated adverse impact on patient outcomes.

Previous studies have documented variability in the timing of protamine administration relative to the termination of cardiotomy suction.[4] These findings, in combination with the perceived safety concerns among members of the intraoperative clinical team, support standardizing protamine administration to reduce the theoretical risk of visible clot formation within the CPB circuit. The MSTCVS-QC has previously undertaken other collaborative learning interventions that include tailored performance feedback and group learning for surgeons.[6-8] To our knowledge,

TABLE 2. Intra- and postoperative characteristics for patients undergoing CABG among Michigan centers stratified by use of agreed-upon cardiotomy suction practices during the whole study period

Variables	Overall (n = 10,394)	Nonadoption of agreed-upon practices (n = 2008)	Adoption of agreed-upon practices (n = 8386)	*P* value
Intraoperative				
Perfusion, min	97.0 [74.0, 126.0]	94.0 [72.0, 127.0]	98.0 [74.0, 126.0]	.05
Crossclamp, min	76.0 [54.0, 100.5]	71.0 [50.0, 97.0]	77.0 [56.0, 101.0]	<.001
Return to cardiopulmonary bypass (yes)	217 (2.1)	34 (1.7)	183 (2.2)	.17
Hemodynamic instability	122 (1.2)	22 (1.1)	100 (1.2)	.72
Technical	110 (1.1)	14 (0.7)	96 (1.1)	.08
Other	7 (0.07)	1 (0.05)	6 (0.07)	1.00
Red cell transfusion				.76
0	9111 (87.7)	1758 (87.5)	7353 (87.7)	
1-2	1045 (10.1)	206 (10.3)	839 (10.0)	
≥3	238 (2.2)	44 (2.2)	194 (2.3)	
Autotransfusion device used	10,165 (97.8)	1833 (91.3)	8332 (99.4)	<.001
Retrograde autologous priming	8959 (86.2)	1905 (94.9)	7054 (84.1)	<.001
Evidence of clot in circuit	50 (0.48)	17 (0.9)	33 (0.4)	.01
Postoperative				
Red cell transfusion				.00
0	7973 (76.7)	1602 (79.8)	6371 (76.0)	
1-2	1752 (16.9)	296 (14.7)	1456 (17.4)	
≥3	669 (6.4)	110 (5.5)	559 (6.6)	
Renal failure, %	202 (2.0)	40 (2.0)	162 (1.9)	.81
Stroke, %	132 (1.3)	18 (0.9)	114 (1.4)	.11
Reoperation for bleeding	184 (1.8)	29 (1.4)	155 (1.8)	.26
Intensive care unit, h	49.0 [26.5, 88.0]	52.9 [36.0, 93.8]	48.0 [25.4, 80.4]	<.001
Ventilation time, h	5.2 [3.7, 8.3]	5.5 [4,9, 8.6]	5.1 [3.6, 8.2]	<.001
Operative mortality	57 (0.5)	9 (0.4)	48 (0.6)	.61

Values are median [interquartile range] or n (%). *CABG*, Coronary artery bypass grafting.

this study is among the first to evaluate a multidisciplinary (surgeons and perfusionists) intraoperative collaborative learning intervention for cardiac surgery. Findings from this study highlight several factors that may have contributed to the success of this multidisciplinary intervention. First, surgeon and perfusionist leaders advocated for the importance of the initiative during quarterly MSTCVS-QC conferences that provided a forum for candid discussions on the topic. Second, identifying a performance benchmark along with a group incentive program focused efforts toward a shared goal. Although prior collaborative learning approaches have focused on advancing clinician and hospital performance,[11-14] this statewide VBR-based initiative provided shared accountability across all 32 Michigan centers.

Previous reports have highlighted the importance and impact of advancing care quality and outcomes through state or regionally based collaborative learning interventions involving surgeons.[6-8] Although many surgeons and perfusionists presented varying opinions regarding the risks and benefits of initiating protamine administration before the cessation of cardiotomy suction during

TABLE 3. Risk-adjusted outcomes for patients undergoing CABG among Michigan centers by use of agreed-upon cardiotomy suction practices during the whole study period

Outcomes	Odds ratio	95% CI	*P* value
Intraoperative red cell transfusion	0.93	0.78-1.11	.42
Renal failure, %	0.73	0.48-1.13	.16
Stroke, %	1.39	0.80-2.41	.25
Postoperative red cell transfusion	1.15	0.97-1.36	.12
Reoperation for bleeding	1.30	0.85-1.98	.23
Operative mortality	1.05	0.48-2.29	.90

CI, Confidence interval; *CABG*, coronary artery bypass grafting.

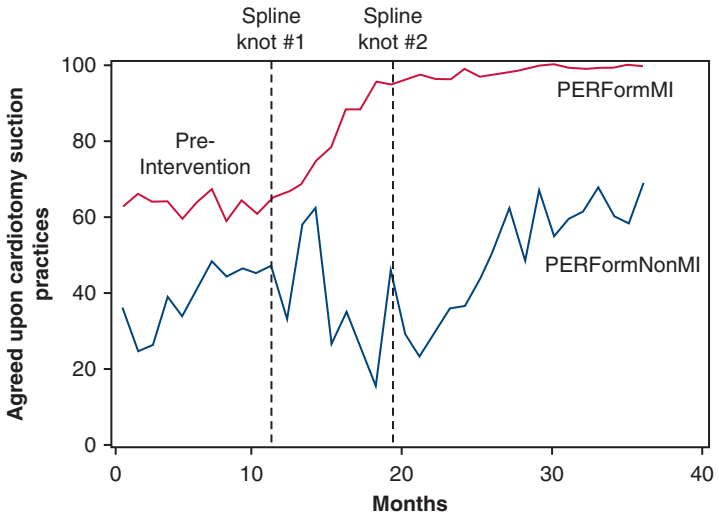
TABLE 4. The changes of trend due to interventions for patients undergoing CABG (pre-vs post- and Michigan vs non-Michigan centers)

Time period and Michigan vs non-Michigan comparisons	Odds ratio (per mo increase)	95% CI		*P* value
Non-Michigan—preintervention	1.16	1.05	1.29	.0049
Non-Michigan—post (time 11-18)	0.74	0.66	0.84	<.0001
Non-Michigan—post (time >18)	1.10	1.04	1.16	.0011
Michigan—pre	0.98	0.94	1.02	.2449
Michigan—post (time 11-18)	1.88	1.78	1.99	<.0001
Michigan—post (time >18)	1.20	1.15	1.26	<.0001
Michigan—post (time 11-18) vs pre	1.93	1.78	2.09	<.0001
Non-Michigan—post (time 11-18) vs pre	0.64	0.52	0.78	<.0001
Pre: Michigan vs non-Michigan	0.84	0.75	0.94	.0024
Post (time 11-18): Michigan vs non-Michigan	2.53	2.21	2.91	<.0001

CI, Confidence interval; *CABG*, coronary artery bypass grafting.

MSTCVS-QC quarterly meetings, both specialties were aligned on the importance of optimizing patient safety. Despite noted concerns about potential adverse sequelae associated with stopping cardiotomy suction before protamine administration, the improvement in adoption of the agreed-upon cardiotomy suction practices was associated with equivalent risk-adjusted patient outcomes.

Findings from this large, multicenter study point to a broader role of multidisciplinary collaborative learning to enhance patient safety. The Northern New England Cardiovascular Disease Study Group was the first regional cardiac surgical collaborative to leverage unblinded center-specific benchmarking data to reduce mortality secondary to fatal low cardiac output.[11-14] Other groups, including the



Procedure	Pre-intervention	Spline knot #1	Spline knot #2
PERFormMI	0.98 (CI9%: 0.94-1.02), *P* = .24	1.88 (CI95%: 1.78-1.99), *P* < .001	1.20 (CI95%: 1.15-1.26), *P* < .001
PERFormNonMI	1.16 (CI95%: 1.05-1.29), *P* = .0049	0.74 (CI95%: 0.66-0.84), *P* < .001	1.10 (CI95%: 1.04-1.16), *P* = .0011
Odds Ratio: per month increments			

FIGURE 1. Use of agreed-upon cardiotomy suction (no cardiotomy suction or cessation before protamine administration) is stratified by the: (1) 32 Michigan centers subjected to the collaborative learning intervention and (2) 4 non-Michigan control centers. The table represents risk-adjusted odds ratios reflecting the incremental change in the adoption of agreed-upon cardiotomy suction practices. *PERForm*, Perfusion Measures and Outcomes; *CI*, confidence interval.

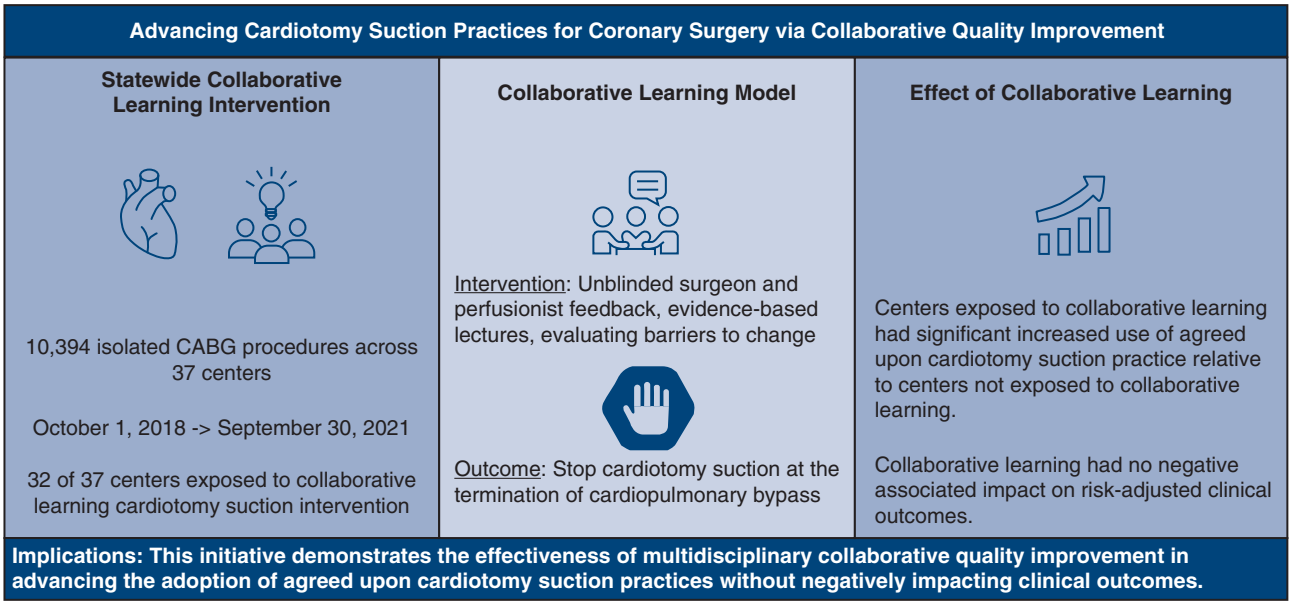


FIGURE 2. Overall study approach and findings. *CABG*, Coronary artery bypass grafting.

MSTCVS-QC, have leveraged this collaborative learning model to advance the use of the internal mammary artery[8] and evidence-based opioid prescribing practices,[15,16] as well as the prevention of postoperative pneumonia.[6,7] During this multidisciplinary intervention, surgeons and perfusionists met during and outside of the MSTCVS-QC's quarterly meetings to discuss unblinded center-specific results, as well as identify and address barriers to achieving agreed-upon performance metrics. This successful approach provides a model for addressing future multidisciplinary initiatives (eg, intraoperative blood product use, and communication during the onset of cardiopulmonary bypass). More broadly, there is a potential role for professional organizations representing surgeons (eg, The American Association for Thoracic Surgery, The Society of Thoracic Surgeons), anesthesiologists (eg, The Society of Cardiovascular Anesthesiologists) and perfusionists (eg, The American Society of ExtraCorporeal Technology, The American Academy of Cardiovascular Perfusion) to develop interdisciplinary quality improvement initiatives that leverage data housed within The Society of Thoracic Surgeons Adult Cardiac Surgical Database.

This study has the following limitations. First, although this study primarily focuses on the evaluation of cardiotomy suction practices across all 32 non-federal hospitals performing cardiac surgery throughout the state of Michigan, findings from this initiative may not be generalizable outside of the study sample. Second, while there is potentially unmeasured confounding in this nonrandomized study (eg, inability to isolate the independent effect of the VBR incentive on performance improvement; Hawthorne effect among non-Michigan centers), the analyses leveraged generalized linear mixed effect modeling accounting for preoperative risk factors and surgeons. Third, there is a lack of observational and randomized trial data supporting the role of a test dose in contributing to visible clot, and AmSECT's Standards and Guidelines do not specify the role of a test dose in contributing to visible clot in the CPB circuit. Nonetheless, the PERForm registry tracks the initiation of protamine to include any test doses. Fourth, although the goals of this project were to advance the cessation of cardiotomy suction prior to protamine administration, future work should evaluate any financial benefit associated with this strategy (eg, blood product use, intensive care unit length of stay). Last, while our registry maintains resources for submitting centers (eg, frequently asked questions[17]), the reported rate of visible clot in the heart–lung machine may be underestimated and insufficiently characterized, given our registry's definition does not specify the size, specific location, or timing of a clot during the operation.

CONCLUSIONS

This statewide, multidisciplinary collaborative learning intervention documents the success of surgeons and perfusionists working together to enhance patient safety during CPB cessation. This initiative, which resulted in a 26.9% absolute improvement in the adoption of agreed-upon cardiotomy suction practices, did not have a negative associated effect on patient outcomes.

Conflict of Interest Statement

Dr Pagani receives partial salary support from Blue Cross/Blue Shield of Michigan as Associate Director of the Michigan Society of Thoracic and Cardiovascular Surgeons Quality Collaborative. Dr Likosky receives partial salary support from Blue Cross/Blue Shield of Michigan as the Perfusion Measures and Outcomes (PERForm) Registry Director of the Michigan Society of Thoracic and Cardiovascular Surgeons Quality Collaborative. Dr Pagani is an ad hoc, noncompensated scientific advisor for Medtronic, Abbott, FineHeart, and CH Biomedical; noncompensated medical monitor for Abiomed; and a member of the Data Safety Monitoring Board for Carmat and the National Heart, Lung, and Blood Institute PumpKIN Study. Dr Stewart received funds through the Veterans Affairs (VA) as a National Clinician Scholars Program research fellow. The opinions, beliefs, and viewpoints expressed by authors do not necessarily reflect those of Agency for Healthcare Research and Quality, National Institutes of Health, VA or the US Department of Health and Human Services, Blue Cross and Blue Shield of Michigan, or its employees. All other authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: cardiac surgery, outcomes, cardiopulmonary bypass, quality improvement

APPENDIX E1. NONAUTHOR CONTRIBUTORS

The authors wish to recognize the following individuals from the Michigan Society of Thoracic and Cardiovascular Surgeons (MSTCVS-QC) Quality Collaborative and the University of Michigan for contributing to this study and manuscript.

- Dr Richard L. Prager, Emeritus Professor of Cardiac Surgery (University of Michigan, Ann Arbor, Mich) and Director Emeritus of the Michigan Society of Thoracic and Cardiovascular Surgeons Quality Collaborative (Ann Arbor, Mich)
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- David Grix, CCP-Emeritus, Education and Audit Coordinator (Michigan Society of Thoracic and Cardiovascular Surgeons Quality Collaborative, Ann Arbor, Mich)
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- Jeremy Wolverton, MS, Application Programmer/Analyst Lead (University of Michigan, Ann Arbor, Mich)

COLLABORATIVE LEARNING APPROACH

This multidisciplinary collaborative learning intervention involved a partnership between the Michigan Society of Thoracic and Cardiovascular Surgeons Quality Collaborative (MSTCVS-QC) and the Michigan Perfusion Society (MPS). Representatives from both groups were made aware of the 2017 American Society of ExtraCorporeal Technology (AmSECT) Standards and Guidelines that included a consensus-based standard related to the timing of protamine administration for adult cardiopulmonary bypass (CPB).

Standard 12.1: Cardiotomy Suction Shall Be Discontinued at the Onset of Protamine Administration to Avoid Clotting Within the CPB Circuit

The impetus for this initiative was grounded in (1) the emergence of these professionally based, consensus drive standards and guidelines; (2) a perceived safety concern regarding the risk of a visible clot in the CPB circuit if protamine were initiated before the termination of cardiotomy suction; and (3) a recent study from Toronto (https://doi.org/10.1016/j.athoracsur.2021.04.059) regarding activated clotting times associated with protamine test doses. The MSTCVS-QC and the MPS had been partnering for some time to advance quality metrics for adult CPB, and centers in the state of Michigan and some outside of Michigan were participating in a voluntary registry (Perfusion Measures and Outcomes [ie, PERForm]) that tracks perfusion practices.

Up to this point, there were rare incidents of visible clot in the circuits, with some perfusionists considering these occurrences to be linked in some fashion to the timing of protamine administration. Nonetheless, to our knowledge, there were no clinical registries at the time that collected the required data elements to track the occurrence of visible clots, let alone associate the timing of protamine administration to their occurrence. Following AmSECT's Standards and Guidelines document, the PERForm registry began collecting information related to the timing of protamine administration as well as visible clots.

The MSTCVS-QC and the MPS began developing scientific presentations at their shared quarterly meetings reflecting the practice of protamine administration and the perceived risks and benefits associated with the initiation of protamine before cardiotomy suction termination. Considering limited data supported one practice versus another, surgeon and perfusion representatives spoke of their perceived safety concerns, including in the event of the need to emergently return to CPB. Following a series of discussions, the group agreed that the benefits of a perceived reduction in the risk of an observed clot (and the lack of an available circuit if there were a need to urgently return to CPB) were sufficient to proceed with a statewide collaborative intervention. The groups compromised that the initial intervention would be focused on isolated coronary artery bypass grafting procedures, rather than on other more complex operations. A financial performance incentive would be delivered to centers if the group achieved its target performance, whereas no incentive would be realized if the target was not achieved. More specifically, the performance target stipulated that 65% for all isolated coronary artery bypass grafting operations would use agreed-upon cardiotomy suction practices entailing either (1) no cardiotomy suction use on initiation of protamine or (2) terminating cardiotomy suction before protamine administration (including a test dose). The intervention officially began between January 1, 2020, through September 30, 2020.

Although the group achieved its performance target, the intervention was voluntary, with variability persisting at the surgeon and center level. Centers embarked on their intervention in a number of ways. In general, a designated surgeon and perfusion champion assigned to each center is tasked, in part, to disseminate information from our statewide collaborative meetings. Slide decks reflecting data that are shared at our statewide meetings are distributed to these champions to further disseminate updates for those who are unable to attend the quarterly meetings. Some of these champions leverage local multi-disciplinary team meetings to raise awareness and share quarterly benchmarking

feedback reports. Anecdotally, teams shared some of the following challenges they experienced in implementing this particular intervention, including.

- Changes to the timing of protamine administration require changes to a surgeon's operative routine
- Concerns about terminating the pump suckers too early may increase the risk of blood transfusion
- Perceived lack of peer-reviewed data to support changing one's operative practice
- In the current era, changes in the configuration and sizes of a circuit have contributed to fewer options for protecting its integrity once exposed to a clot
- Differences in perspective regarding the rate of occurrence (and associated impact) of clots in a circuit
- Misunderstanding of the design and capabilities of increasingly lower-prime circuits to mitigate the risk and impact of clots

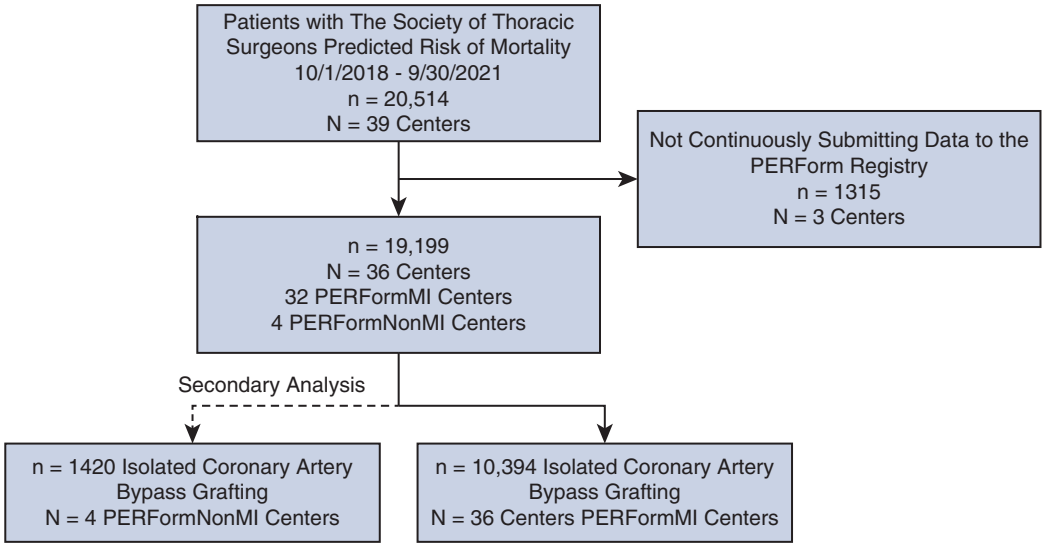

FIGURE E1. CONSORT diagram representing study sample sizes (ie, patients and centers). *CONSORT*, Consolidated Standards of Reporting Trials; *PERForm*, Perfusion Measures and Outcomes.

TABLE E1. Presentations and discussions during the 2019 Summer MSTCVS-QC's quarterly conference

Meeting topic	Presentations	Discussion: surgeons	Discussion: perfusionists
Physiology of the timing of protamine administration in relation to the termination of cardiotomy suction	(1) Pharmacokinetics of protamine in relationship to activated clotting time; (2) potential risk associated with terminating cardiotomy suction after protamine administration; and (3) interhospital variability in the timing of protamine administration.	Local practice patterns varied from essentially no routine use of cardiotomy suction, with or without the use of autotransfusion devices, to extending the use of pump suckers to some varying time frame beyond the initiation of protamine reversal, particularly during more complex procedures.	Concerns were noted about risking the integrity of the CPB circuit if requiring urgent reinstitution of CPB. Autotransfusion devices are available to process shed blood without contaminating the oxygenator.

CPB, Cardiopulmonary bypass; *MSTCVS-QC*, Michigan Society of Thoracic and Cardiovascular Surgeons Quality Collaborative.

TABLE E2. Preoperative characteristics of 10,394 patients undergoing coronary artery bypass grafting, stratified by time period and use of agreed-upon cardiotomy suction practices

Variables	Preintervention cardiotomy suction practice			After intervention cardiotomy suction practice		
	Nonadoption of agreed-upon practices	Adoption of agreed-upon practices	*P* value	Nonadoption of agreed-upon practices	Adoption of agreed-upon practices	*P* value
Patients	1297	2194		711	6192	
Preoperative	3491			6903		
Age, y	67.0 [60.0, 74.0]	66.0 [60.0, 73.0]	.11	67.0 [60.0, 73.0]	67.0 [60.0, 73.0]	.84
Body surface area, m^2	2.1 [1.9, 2.3]	2.1 [1.9, 2.2]	.61	2.1 [1.9, 2.2]	2.1 [1.9, 2.2]	.15
Female	292 (22.5)	508 (23.2)	.69	166 (23.3)	1419 (22.9)	.83
Race			.06			.00
Black	87 (6.7)	180 (8.2)		39 (5.5)	225 (3.6)	
Asian	10 (0.8)	31 (1.4)		10 (1.4)	41 (0.7)	
White and other	1200 (92.5)	1983 (90.4)		662 (93.1)	5926 (95.7)	
Ejection faction	57.0 [47.5, 62.5]	55.5 [47.0, 60.0]	.71	58.0 [48.0, 62.5]	57.5 [48.0, 61.0]	.28
Creatinine, mg/dL	1.0 [0.86, 1.2]	0.97 [0.82, 1.2]	.00	1.0 [0.85, 1.2]	1.0 [0.83, 1.2]	.19
Hematocrit	40.4 [37.1, 43.7]	40.2 [36.6, 43.2]	.06	40.5 [37.0, 43.7]	40.5 [37.0, 43.8]	.65
White blood cell count, thousands	7.9 (3.4)	8.0 (2.8)	.89	7.9 (3.2)	8.0 (3.1)	.40
Shock	18 (1.4)	52 (2.4)	.06	6 (0.8)	118 (1.9)	.06
Atrial fibrillation	94 (7.2)	135 (6.2)	.23	45 (6.3)	339 (5.5)	.39
Cardiac presentation at admission			<.001			.06
No symptom	40 (3.1)	83 (3.8)		32 (4.5)	282 (4.6)	
Stable angina	106 (8.2)	274 (12.5)		78 (11.0)	831 (13.4)	
Unstable angina	599 (46.2)	833 (38.0)		268 (37.7)	2147 (34.7)	
Non-STEMI	322 (24.8)	644 (29.4)		186 (26.2)	1812 (29.3)	
Other (includes STEMI)	230 (17.7)	360 (16.4)		147 (20.7)	1120 (18.1)	
Cerebrovascular disease	365 (28.1)	593 (27.0)	.50	190 (26.7)	1657 (26.8)	1.00
Stroke	106 (8.2)	196 (8.9)	.48	46 (6.5)	508 (8.2)	.12
Diabetes and control method			.82			.10
Insulin diabetes	253 (19.5)	422 (19.2)		115 (16.2)	1203 (19.4)	
Noninsulin diabetes	380 (29.3)	665 (30.3)		225 (31.6)	1825 (29.5)	
Other or no diabetes	664 (51.2)	1107 (50.5)		371 (52.2)	3164 (51.1)	
New York Heart Association class III/IV	105 (8.1)	251 (11.4)	.00	64 (9.0)	603 (9.7)	.57
Home oxygen	33 (2.5)	27 (1.2)	.01	12 (1.7)	89 (1.4)	.72
Recent pneumonia	22 (1.7)	53 (2.4)	.20	17 (2.4)	115 (1.9)	.40
Recent smoker	302 (23.3)	458 (20.9)	.10	139 (19.5)	1383 (22.3)	.10
Hypertension	1205 (92.9)	2010 (91.6)	.19	668 (94.0)	5624 (90.8)	.01
Immunosuppressive therapy	54 (4.2)	97 (4.4)	.78	34 (4.8)	245 (4.0)	.34
Left main disease	429 (33.1)	756 (34.5)	.43	227 (31.9)	922 (14.9)	<.001
Liver disease	47 (3.6)	80 (3.6)	1.00	23 (3.2)	167 (2.7)	.48
Myocardial infarction within 7 d	314 (24.2)	652 (29.7)	.00	178 (25.0)	1872 (30.2)	.01
Number of diseased vessels			.34			.27
One or fewer	26 (2.0)	53 (2.4)		20 (2.8)	154 (2.5)	
Two	216 (16.7)	400 (18.2)		114 (16.0)	1140 (18.4)	
Three	1055 (81.3)	1741 (79.4)		577 (81.2)	4898 (79.1)	
Previous cardiac intervention	443 (34.2)	782 (35.6)	.39	249 (35.0)	2146 (34.7)	.88
Percutaneous coronary intervention within 6 h	12 (0.9)	10 (0.5)	.14	4 (0.6)	37 (0.6)	1.00
Preoperative intra-aortic balloon pump or inotropes	57 (4.4)	180 (8.2)	<.001	37 (5.2)	443 (7.2)	.06
Peripheral arterial disease	202 (15.6)	337 (15.4)	.90	130 (18.3)	912 (14.7)	.01

(Continued)

TABLE E2. Continued

Variables	Preintervention cardiotomy suction practice			After intervention cardiotomy suction practice		
	Nonadoption of agreed-upon practices	Adoption of agreed-upon practices	*P* value	Nonadoption of agreed-upon practices	Adoption of agreed-upon practices	*P* value
Dialysis	29 (2.2)	66 (3.0)	.21	15 (2.1)	147 (2.4)	.76
Status			.03			.35
Elective	546 (42.1)	826 (37.6)		286 (40.2)	2374 (38.4)	
Urgent	719 (55.4)	1317 (60.0)		414 (58.2)	3678 (59.4)	
Emergent	32 (2.5)	51 (2.3)		11 (1.5)	138 (2.2)	
Anticoagulants within 48 h	547 (42.2)	1124 (51.2)	<.001	332 (46.7)	3141 (50.7)	.05

STEMI, ST-Segment elevation myocardial infarction.

TABLE E3. Intra- and postoperative characteristics of 10,394 patients undergoing coronary artery bypass grafting, stratified by time period and use of agreed-upon cardiotomy suction practices

Variables	Preintervention cardiotomy suction practice			After intervention cardiotomy suction practice		
	Nonadoption of agreed-upon practices	Adoption of agreed-upon practices	*P* value	Nonadoption of agreed-upon practices	Adoption of agreed-upon practices	*P* value
Patients	1297	2194		711	6192	
Intraoperative						
Perfusion, min	94.0 [72.0, 129.0]	100.0 [77.0, 125.0]	.01	95.0 [73.0, 124.0]	97.00 [73.0, 126.8]	.42
Crossclamp, min	71.0 [49.0, 99.0]	80.0 [61.0, 102.0]	<.001	72.0 [51.0, 95.0]	75.0 [54.0, 101.0]	.01
Heparin management						
Method of determining initial heparin dose						
Fixed weight-based	1078 (83.4)	1781 (81.7)	.19	581 (81.8)	5370 (87.0)	.0002
Heparin dose response	214 (16.6)	399 (18.3)		129 (18.2)	805 (13.0)	
Total dose for CPB, units	31,000 [28,000, 40,000]	34,000 [30,000, 40,000]	.0003	30,000 [27,000, 39,000]	340,000 [30,000, 40,000]	<.0001
Anticoagulation monitoring						
Method for monitoring						
Activated clotting time	1268 (99.6)	2180 (99.4)	.43	693 (99.9)	6165 (99.7)	.99
Heparin concentration	51 (4.0)	227 (10.4)	<.0001	10 (1.44)	329 (5.3)	<.0001
PT/PTT	0 (0)	1 (0.05)	.99	0 (0)	0 (0)	NA
Other	2 (0.2)	2 (0.1)	.63	0 (0)	0 (0)	NA
Retrograde autologous priming	1231 (94.9)	1799 (82.0)	<.0001	674 (94.8)	5255 (84.9)	<.0001
Static prime volume, mL	910.0 [900.0, 1053.0]	930 [820.0, 1100.0]	.01	910.0 [900.0, 1053.0]	910.0 [820.0, 1000.0]	<.0001
Use of antifibrinolytics						
Coagulation monitoring						
No	930 (73.1)	1317 (60.1)	<.0001	468 (67.4)	4339 (70.2)	0.13
Yes, before CPB	85 (6.7)	651 (29.7)	<.0001	19 (2.7)	1204 (19.5)	<.0001
Yes, during CPB	3 (0.2)	194 (8.9)	<.0001	1 (0.1)	299 (4.8)	<.0001
Yes, after CPB cessation	230 (18.1)	519 (23.7)	.0001	78 (11.2)	1128 (18.3)	<.0001
Return to cardiopulmonary bypass (yes)	22 (1.7)	50 (2.3)	.24	12 (1.7)	133 (2.2)	.42
Hemodynamic instability	16 (1.2)	34 (1.6)	.45	6 (0.8)	66 (1.1)	.58
Technical	8 (0.6)	23 (1.1)	.19	6 (0.8)	73 (1.2)	.43
Other	0 (0.0)	1 (0.1)	1.00	1 (0.1)	5 (0.1)	.48
Red cell transfusion			.96			.25
0	1149 (88.6)	1939 (88.4)		609 (85.7)	5414 (87.4)	
1-2	122 (9.4)	214 (9.8)		84 (11.8)	625 (10.1)	
≥3	26 (2.0)	41 (1.8)		18 (2.5)	151 (2.5)	
Hematocrit						
Nadir on CPB	25.8 [22.0, 29.0]	26.0 [23.0, 30.0]	<.001	24.2 [21.0, 28.0]	26.0 [22.9, 29.6]	<.001
Before first RBC transfusion	20.0 [17.5, 22.0]	20.0 [18.0, 23.0]	.03	20.0 [18.0, 21.0]	20.0 [18.0, 22.0]	.14
Before second RBC transfusion	20.5 [19.0, 23.0]	20.0 [18.0, 23.0]	.74	20.5 [19.0, 26.0]	20.0 [19.0, 22.0]	.18
Intra-aortic balloon pump	17 (1.3)	40 (1.8)	.31	11 (1.5)	100 (1.6)	1.00
Conventional ultrafiltration	279 (21.5)	394 (18.0)	.01	133 (18.7)	1036 (16.7)	.20
Ultrafiltration volume per kg, mL/kg	17.8 [11.2, 30.0]	13.9 [8.7, 23.8]	<.0001	18.02 [9.9, 30.7]	12.69 [8.,0, 21.5]	<.001
Nadir hematocrit on cardiopulmonary bypass	25.8 [22.0, 29.0]	26.0 [23.0, 30.0]	<.001	24.2 [21.0, 28.0]	26.0 [22.9, 29.6]	<.001
Cardiotomy suction						
Not used	0 (0.0)	609 (27.8)	<.0001	0 (0.0)	346 (5.6)	<.0001
Used and stopped before protamine	0 (0.0)	1585 (72.2)	<.0001	0 (0.0)	5846 (94.4)	<.0001

(Continued)

TABLE E3. Continued

Variables	Preintervention cardiotomy suction practice			After intervention cardiotomy suction practice		
	Nonadoption of agreed-upon practices	Adoption of agreed-upon practices	*P* value	Nonadoption of agreed-upon practices	Adoption of agreed-upon practices	*P* value
Protamine dosing, mg	300.0 [300.0, 400.0]	300.0 [250.0, 450.0]	.97	300.0 [300.0, 350.0]	300.0 [250.0, 400.0]	.002
Method for calculating initial protamine dose						
Fixed dose	25 (1.9)	302 (13.9)	<.0001	11 (1.6)	298 (4.8)	<.0001
Heparin protamine titration	302 (23.4)	203 (9.3)		174 (24.5)	782 (12.7)	
Ratio dose of heparin given	963 (74.5)	1640 (75.2)		525 (73.9)	4997 (80.9)	
Protamine not given	0 (0)	0 (0)		0 (0)	0 (0)	
Other	2 (0.2)	36 (1.7)		0 (0)	98 (1.6)	
Non-RBC transfusion (amount in units)						
In prime						
Fresh-frozen plasma	0 [0, 0]	0 [0, 0]	.13	0 [0, 0]	0 [0,0]	.68
During CPB						
Platelets	0 [0, 0]	0 [0, 0]	.48	0 [0, 0]	0 [0, 0]	.50
Fresh-frozen plasma	0 [0, 0]	0 [0, 0]	.83	0 [0, 0]	0 [0, 0]	.11
Non-CPB						
Platelets	2 [1, 2]	2 [1, 2]	.83	1 [1, 2]	1 [1, 2]	.61
Fresh-frozen plasma	2 [1, 2]	2 [2, 2]	.82	2 [1, 2]	2 [2, 2]	.07
Autotransfusion device used	1188 (91.6)	2182 (99.5)	<.0001	645 (90.7)	6150 (99.3)	<.0001
Evidence of clot in circuit	14 (1.1)	9 (0.4)	.02	3 (0.4)	24 (0.4)	.75
Postoperative						
Red cell transfusion, %			.07			.16
0	1038 (80.0)	1693 (77.2)		564 (79.3)	4678 (75.5)	
1-2	193 (14.9)	369 (16.8)		103 (14.5)	1087 (17.6)	
≥3	66 (5.1)	132 (6.0)		44 (6.2)	427 (6.9)	
Reoperation for bleeding, %	16 (1.2)	41 (1.9)	.20	13 (1.8)	114 (1.8)	1.00
Renal failure, %	20 (1.6)	45 (2.1)	.31	20 (2.9)	117 (1.9)	.09
Stroke, %	10 (0.8)	27 (1.2)	.21	8 (1.1)	87 (1.4)	.56
Intensive care unit, h	52.9 [39.8, 92.9]	49.9 [26.6, 88.7]	<.001	53.0 [30.4, 95.9]	47.5 [25.1, 78.5]	<.001
Ventilation time, h	5.5 [4.0, 8.8]	5.2 [3.7, 8.9]	.00	5.4 [3.9, 8.2]	5.1 [3.6, 7.9]	.01
Operative mortality, %	5 (0.4)	9 (0.4)	1.00	4 (0.6)	39 (0.6)	1.00

CPB, Cardiopulmonary bypass; *PT/PTT*, prothrombin time/partial thromboplastin time; *NA*, not available; *RBC*, red blood cell.

TABLE E4. Characteristics of 1420 patients undergoing coronary artery bypass grafting over the study period at non-Michigan centers, stratified by use of agreed-upon cardiotomy suction practices

Variables	Cardiotomy suction practice		*P* value
	Nonadoption of agreed-upon practices	Adoption of agreed-upon practices	
Patients	800	620	
Preoperative			
Age, y	65.0 [58.0, 72.0]	65.0 [58.0, 72.0]	.78
Body surface area, m^2	2.0 [1.9, 2.2]	2.0 [1.8, 2.2]	.71
Female	195 (24.4)	105 (16.9)	.00
Race			<.001
Black	125 (15.6)	40 (6.5)	
Asian	47 (5.9)	79 (12.7)	
White and other	628 (78.5)	501 (80.8)	
Ejection fraction	55.0 [45.0, 60.0]	57.0 [49.0, 62.0]	.00
Creatinine, mg/dL	1.0 [0.80, 1.2]	1.0 [0.90, 1.2]	.01
Hematocrit	40.1 [36.6, 44.0]	40.9 [37.2, 43.6]	.41
White blood cell count, thousands	8.1 (2.6)	8.1 (3.2)	.90
Shock	20 (2.5)	14 (2.3)	.90
Atrial fibrillation	46 (5.8)	15 (2.4)	.00
Cardiac presentation at admission			<.001
No symptom	115 (14.4)	32 (5.2)	
Stable angina	153 (19.1)	203 (32.7)	
Unstable angina	222 (27.8)	97 (15.6)	
Non-STEMI	206 (25.8)	200 (32.3)	
Other (includes STEMI)	104 (13.0)	88 (14.2)	
Cerebrovascular disease	148 (18.5)	100 (16.1)	.27
Stroke	63 (7.9)	46 (7.4)	.83
Diabetes and control method, %			.26
Insulin diabetes	174 (21.8)	113 (18.2)	
Noninsulin diabetes	236 (29.5)	192 (31.0)	
Other or no diabetes	390 (48.8)	315 (50.8)	
New York Heart Association class III/IV, %	68 (8.5)	36 (5.8)	.07
Home oxygen, %	5 (0.6)	3 (0.5)	1.00
Recent pneumonia, %	23 (2.9)	30 (4.8)	.07
Recent smoker, %	153 (19.1)	78 (12.6)	.00
Hypertension, %	684 (85.5)	545 (87.9)	.22
Immunosuppressive therapy, %	24 (3.0)	24 (3.9)	.45
Left main disease, %	153 (19.1)	129 (20.8)	.47
Liver disease, %	11 (1.4)	18 (2.9)	.07
Myocardial infarction within 7 d, %	225 (28.1)	198 (31.9)	.13
Number of diseased vessels, %			.41
One or fewer	25 (3.1)	27 (4.4)	
Two	159 (19.9)	129 (20.8)	
Three	616 (77.0)	464 (74.8)	
Previous cardiac intervention, %	230 (28.7)	182 (29.4)	.85
Percutaneous coronary intervention within 6 h, %	8 (1.0)	2 (0.3)	.23
Preoperative intra-aortic balloon pump or inotropes, %	62 (7.8)	24 (3.9)	.00
Peripheral arterial disease, %	84 (10.5)	55 (8.9)	.35
Dialysis, %	25 (3.1)	20 (3.2)	1.00
Status, %			<.001
Elective	389 (48.6)	232 (37.4)	
Urgent	382 (47.8)	380 (61.3)	
Emergent	29 (3.6)	8 (1.3)	
Anticoagulants within 48 h, %	332 (41.5)	337 (54.4)	<.001

(Continued)

TABLE E4. Continued

Variables	Cardiotomy suction practice		*P* value
	Nonadoption of agreed-upon practices	Adoption of agreed-upon practices	
Intraoperative			
Perfusion, min	94.0 [73.0, 116.0]	90.0 [76.0, 111.0]	.29
Crossclamp, min	72.0 [53.0, 89.0]	68.0 [54.0, 85.0]	.14
Heparin management			
Method of determining initial heparin dose			<.0001
Fixed weight-based	330 (41.6)	23 (3.7)	
Heparin dose response	464 (58.4)	596 (96.3)	
Total dose for CPB, units	30,000 [25,000, 35,000]	25,000 [20,500, 30,000]	<.0001
Anticoagulation monitoring			
Method for monitoring			
Activated clotting time	622 (77.8)	619 (99.8)	<.0001
Heparin concentration	464 (58.0)	598 (96.5)	<.0001
PT/PTT	0 (0)	0 (0)	NA
Other	85 (10.6)	596 (96.1)	<.0001
Retrograde autologous priming	719 (89.9)	613 (98.9)	<.0001
Static prime volume, mL	950.0 [850.0, 1050.0]	1100.0 [1100.0, 1650.0]	<.0001
Use of antifibrinolytics			
Coagulation monitoring			
No	557 (69.6)	18 (2.9)	<.0001
Yes, before CPB	105 (13.1)	599 (96.6)	<.0001
Yes, during CPB	5 (0.6)	0 (0)	.07
Yes, after CPB cessation	2 (0.3)	0 (0)	.51
Return to cardiopulmonary bypass	21 (2.6)	9 (1.5)	.13
Hemodynamic instability	8 (1.0)	5 (0.8)	.70
Technical	13 (1.6)	3 (0.5)	.04
Other	2 (0.3)	3 (0.5)	.66
Red cell transfusion			.01
0	711 (88.9)	582 (93.9)	
1-2	71 (8.9)	34 (5.5)	
≥3	18 (2.2)	4 (0.7)	
Hematocrit			
Nadir on CPB	27.0 [23.1, 30.4]	26.7 [24.0, 29.7]	.82
Before first RBC transfusion	21.0 [19.0, 22.0]	21.0 [19.0, 22.0]	.97
Before second RBC transfusion	20.5 [20.0, 22.0]	21.0 [21.0, 23.0]	.09
Intra-aortic balloon pump	11 (1.4)	9 (1.5)	1.00
Conventional ultrafiltration	353 (44.1)	89 (14.4)	<.001
Ultrafiltration volume per kg, mL/Kg	17.5 [10.5, 28.9]	15.3 [11.5,24.0]	0.20
Cardiotomy suction			
Not used	0 (0.0)	249 (40.2)	<.0001
Used and stopped before protamine	0 (0.0)	371 (59.8)	<.0001
Protamine dosing, mg	250.0 [235.0, 300.0]	250.0 [200.0, 300.0]	<.0001
Method for calculating initial protamine dose			<.0001
Fixed dose	0 (0)	2 (0.3)	
Heparin protamine titration	464 (58.4)	593 (95.8)	
Ratio dose of heparin given	330 (41.6)	24 (3.9)	
Protamine not given	0 (0)	0 (0)	
Other	0 (0)	0 (0)	
Non-RBC transfusion (amount in units)			
In prime			
Fresh-frozen plasma	0 [0, 0]	0 [0, 0]	.99
During CPB			
Platelets	0 [0, 0]	0 [0, 0]	.07
Fresh-frozen plasma	0 [0, 0]	0 [0, 0]	.46

(Continued)

TABLE E4. Continued

Variables	Cardiotomy suction practice		*P* value
	Nonadoption of agreed-upon practices	Adoption of agreed-upon practices	
Non-CPB			
Platelets	2 [1, 2]	1 [1, 2]	.09
Fresh-frozen plasma	2 [2, 2]	2 [2, 2]	.97
Autotransfusion device used	785 (98.1)	605 (97.6)	.48
Evidence of clot in circuit	5 (0.6)	4 (0.7)	1.00
Postoperative			
Red cell transfusion			<.001
0	601 (75.1)	560 (90.3)	
1-2	146 (18.2)	51 (8.2)	
≥3	53 (6.6)	9 (1.5)	
Reoperation for bleeding	18 (2.2)	5 (0.8)	.05
Renal failure, %	9 (1.1)	7 (1.1)	.99
Stroke, %	10 (1.3)	4 (0.7)	.24
Intensive care unit, h	66.0 [30.0, 99.2]	31.4 [21.8, 54.9]	<.001
Ventilation time, h	5.3 [3.8, 9.3]	4.0 [3.1, 5.6]	<.001
Operative mortality	4 (0.5)	0 (0.0)	.21

STEMI, ST-Segment elevation myocardial infarction; *CPB*, cardiopulmonary bypass; *PT/PTT*, prothrombin time/partial thromboplastin time; *NA*, not available; *RBC*, red blood cell.

TABLE E5. Anticoagulation and blood-management practices among low- and high-performing Michigan versus non-Michigan centers

Variables	Michigan centers: Lowest center tercile of agreed-upon cardiotomy suction	Michigan centers: Highest center tercile of agreed-upon cardiotomy suction	*P* value	Non-Michigan centers: Lowest 2 cardiotomy suction performing centers	Non-Michigan centers: Highest 2 cardiotomy suction performing centers	*P* value
Centers	10	11		2	2	
Patients	2620	4116		380	1040	
Heparin management						
Method of determining initial heparin dose			.037			<.0001
Fixed weight-based	2094 (80.5)	3388 (82.6)		0 (0)	353 (34.1)	
Heparin dose response	506 (19.5)	716 (17.5)		379 (100.0)	681 (65.9)	
Anticoagulation monitoring						
Activated clotting time	2548 (99.7)	4104 (99.7)	.96	207 (54.5)	1034 (99.4)	<.0001
Heparin concentration	79 (3.1)	214 (5.2)	<.0001	379 (99.7)	683 (65.7)	<.0001
PT/PTT	0 (0)	0 (0)	–	0 (0)	0 (0)	–
Other	2 (0.1)	2 (0.05)	.63	0 (0)	681 (65.5)	<.0001
Coagulation monitoring						
No	1609 (63.0)	2930 (71.2)	<.0001	375 (98.7)	200 (19.2)	<.0001
Yes, before CPB	0 (0)	823 (20)	<.0001	0 (0)	704 (67.7)	<.0001
Yes, during CPB	0 (0)	304 (7.4)	<.0001	0 (0)	5 (0.5)	.18
Yes, after CPB cessation	416 (16.3)	758 (18.4)	.026	0 (0)	2 (0.2)	.39
Hematocrit						
Nadir on CPB	24.3 [21.0, 28.0]	26.1 [23.0, 30.0]	<.0001	27.0 [24.0, 30.5]	26.5 [23.7, 30.0]	.25
Before first RBC transfusion	19.0 [17.0, 22.0]	21.0 [19.0, 23.0]	<.0001	21.00 [19.0, 22.0]	21.0 [19.0, 22.0]	.90
Before second RBC transfusion	20.0 [19.0, 23.0]	21.0 [19.0, 23.0]	.24	21.00 [20.0, 22.0]	21.0 [20.0, 22.0]	.49
Red cell transfusion			.051			.76
0	4 (1.3)	0 (0)		0 (0)	0 (0)	
1-2	251 (80.2)	313 (78.5)		22 (73.3)	42 (76.4)	
≥3	58 (18.5)	86 (21.6)		8 (26.7)	13 (23.6)	
Protamine dosing, mg	300.0 [250.0, 350.0]	250.0 [250.0, 350.0]	<.0001	290.0 [225.0, 350.0]	250.0 [200.0, 250.0]	<.0001
Method for calculating initial protamine dose			<.0001			<.0001
Fixed dose	51 (2.0)	71 (1.7)		0 (0)	2 (0.2)	
Heparin protamine titration	517 (19.9)	266 (6.5)		379 (100.0)	678 (65.6)	
Ratio dose of heparin given	2030 (78.1)	3637 (88.6)		0 (0)	354 (34.2)	
Other	2 (0.1)	130 (3.2)		0 (0)	0 (0)	
Non-RBC transfusion (amount in units)						
In prime						
Fresh-frozen plasma	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	.073	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	–
During CPB						
Platelets	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	.098	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	.32
Fresh-frozen plasma	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	.82	0.0 [0.0, 0.0]	0.0 [0.0, 0.0]	.32
Non-CPB						
Platelets	1.0 [1.0, 2.0]	1.0 [1.0, 2.0]	.96	1.0 [1.0, 2.0]	1.0 [1.0, 2.0]	.73
Fresh-frozen plasma	2.0 [1.0, 2.0]	2.0 [2.0, 2.0]	.0002	2.0 [2.0, 2.0]	2.0 [2.0, 2.0]	.13

PT/PTT, Prothrombin time/partial thromboplastin time; *CPB*, cardiopulmonary bypass; *RBC*, red blood cell.

TABLE E6. Characteristics of 11,814 patients undergoing coronary artery bypass grafting over the study period: Michigan versus non-Michigan center comparison

Variables	Non-Michigan centers	Michigan centers	*P* value
Patients	1420	10,394	
Preoperative			
Age, y	65.0 [58.0, 72.0]	67.0 [60.0, 73.0]	<.001
Body surface area, m^2	2.0 [1.9, 2.2]	2.1 [1.9, 2.2]	<.001
Female	300 (21.1)	2385 (22.9)	.13
Race			<.001
Black	165 (11.6)	531 (5.1)	
Asian	126 (8.9)	92 (0.9)	
White and other	1129 (79.5)	9771 (94.0)	
Ejection fraction	56.0 [45.0, 61.0]	57.0 [48.0, 61.0]	.67
Creatinine, mg/dL	1.0 [0.83, 1.2]	1.0 [0.83, 1.2]	.02
Hematocrit	40.4 [36.8, 43.8]	40.4 [36.9, 43.7]	.95
White blood cell count, thousands	8.1 (2.9)	8.0 (3.1)	.19
Shock	34 (2.4)	194 (1.9)	.21
Atrial fibrillation	61 (4.3)	613 (5.9)	.02
Cardiac presentation at admission			<.001
No symptom	147 (10.4)	437 (4.2)	
Stable angina	356 (25.1)	1289 (12.4)	
Unstable angina	319 (22.5)	3847 (37.0)	
Non-STEMI	406 (28.6)	2964 (28.5)	
Other (includes STEMI)	192 (13.5)	1857 (17.9)	
Cerebrovascular disease	248 (17.5)	2805 (27.0)	<.001
Stroke	109 (7.7)	856 (8.2)	.50
Diabetes and control method, %			.54
Insulin diabetes	287 (20.2)	1993 (19.2)	
Noninsulin diabetes	428 (30.1)	3095 (29.8)	
Other or no diabetes	705 (49.6)	5306 (51.0)	
New York Heart Association class III/IV, %	104 (7.3)	1023 (9.8)	.00
Home oxygen, %	8 (0.6)	161 (1.5)	.01
Recent pneumonia, %	53 (3.7)	207 (2.0)	<.001
Recent smoker, %	231 (16.3)	2282 (22.0)	<.001
Hypertension, %	1229 (86.5)	9507 (91.5)	<.001
Immunosuppressive therapy, %	48 (3.4)	430 (4.1)	.20
Left main disease, %	282 (19.9)	2334 (22.5)	.03
Liver disease, %	29 (2.0)	317 (3.0)	.04
Myocardial infarction within 7 d, %	423 (29.8)	3016 (29.0)	.57
Number of diseased vessels, %			.00
One or fewer	52 (3.7)	253 (2.4)	
Two	288 (20.3)	1870 (18.0)	
Three	1080 (76.1)	8271 (79.6)	
Previous cardiac intervention, %	412 (29.0)	3620 (34.8)	<.001
Percutaneous coronary intervention within 6 h, %	10 (0.7)	63 (0.6)	.79
Preoperative intra-aortic balloon pump or inotropes, %	86 (6.1)	717 (6.9)	.26
Peripheral arterial disease, %	139 (9.8)	1581 (15.2)	<.001
Dialysis, %	45 (3.2)	257 (2.5)	.14
Status, %			.00
Elective	621 (43.7)	4032 (38.8)	
Urgent	762 (53.7)	6128 (59.0)	
Emergent	37 (2.6)	232 (2.2)	
Anticoagulants within 48 h, %	669 (47.1)	5144 (49.5)	.10
Intraoperative			
Perfusion, min	92.0 [75.0, 114.0]	97.0 [74.0, 126.0]	<.001
Crossclamp, min	70.0 [53.0, 88.0]	76.0 [54.0, 100.5]	<.001

(Continued)

TABLE E6. Continued

Variables	Non-Michigan centers	Michigan centers	*P* value
Heparin management			
Method of determining initial heparin dose			<.0001
Fixed weight-based	353 (25.0)	8810 (85.1)	
Heparin dose response	1060 (75.0)	1547 (14.9)	
Total dose for CPB, units	28,000 [23,000, 34,000]	33,000 [30,000, 40,000]	<.0001
Anticoagulation monitoring			
Method for monitoring			
ACT	1241 (87.4)	10,306 (99.7)	<.0001
Heparin concentration	1062 (74.8)	617 (6.0)	<.0001
PT/PTT	0 (0)	1 (0.01)	.99
Other	681 (48.0)	4 (0.04)	<.0001
Retrograde autologous priming	1332 (93.8)	8959 (86.2)	<.0001
Static prime volume, mL	1050.0 [850.0,1200.0]	910.0 [820.0, 1053.0]	<.0001
Use of antifibrinolytics			
Coagulation monitoring			
No	575 (40.5)	7054 (68.2)	<.0001
Yes, before CPB	704 (49.6)	1959 (18.9)	<.0001
Yes, during CPB	5 (0.4)	497 (4.8)	<.0001
Yes, after CPB cessation	2 (0.1)	1955 (18.9)	<.0001
Return to cardiopulmonary bypass	30 (2.1)	217 (2.1)	.95
Hemodynamic instability	13 (0.9)	122 (1.2)	.39
Technical	16 (1.1)	110 (1.1)	.81
Other	5 (0.4)	7 (0.1)	.01
Red cell transfusion			.00
0	1293 (91.1)	9111 (87.7)	
1-2	105 (7.4)	1045 (10.1)	
≥3	22 (1.5)	238 (2.3)	
Hematocrit			
Nadir on CPB	26.7 [23.8, 30.0]	26.0 [22.4, 29.4]	<.001
Before first RBC transfusion	21.0 [19.0, 22.0]	20.0 [18.0, 22.0]	.24
Before second RBC transfusion	21.0 [20.0, 22.0]	20.0 [19.0, 23.0]	.35
Intra-aortic balloon pump	20 (1.4)	168 (1.6)	.64
Conventional ultrafiltration	442 (31.1)	1842 (17.7)	<.001
Ultrafiltration volume per kg, mL/kg	16.9 [10.6, 27.4]	14.1 [8.7, 24.1]	<.0001
Cardiotomy suction			
Not used	249 (17.5)	955 (9.2)	<.0001
Used and stopped before protamine	371 (26.1)	7431 (71.5)	<.0001
Protamine dosing, mg	250.0 [200.0, 300.0]	300.0 [250.0, 400.0]	<.0001
Method for calculating initial protamine dose			<.0001
Fixed dose	2 (0.1)	636 (6.1)	
Heparin protamine titration	1057 (74.8)	1461 (14.1)	
Ratio dose of heparin given	354 (25.1)	8125 (78.4)	
Protamine not given	0 (0)	0 (0)	
Other	0 (0)	136 (1.3)	
Non-RBC transfusion (amount in units)			
In prime	0 [0, 0]	0 [0, 0]	
Fresh-frozen plasma	0 [0, 0]	0 [0, 0]	.56
During CPB			
Platelets	0 [0, 0]	0 [0, 0]	.002
Fresh-frozen plasma	0 [0, 0]	0 [0, 0]	.44
Non-CPB			
Platelets	2 [1, 2]	1 [1, 2]	.81
Fresh-frozen plasma	2 [2, 2]	2 [2, 2]	.11
Autotransfusion device used	1390 (97.9)	10,165 (97.8)	.83
Evidence of clot in circuit	9 (0.6)	50 (0.5)	.44

(Continued)

TABLE E6. Continued

Variables	Non-Michigan centers	Michigan centers	*P* value
Postoperative			
Red cell transfusion			<.001
0	1161 (81.8)	7973 (76.7)	
1-2	197 (13.9)	1752 (16.9)	
≥3	62 (4.4)	669 (6.4)	
Renal failure, %	16 (1.1)	202 (2.0)	.03
Stroke, %	14 (1.0)	132 (1.3)	.38
Reoperation for bleeding	23 (1.6)	184 (1.8)	.77
Intensive care unit, h	47.0 [24.1, 76.0]	49.0 [26.5, 88.0]	<.001
Ventilation time, h	4.8 [3.5, 7.0]	5.2 [3.7, 8.3]	<.001
Operative mortality	4 (0.3)	57 (0.5)	.26

STEMI, ST-Segment elevation myocardial infarction; *CPB*, cardiopulmonary bypass; *ACT*, activated clotting time; *PT/PTT*, prothrombin time/partial thromboplastin time; *RBC*, red blood cell.