Outcomes of nonemergency cardiac surgery after overnight operative workload: A statewide experience

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Tyler M. Bauer, MD,[a] Michael J. Pienta, MD,[a] Xiaoting Wu, PhD,[a] Michael P. Thompson, PhD,[a] Robert B. Hawkins, MD,[a] Andrew L. Pruitt, MD,[b] Alphonse Delucia III, MD,[c] Shelly C. Lall, MD,[d] Francis D. Pagani, MD, PhD,[a] and Donald S. Likosky, PhD,[a] on behalf of the The Michigan Society of Thoracic and Cardiovascular Surgeons Quality Collaborative and The Video Assessment of CaRdiac Surgery QualITY (VARSITY) Surgery Investigators

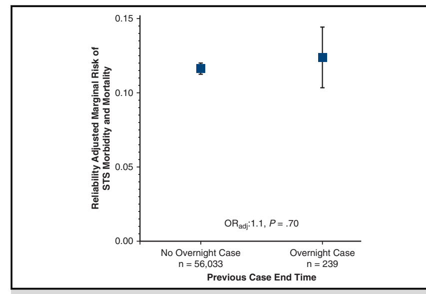
ABSTRACT

Objective: Cardiac surgeons experience unpredictable overnight operative responsibilities, with variable rest before same-day, first-start scheduled cases. This study evaluated the frequency and associated impact of a surgeon's overnight operative workload on the outcomes of their same-day, first-start operations.

Methods: A statewide cardiac surgery quality database was queried for adult cardiac surgical operations between July 1, 2011, and March 1, 2021. Nonemergency, first-start, Society of Thoracic Surgeons predicted risk of mortality operations were stratified by whether or not the surgeon performed an overnight operation that ended after midnight. A generalized mixed effect model was used to evaluate the effect of overnight operations on a Society of Thoracic Surgeons composite outcome (5 major morbidities or operative mortality) of the first-start operation.

Results: Of all first-start operations, 0.4% (239/56,272) had a preceding operation ending after midnight. The Society of Thoracic Surgeons predicted risk of morbidity and mortality was similar for first-start operations whether preceded by an overnight operation or not (overnight operation: 11.3%; no overnight operation: 11.7%, $P = .42$). Unadjusted rates of the primary outcome were not significantly different after an overnight operation (overnight operation: 13.4%; no overnight operation: 12.3%, $P = .59$). After adjustment, overnight operations did not significantly impact the risk of major morbidity or mortality for first-start operations (adjusted odds ratio, 1.1, $P = .70$).

Conclusions: First-start cardiac operations performed after an overnight operation represent a small subset of all first-start Society of Thoracic Surgeons predicted risk operations. Overnight operations do not significantly influence the risk of major morbidity or mortality of first-start operations, which suggests that surgeons exercise proper judgment in determining appropriate workloads. (JTCVS Open 2024;20:101-11)



Marginal risk of previous case end time on STS morbidity and mortality.

CENTRAL MESSAGE

Cardiac surgeons infrequently perform first-start operations after operating past midnight. In instances where it is necessary, there is no associated increased risk of STS-defined morbidity or mortality.

PERSPECTIVE

This statewide analysis of 56,272 cardiac surgical operations identifies no associated increased risk for STS-defined morbidity and mortality for first-start cases in which the surgeon was operating past midnight the night before. Surgeons exercise appropriate judgement in choosing when to operate after cases that end late the night before.

From the [a]Department of Cardiac Surgery, University of Michigan, Ann Arbor, Mich; [b]Department of Cardiac Surgery, St Joseph Mercy, Ann Arbor, Mich; [c]Department of Cardiac Surgery, Bronson Medical Center, Kalamazoo, Mich; and [d]Department of Cardiac Surgery, Munson Healthcare, Traverse City, Mich.

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Address for reprints: Donald S. Likosky, PhD, Section of Health Services Research and Quality, Department of Cardiac Surgery, University of Michigan, 1500 E Medical Center Dr, Ann Arbor, MI 48109 (E-mail: likosky@med.umich.edu).

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Abbreviations and Acronyms

IQR	= interquartile range
MPOG	= Multicenter Perioperative Outcomes Group
MSTCVS-QC	= Michigan Society of Thoracic and Cardiovascular Surgeons Quality Collaborative
STS-ACSD	= Society of Thoracic Surgeons Adult Cardiac Surgical Database
STS-PROM	= Society of Thoracic Surgeons Predicted Risk of Mortality

Complication rates after cardiac surgery are common and vary in rate across hospitals and surgeons. Clinical outcomes have improved over time, attributed in part to technological innovations (eg, valve designs), advancements in intensive care unit practices (eg, fast-track extubation), the development of national clinically informed databases, and regional physician-led quality collaboratives.[1,2] Perhaps surprisingly, approximately only 2% of interhospital variability in some postoperative outcomes are attributed to differences in patient risk and conventionally evaluated intraoperative (eg, cardiopulmonary bypass duration) and postoperative (eg, time to initial extubation) practices.[3-5]

Beyond traditional risk factors, a surgeon's unpredictable operative responsibilities and workload may contribute to a patient's risk of complications.[6] Simulation data document deterioration in both technical and nontechnical skills during periods of sleep deprivation.[6-10] A recent meta-analysis of 6 cohort studies involving multiple surgical subspecialities revealed no significant relationship between a surgeon's sleep deprivation and postoperative morbidity and mortality.[11] Although the analysis predominantly included single-center experiences, there were noted differences in the measurement of surgeon fatigue (eg, interval of time between cases, tracked sleep hours) and significant heterogeneity across studies in the rate of intraoperative complications and duration of length of stay.[12,13]

With the use of a large, contemporary, multicenter observational cohort leveraged from data housed within the Michigan Society of Thoracic and Cardiovascular Surgeons Quality Collaborative (MSTCVS-QC), this study evaluated the associated impact of a surgeon's overnight operative workload on postoperative outcomes. The objectives of the study were to (1) describe the frequency and practice patterns of operations starting between 6:00 AM and 9:00 AM after a cardiac operation concluding after midnight; and (2) evaluate the relationship between overnight operative workload and outcomes of subsequent first-start surgical operations.

MATERIALS AND METHODS

The University of Michigan Institutional Review Board approved this study as "Not Regulated" (HUM00202111, 6/25/2021). The MSTCVS-QC collects institutional Society of Thoracic Surgeons Adult Cardiac Surgery Database (STS-ACSD) data from all nonfederal centers where cardiac surgery is performed in the state of Michigan. The MSTCVS-QC database was queried for all operations performed across 33 centers by 164 cardiac surgeons between July 1, 2011, and March 1, 2021. The sample included nonemergency, first-start (first operations performed by a surgeon between 6:00 AM and 9:00 AM) Society of Thoracic Surgeons (STS) predicted risk of mortality (PROM) operations.[14] For each first-start operation, the end time of the most recently performed operation by the same surgeon was identified.

The primary exposure was whether the surgeon's previous operation ended after midnight ("overnight operation"). The primary outcome, termed "STS major morbidity and mortality," was a composite of STS-ACSD major morbidity (eg, stroke, reoperation for any cardiac reason, deep sternal wound infection, postoperative renal failure, prolonged intubation) and operative mortality for the first-start operations. Baseline demographics and comorbidities were extracted from the STS-ACSD data for each patient. Definitions used in these analyses adhered to the STS-ACSD (versions 2.73-2.90). Missing values were handled in accordance with the STS-ACSD approaches.[15]

Patient risk factors, laboratory values, and intraoperative and postoperative variables were compared with the presence or absence of an overnight operation. Descriptive analyses were used to determine the frequency at which first-start cases followed overnight cases by operative surgeon and hospital. Categorical variables were tested for significant differences using chi-square and Fisher exact tests, and Wilcoxon rank-sum test was used for continuous variables. Univariate analyses were informed by prior published reports and the MSTCVS-QC surgical community.

Multivariable logistic regression was used to determine if the presence of an overnight operation increased the odds of the composite outcome among subsequent, first-start STS-PROM cases. All variables included within the STS-ACSD short-term risk calculator that were accessible in the MSTCVS-QC were included in multivariate analyses, in addition to operation type (prior and first-start) and overnight case acuity.[14] The final generalized linear mixed model used a logit link function to model the composite outcome and included hospital and surgeon as random effects for reliability adjustment.[16] Marginal risk was calculated from this model.[17] A sensitivity analysis was performed to evaluate whether the relationship between an overnight operation and the composite end point was robust when expanding to all first-start operations (ie, PROM and non-PROM operations). Both unadjusted and adjusted comparisons of STS morbidity and mortality were performed in the sensitivity analysis. The multivariable analyses included all STS-ACSD short-term risk calculator variables, as well as the case acuity of both the overnight and first-start cases. Statistical analyses were performed using STATA version 17 (StataCorp).

RESULTS

A total of 110,602 cardiac surgical procedures were identified over the study period, including 79,913 (72%) first-start operations (nonemergency PROM: n = 56,272; nonemergency non-PROM: n = 23,641). Of all operations, 1.2% (1346/110,602) finished after midnight, resulting in 239 of 56,272 (0.4%) nonemergency, first-start operations performed after an overnight case.

TABLE 1. Baseline demographics of first-start operations stratified by presence of an overnight operation

Covariate (N, %), unless otherwise stated	Total N = 56,272	Before midnight N = 56,033	After midnight N = 239	*P* value
Demographics				
Age (IQR)	67 (59-74)	67 (59-74)	67 (59-73)	.51
Gender	40,170 (71.4%)	39,999 (71.4%)	171 (71.5%)	.95
Weight in kg (IQR)	88 (76-101.9)	88 (76-101.9)	88.5 (75-102)	.96
Height in cm (IQR)	172.7 (165.1-180.0)	172.7 (165.1-180.0)	172.7 (165.0-178.0)	.71
Black race	3978 (7.1%)	3967 (7.1%)	11 (4.6%)	.14
Ethnicity (Latino)	954 (1.7%)	947 (1.7%)	7 (2.7%)	.22
Preoperative laboratories				
Hematocrit (IQR)	40 (36-43)	40 (36-43)	40 (36.2-43)	.68
Platelets (IQR)	209 (173-252)	209 (173-252)	205 (167-248)	.25
White count (IQR)	7.3 (6.1-8.9)	7.30 (6.1-8.9)	7.60 (6.3-9.0)	.09
Serum creatinine (IQR)	1 (0.80-1.19)	1.00 (0.80-1.19)	0.97 (0.80-1.12)	.10
Cardiac history				
Diabetes	23,720 (42.2%)	23,616 (42.2%)	104 (39.8%)	.45
Hypertension	49,441 (87.9%)	49,215 (87.9%)	226 (86.6%)	.53
Peripheral arterial disease	8260 (14.7%)	8223 (14.7%)	37 (15.5%)	.73
Cerebrovascular disease	12,341 (21.9%)	12,283 (21.9%)	58 (24.3%)	.38
Endocarditis	1173 (2.1%)	1166 (2.1%)	7 (2.9%)	.36
Sleep apnea	10,040 (17.8%)	9997 (17.8%)	43 (18.0%)	.95
Intra-aortic balloon pump	2967 (5.3%)	2951 (5.3%)	16 (6.7%)	.32
No. of previous interventions				<.001
None	53,253 (94.6%)	53,010 (94.6%)	243 (93.1%)	
First cardiac intervention	2803 (5.0%)	2789 (5.0%)	14 (5.4%)	
Second cardiac intervention	177 (0.3%)	174 (0.3%)	3 (1.1%)	
Third cardiac intervention	27 (0.0%)	27 (0.0%)	0 (0.0%)	
Fourth cardiac intervention	15 (0.0%)	14 (0.0%)	1 (0.4%)	
Preoperative risk factors				
Liver dysfunction	1844 (3.3%)	1837 (3.3%)	7 (2.9%)	.76
Dialysis dependent	855 (1.5%)	852 (1.5%)	3 (1.3%)	.74
Mediastinal radiation	768 (1.4%)	765 (1.4%)	3 (1.3%)	.88
Previous cancer	3056 (5.4%)	3043 (5.4%)	13 (5.4%)	.99
Familial history of premature coronary artery disease	9566 (17.0%)	9528 (17.0%)	38 (15.9%)	.65
Ace inhibitor	18,683 (33.2%)	18,593 (33.2%)	90 (37.7%)	.14
Beta-blocker	48,378 (86.0%)	48,178 (86.0%)	200 (83.7%)	.31
ADP inhibitor within 5 days	3201 (5.7%)	3187 (5.7%)	14 (5.9%)	.91
Inotropes	464 (0.8%)	460 (0.8%)	4 (1.7%)	.15
Immunosuppression	2511 (4.5%)	2498 (4.5%)	13 (5.4%)	.46
Chronic lung disease				
None	40,476 (71.9%)	40,286 (71.9%)	190 (79.5%)	.023
Mild	9621 (17.1%)	9597 (17.1%)	24 (10.0%)	
Moderate	3221 (5.7%)	3206 (5.7%)	15 (6.3%)	
Severe	2957 (5.3%)	2947 (5.3%)	10 (4.2%)	
Alcohol dependence				
Yes	23,202 (41.2%)	23,102 (41.2%)	100 (41.8%)	.85
Home oxygen				
None	55,458 (98.5%)	55,221 (98.5%)	237 (99.2%)	.99
Yes, dependent	435 (0.8%)	434 (0.8%)	1 (0.4%)	
Yes, PRN	382 (0.7%)	381 (0.7%)	1 (0.4%)	

IQR, Interquartile range; *ADP*, adenosine diphosphate receptor; *PRN*, pro re nata.

Baseline demographics of first-start cases that followed overnight operations compared with those that did not are shown in Table 1. The median (interquartile range [IQR]) age was 67 years (59-74), 71.4% were male, and 7.1% were Black. Peripheral arterial disease was present among 14.7% of patients, with 42.2% having diabetes, 21.9%

having cerebrovascular disease, and 11.0% having moderate to severe chronic lung disease. Preoperative beta-blockers and angiotensin-converting enzyme inhibitors were used among 86.0% and 33.2% of patients, respectively. There were no clinically relevant demographic differences between first-start operations that followed an overnight operation compared with those that did not.

Operation-specific covariates for first-start operations were stratified by the presence of an overnight operation as shown in Table 2. When a first-start case followed an overnight operation, the median (IQR) time between cases was 6.3 (4.2-7.3) hours, as opposed to 40.6 (17.5-89.2) hours when operations did not follow overnight operations. Urgent status of the first-start case was similar for cases that followed overnight operations as opposed to those that did not (46.0% vs 44.5%, $P = .64$). The most common first-start operation was CABG (overnight operation: 60.7% vs no overnight operation: 64.7%), followed by isolated valve (overnight operation: 26.4% vs no overnight operation: 22.3%); procedure type did not differ between groups ($P = .31$). The STS predicted risk of morbidity and mortality was equivalent for cases preceded by an overnight operation, compared with those that were not (11.3% vs 11.7%, $P = .42$).

There was a small absolute difference in the annual proportion of first-start cases after an overnight operation over time (Cochran-Armitage test of trend $P = .05$) (Figure E1). There was large variation in the proportion of first-start cases that were preceded by overnight operations at the surgeon level (range, 0%-8.7%, IQR, 0-0.4), with 18.3% (30/164) of surgeons accounting for 80.3% of all first-start operations preceded by overnight operations (Figure 1, *A*). Likewise, there was appreciable interhospital variability in the primary exposure (range, 0%-2.0%, IQR, 0.1-0.42) (Figure 1, *B*), with 45.5% (15/33) of centers accounting for 81.6% of all first-start operations after overnight operations.

Univariate and Adjusted Outcomes

There was no significant association between the presence of an overnight operation and the observed rates of the STS major morbidity and mortality (overnight operation: 13.4% vs no overnight operation: 12.3%, $P = .59$). This finding was robust when evaluating components of the composite outcome (Figure 2). Median postoperative length of stay was qualitatively similar between operations having a preceding overnight operation, compared to those that did not (median = 6.20 days vs

TABLE 2. Operative covariates for first-start operations stratified by presence of an overnight operation

Covariate, (N, %) unless otherwise stated	Total N = 56,272	Before midnight N = 56,033	After midnight N = 239	*P* value
First-start operation				
Procedure type				
CABG	36,388 (64.7%)	36,243 (64.7%)	145 (60.7%)	.31
Isolated valve	12,556 (22.3%)	12,493 (22.3%)	63 (26.4%)	
Valve + CABG	7331 (13.0%)	7300 (13.0%)	31 (13.0%)	
Predicted morbidity and mortality (%)	11.70 (7.59-19.10)	11.74 (7.60-19.10)	11.27 (7.20-18.97)	.42
Status				
Elective	31,228 (55.5%)	31,099 (55.5%)	129 (54.0%)	.64
Urgent	25,047 (44.5%)	24,937 (44.5%)	110 (46.0%)	
Hours since last case	40.5 (17.5-89.2)	40.6 (17.5-89.3)	6.3 (4.2-7.3)	<.001
Total operative time (min, Median [IQR])	329 (272-394)	329 (272-394)	352 (301-427)	<.001
Crossclamp time (min, Median [IQR])	82 (61-109)	82 (61-109)	94 (69-125)	<.001
Most recent operation				
Previous case type				
CABG	30,016 (53.3%)	29,958 (53.5%)	58 (24.3%)	<.001
Isolated valve	7601 (13.5%)	7590 (13.5%)	11 (4.6%)	
Other	13,798 (24.5%)	13,635 (24.3%)	163 (68.2%)	
Valve + CABG	4860 (8.6%)	4853 (8.7%)	7 (2.9%)	
Previous case predicted morbidity and mortality (%)	9.12 (3.80-16.70)	9.15 (3.89-16.70)	0.00 (0.00-16.57)	<.001
Previous case status				
Elective	29,004 (51.5%)	28,970 (51.7%)	34 (14.2%)	<.001
Emergency salvage	90 (0.2%)	81 (0.1%)	9 (3.8%)	
Emergency	1983 (3.5%)	1845 (3.3%)	138 (57.7%)	
Urgent	25,198 (44.8%)	25,140 (44.9%)	58 (24.3%)	

CABG, Coronary artery bypass grafting; *IQR*, interquartile range.

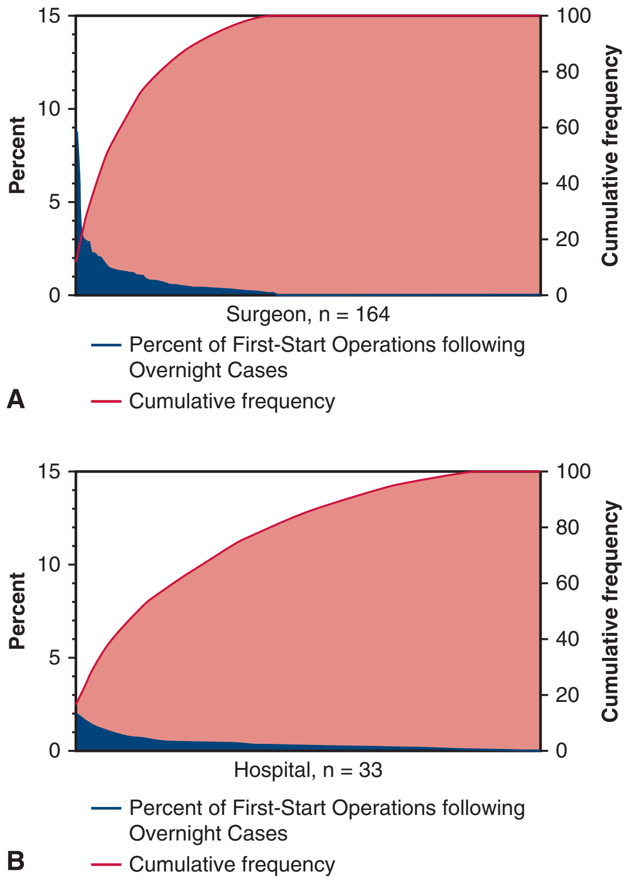

FIGURE 1. Proportion of first-start, nonemergency, STS-PROM operations that followed overnight operations by (A) surgeon and (B) hospital.

6.16 days, $P = .02$). Operations that followed overnight versus nonovernight cases had longer associated median operative (352 minutes vs 326 minutes, $P < .001$) and cross-clamp (94 minutes vs 82 minutes, $P < .001$) durations.

After adjustment, the presence of an overnight operation was associated with a nonsignificantly increased odds of STS major morbidity or mortality (overnight operation: 13.1% vs no overnight operation: 11.8%; OR_{adj}: 1.10, $P = .70$) (Figure 3). The final multivariable logistic regression model results are shown in Table E1.

The primary findings were confirmed in a sensitivity analysis including all nonemergency first-start operations (non-PROM and PROM operations). Of 78,708 first-start cases, 438 (0.6%) followed an overnight operation. The rates of STS major morbidity or mortality did not significantly differ in observed (overnight operation: 15.3% vs no overnight operation: 14.3%; $P = .48$) and risk-adjusted analyses (OR_{adj}: 0.97, $P = .83$) (Figure E2).

DISCUSSION

This large, multicenter observational study documents statewide practice patterns and their associated outcomes for nonemergency cardiac surgical operations performed after an overnight cardiac operation. First, findings from this study document that first-start operations after overnight operations occur infrequently. Second, this study reports considerable inter-provider and inter-hospital variation in the frequency of first-start cases after overnight operations. Last, the occurrence of an overnight operation was not associated with a significant associated increase

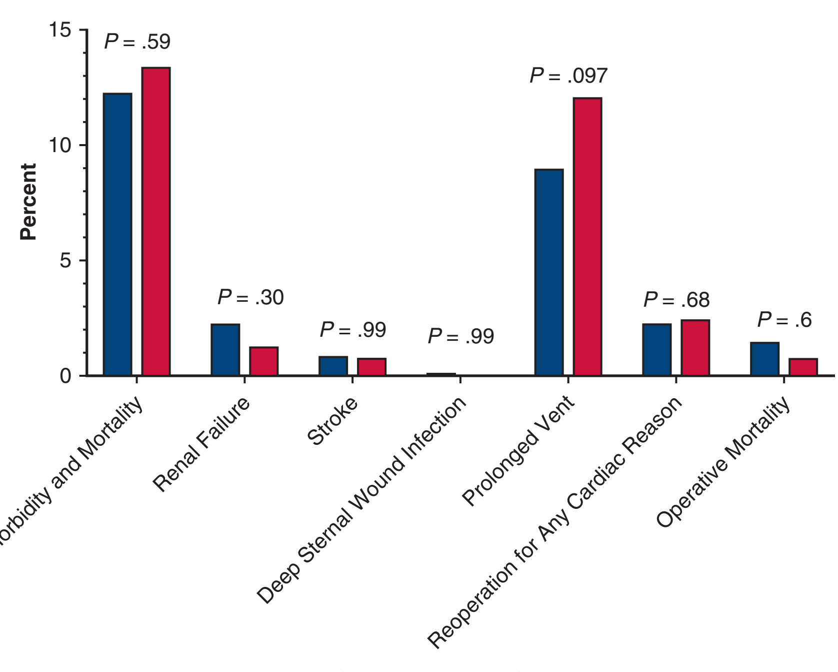

FIGURE 2. Unadjusted outcomes by whether a first-start case was preceded by an overnight case. *STS*, Society of Thoracic Surgeons.

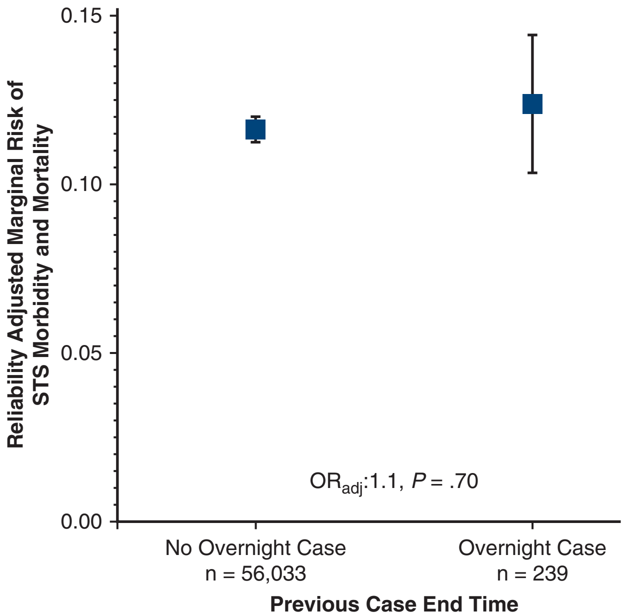

FIGURE 3. Reliability-adjusted marginal risk of outcomes by whether a first-start case was preceded by an overnight case. Central point represents point estimate of reliability adjusted marginal risk of STS-defined morbidity and mortality. Error bars represent 95% CI. *STS*, Society of Thoracic Surgeons.

in the adjusted odds of major morbidity or mortality for first-start cardiac surgical operations.

A focus on the relationship between a surgeon's overnight operative and subsequent first-start case workload is important given its potential contribution to sleep deprivation for the operating surgeon.[18,19] Prior work has highlighted the relationship between sleep deprivation and technical and nontechnical skills.[6-10] Large multispecialty clinical database analyses have evaluated the relationship between overnight operations on subsequent surgical outcomes.[20,21] Nonetheless, the generalizability of these findings to cardiac surgery may be limited given differential technical and nontechnical skill demands across surgical subspecialties. For these reasons, the evaluation of overnight operative workload responsibilities on adverse sequelae after cardiac surgery would benefit from the findings from this specialty-specific evaluation.

In this statewide experience, 0.4% of all nonemergency, first-start, STS-PROM cardiac surgical operations had a preceding operation that ended after midnight. The Multicenter Perioperative Outcomes Group (MPOG), a multicenter registry of surgical and diagnostic procedures using anesthesia, recently reported its cross-sectional experience with next-day operations following an attending surgeon's overnight workload.[20] The reported rate of cases after overnight operations was 2.6% in the MPOG study as opposed to 0.4% in this study. However, the MPOG study used different definitions for what constituted an operation after overnight surgical workload, including (1) a broad spectrum of surgical procedures, rather than focusing solely on cardiac surgery; and (2) using more inclusive criteria to define overnight workload (ie, any surgery that finished after 11 PM as opposed to midnight) and next-day operations (ie, including any operation up through 5:00 PM, rather than constraining to first-start operations). Similar to the present MSTCVS-QC evaluation, the MPOG investigators found no significant effect between overnight workload requirements and adverse sequelae associated with subsequent operations.[20]

The analysis presented is among the first to document variability across surgeons and hospitals in overnight operations preceding first-start cardiac surgical procedures. Approximately 80% of all overnight operations were accounted for by less than 20% of surgeons and less than half of centers. A number of theoretical explanations may help explain this finding, including subspecialization within cardiac surgery at the surgeon (eg, aortic surgeons) and institutional level (ie, only 3 of 33 of the cardiac surgical hospitals in the state of Michigan perform heart transplantation). Of note, approximately 70% of the overnight cases that preceded first-start cases were reported as emergency or emergency salvage operations, including but not limited to aortic emergencies and heart transplantations.

Study Limitations

A number of study-related limitations are worthy of discussion. First, although this study focuses on the operative cardiac surgery-specific workload of all cardiac surgeons in the state of Michigan, some surgeons may have other unpredictable overnight operative (eg, thoracic, vascular) and nonoperative (eg, intensive care unit) responsibilities that may contribute to fatigue. Second, although this study adhered to the STS-ACSD national data collection standards, there is a risk of underestimating the true overnight workload (ie, timing of reoperations for complications such as bleeding are not recorded in the STS-ACSD). Third, although there is a risk of unmeasured confounding, the multivariable analysis considers variables included in the STS-ACSD short-term risk calculator.[14] Fourth, while accounting for a minority of first-start PROM operations, emergency and emergency-salvage operations were excluded given they could not be delayed if the surgeon was operating overnight. Last, although the present study is among the largest reported cardiac surgical series, the results may only be generalizable to patients within the state of Michigan.

CONCLUSIONS

A small proportion of all first-start, nonemergency STS-ACSD predicted risk operations are preceded by an overnight cardiac operation. The exposure of an overnight operative workload does not significantly increase a patient's risk-adjusted odds of major morbidity or operative mortality for first-start cases. These findings suggest that surgeons are not assuming inappropriate risk in opting to operate after overnight surgical responsibilities.

Conflict of Interest Statement

The 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: CABG, operative workload, quality, valve

APPENDIX E1. VARSITY SURGERY INVESTIGATORS

VARSITY Surgery Authors: Tyler M. Bauer, Xiaoting Wu, PhD, Francis D. Pagani, and Donald S. Likosky.

VARSITY Surgery nonauthor contributors. All individuals provided nonfinancial contributions, including framing of the discussion. All individuals are affiliated with Michigan Medicine (Ann Arbor, Mich) unless otherwise noted: Matthew D. Caldwell, MD; Jason J. Corso, PhD; Roger D. Dias, MD, MBA, PhD (Brigham and Women's Hospital, Boston, Mass); Steven D. Harrington, MD (Clinton Township, Mich); Nathan Louis, BS, MS; Allison M. Janda, MD; Sarah L. Krein, PhD, RN; Milisa Manojlovich, PhD, RN; Michael R. Mathis, MD; Gabriela M. Querejeta Roca, MD (Brigham and Women's Hospital, Boston, Mass); Douglas C. Shook, MD (Brigham and Women's Hospital, Boston, Mass); Thoralf Sundt, MD (Massachusetts General Hospital, Boston, Mass); Suraj Yalamuri, MD (Mayo Clinic, Rochester, Minn); Timothy Dickinson, CCP (Mayo Clinic, Rochester, Minn); Jennifer Lawton, MD (Johns Hopkins Hospital, Baltimore, Md); Jake Abernathy, MD (Johns Hopkins Hospital, Baltimore, Md); George Justison, CCP (University of Colorado, Aurora, Colo); Korana Stakich-Alpirez, MS, CCRP; Min Zhang, PhD; Steve Yule, PhD (University of Edinburgh, Scotland, UK); Kaneko Tsuyoshi, MD (Washington University School of Medicine, St Louis, Mo); David Sturmer, CCP.

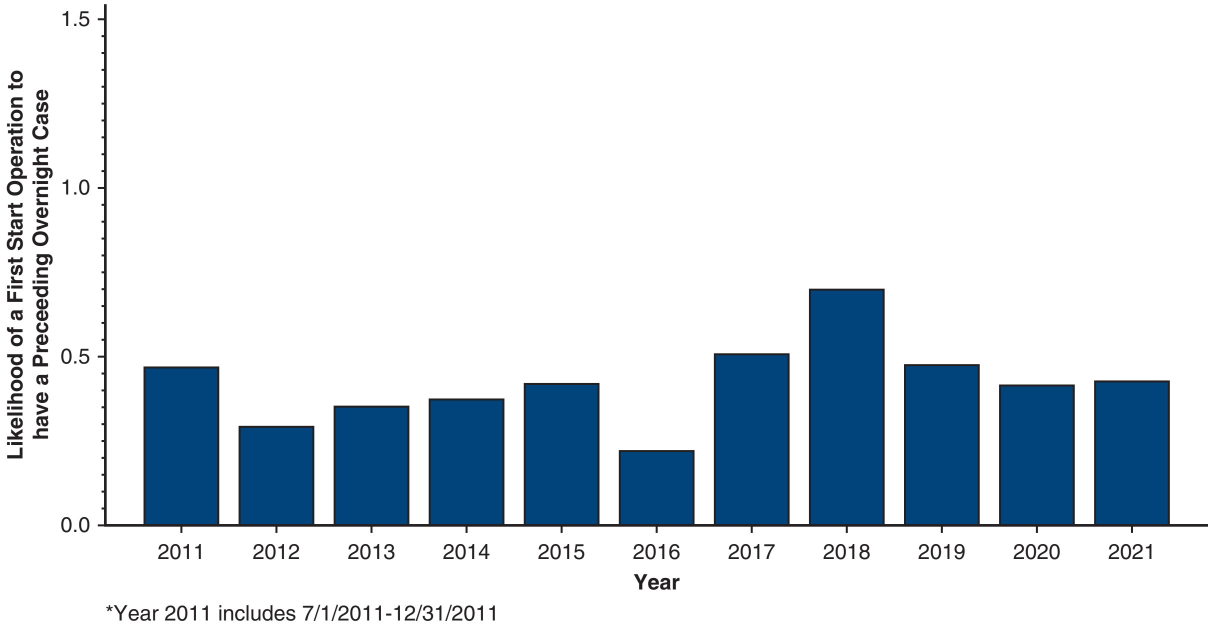

FIGURE E1. Proportion of first-start, nonemergency, STS-PROM operations that followed overnight operations by year.

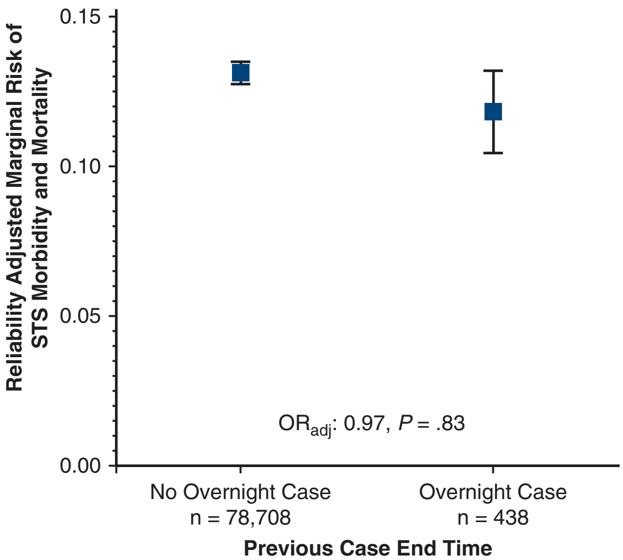

FIGURE E2. Reliability-adjusted marginal risk of outcomes by whether a first-start case was preceded by an overnight case; sensitivity analysis on all first-start cases. Central point represents point estimate of reliability adjusted marginal risk of STS-defined morbidity and mortality. Error bars represent 95% CI.

TABLE E1. Multivariable model results for major morbidity and mortality on all nonemergency, first-start, Society of Thoracic Surgeons predicted risk of mortality cases

Multivariable logistic regression results, PROM cases						
Covariate	OR	SE	z	*P* > z	95% CI Upper limit	95% CI Lower limit
Primary exposure, ref = no overnight case						
Overnight case finishing after Midnight	1.09	0.23	0.39	.70	0.72	1.65
Baseline demographics						
Age	1.02	0.00	10.95	.00	1.01	1.02
Gender	0.91	0.04	−2.26	.02	0.84	0.99
Hypertension	1.09	0.06	1.59	.11	0.98	1.20
Black race	1.41	0.10	4.74	.00	1.22	1.62
White race	1.05	0.06	1.00	.32	0.95	1.17
Asian race	1.58	0.23	3.12	.00	1.19	2.11
Native American race	1.16	0.25	0.69	.49	0.76	1.76
Pacific Islander race	1.18	0.48	0.40	.69	0.53	2.60
Liver disease	1.31	0.10	3.64	.00	1.13	1.51
Preoperative laboratories						
Weight (kg)	1.01	0.00	9.49	.00	1.01	1.01
Height (kg)	0.99	0.00	−7.52	.00	0.98	0.99
Hematocrit	0.98	0.00	−5.60	.00	0.98	0.99
White count	1.03	0.00	6.35	.00	1.02	1.03
Platelets	1.00	0.00	−1.62	.10	1.00	1.00
Creatinine	1.16	0.01	11.97	.00	1.13	1.19
Cardiac history						
Diabetes	1.05	0.02	2.99	.00	1.02	1.08
Peripheral vascular disease	1.35	0.05	7.76	.00	1.25	1.46
Cerebrovascular disease	1.19	0.04	5.11	.00	1.12	1.28
Syncope	0.99	0.07	−0.21	.83	0.86	1.13
Endocarditis	1.49	0.13	4.44	.00	1.25	1.77
Previous cardiovascular intervention	1.03	0.04	1.01	.31	0.97	1.11
No. of previous interventions ref = none						
Second cardiac intervention	1.43	0.09	5.56	.00	1.26	1.62
Third cardiac intervention	2.20	0.45	3.87	.00	1.48	3.28
Fourth cardiac intervention	4.67	2.15	3.35	.00	1.90	11.50
Fifth cardiac intervention	0.64	0.73	−0.39	.70	0.07	6.11
Atrial fibrillation, ref = none						
Paroxysmal	1.23	0.07	3.75	.00	1.10	1.37
Constant	1.27	0.09	3.25	.00	1.10	1.46
Atrial flutter, ref = none						
Remote	0.81	0.14	−1.18	.24	0.57	1.15
Recent	1.08	0.17	0.45	.65	0.78	1.48
Preoperative risk factors						
Mediastinal radiation	1.21	0.14	1.64	.10	0.96	1.52
Cancer within 5 years	1.07	0.07	1.07	.29	0.95	1.21
Familial history of premature coronary artery disease	0.94	0.04	−1.52	.13	0.86	1.02
Sleep apnea	1.03	0.04	0.84	.40	0.96	1.12
Intra-aortic balloon pump	6.53	0.32	38.76	.00	5.94	7.18
ECMO before surgery	60.73	25.63	9.73	.00	26.56	138.86
Resuscitated 24 hour before surgery	1.02	0.24	0.10	.92	0.65	1.61
Pneumonia ref = none						
Recent	1.42	0.11	4.52	.00	1.22	1.65
Remote	1.11	0.06	1.90	.06	1.00	1.23

(Continued)

TABLE E1. Continued

Multivariable logistic regression results, PROM cases						
Covariate	**OR**	**SE**	**z**	***P* > z**	**95% CI Upper limit**	**95% CI Lower limit**
Cardiogenic shock ref = none						
Yes, at time of procedure	1.29	0.25	1.34	.18	0.89	1.88
Yes, >24 hours before procedure	1.23	0.30	0.84	.40	0.76	1.97
ACE inhibitor within 48 hours of surgery	0.92	0.03	−2.39	.02	0.87	0.99
Beta-blocker	1.03	0.05	0.70	.48	0.94	1.13
ADP inhibitor within 5 d	1.13	0.07	2.00	.05	1.00	1.27
Inotropes	1.97	0.24	5.49	.00	1.55	2.51
Immunosuppressed	1.27	0.08	3.89	.00	1.13	1.44
Chronic lung disease ref: none						
Mild	1.23	0.05	5.27	.00	1.14	1.33
Moderate	1.52	0.09	7.38	.00	1.36	1.70
Severe	1.83	0.10	10.79	.00	1.64	2.05
Alcohol use	0.99	0.03	−0.23	.82	0.93	1.06
Intravenous drug abuse, ref = none						
Recent	1.07	0.11	0.64	.52	0.88	1.30
Remote	0.95	0.12	−0.42	.68	0.75	1.21
Tobacco use, ref = none						
Current every day smoker	1.10	0.06	1.92	.05	1.00	1.22
Current some day smoker	0.74	0.11	−2.07	.04	0.55	0.98
Current, status unknown	1.39	0.37	1.23	.22	0.82	2.33
Former	0.89	0.03	−3.08	.00	0.83	0.96
Home oxygen use, ref = none						
Yes, PRN	1.20	0.17	1.28	.20	0.91	1.60
Yes, dependent	1.22	0.17	1.44	.15	0.93	1.60
Procedural data						
Procedure type, ref = CABG						
Isolated valve	1.62	0.07	10.50	.00	1.48	1.78
Valve + CABG	2.18	0.09	18.83	.00	2.01	2.36
Status, ref = elective						
Urgent	1.10	0.04	2.69	.01	1.03	1.18
Previous procedure data						
Previous procedure type, ref = CABG						
Isolated valve	0.96	0.05	−0.77	.44	0.88	1.06
Other	0.98	0.04	−0.41	.68	0.91	1.06
Valve + CABG	1.00	0.05	−0.09	.93	0.89	1.11
Previous case status, ref = elective						
Emergency salvage	0.83	0.34	−0.45	.65	0.37	1.86
Emergency	1.01	0.08	0.08	.94	0.86	1.18
Urgent	0.99	0.03	−0.27	.79	0.93	1.06
Provider						
var(_cons)	0.1474408	0.04	0.09	.24		
Provider > hospital						
var(_cons)	0.0332604	0.02	0.01	.13		

PROM, Predicted risk of mortality; *OR*, odds ratio; *SE*, standard error; *ECMO*, extracorporeal membrane oxygenation; *ACE*, angiotensin-converting enzyme; *ADP*, adenosine diphosphate; *PRN*, pro re nata; *CABG*, coronary artery bypass grafting.