Compliance with Surgical Care Improvement Project for Body Temperature Management (SCIP Inf-10) Is Associated with Improved Clinical Outcomes

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ABSTRACT

Background: In an effort to measure and improve the quality of perioperative care, the Surgical Care Improvement Project (SCIP) was introduced in 2003. The SCIP guidelines are evidence-based process measures designed to reduce preventable morbidity, but it remains to be determined whether SCIP-measure compliance is associated with improved outcomes.

Methods: The authors retrospectively analyzed the electronic medical record data from 45,304 inpatients at a single institution to assess whether compliance with SCIP Inf-10 (body temperature management) was associated with a reduced incidence of morbidity and mortality. The primary outcomes were hospital-acquired infection and ischemic cardiovascular events. Secondary outcomes were mortality and hospital length of stay.

Results: Body temperature on admission to the postoperative care unit was higher in the SCIP-compliant group (36.6° ± 0.5°C; n = 44,064) compared with the SCIP-noncompliant group (35.5° ± 0.5°C; n = 1,240) ($P < 0.0001$). SCIP compliance was associated with improved outcomes in both nonadjusted and risk-adjusted analyses. SCIP compliance was associated with a reduced incidence of hospital-acquired infection (3,312 [7.5%] *vs.*160 [12.9%] events; risk-adjusted odds ratio [OR], 0.68; 95% CI, 0.54 to 0.85), ischemic cardiovascular events (602 [1.4%] *vs.* 38 [3.1%] events; risk-adjusted OR, 0.60; 95% CI, 0.41 to 0.92), and mortality (617 [1.4%] *vs.* 60 [4.8%] events; risk-adjusted OR, 0.41; 95% CI, 0.29 to 0.58). Median (interquartile range) hospital length of stay was also decreased: 4 (2 to 8) *versus* 5 (2 to 14) days; $P < 0.0001$.

Conclusion: Compliance with SCIP Inf-10 body temperature management guidelines during surgery is associated with improved clinical outcomes and can be used as a quality measure. **(ANESTHESIOLOGY 2015; 123:116-25)**

THE optimal methods for measuring and reporting quality of surgical care are controversial.[1–3] In the past decade, quality assessment has been based predominantly on process measures rather than outcome measures, because these are easy to report and may not require risk adjustment.[4,5] The Surgical Care Improvement Project (SCIP)[6] was instituted in 2003 in an effort to improve the quality of perioperative care and reduce preventable adverse outcomes. The SCIP National Quality Core Measures are evidence-based clinical care guidelines that are audited and reported to a national database and have been used as a quality measure to compare hospitals. Such a database, called the Hospital Compare Web site,[7] is made publically available to consumers by the Centers for Medicare and Medicaid Services. What remains to be determined is whether SCIP-measure compliance correlates with reduced morbidity or mortality. In fact, numerous prior studies have reported no difference in morbid outcomes in relation to SCIP-measure compliance,[8–14] calling into question the use of process measures rather than outcome measures for quality assessment.

Initially, the SCIP measures were created to reduce the incidence of hospital-acquired infection, deep venous thrombosis, pulmonary embolus, and ischemic cardiovascular events. Of these morbid outcomes, infection is most common and has been associated with substantially increased cost, length of stay, and even mortality.[15] There are eight SCIP measures intended to reduce hospital-acquired infection, including SCIP Inf-10, which relates to the maintenance of normothermia in surgical patients. SCIP Inf-10 is

What We Already Know about This Topic

- There is limited evidence that compliance with process measures such as maintenance of normothermia reduces postoperative morbidity
- The hypothesis that compliance with the Surgical Care Improvement Project maintenance of normothermia measure reduces postoperative infection and cardiovascular ischemia was analyzed retrospectively

What This Article Tells Us That Is New

- Data from 45,304 noncardiac surgical patients at a single academic medical center found that 1,240 were noncompliant (body temperature <36°C or no use of active warming)
- Noncompliant patients had an increased risk of infection, ischemic events, and mortality, supporting maintenance of normothermia as a useful perioperative quality measure

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based on the findings of a randomized clinical trial by Kurz *et al.*,[16] published in 1996, wherein the investigators demonstrated that active warming of patients undergoing colorectal surgery was associated with a threefold reduction in the incidence of wound infections. Another reason for actively warming patients is that residual postoperative hypothermia has been associated with an increased incidence of ischemic cardiovascular events.[17] Despite the evidence-based nature of the SCIP Inf-10 body temperature management guideline, little evidence shows that compliance with this process measure is helpful in reducing perioperative morbidity.

The SCIP Inf-10 measure states that patients who undergo surgical procedures that last greater than or equal to 60 min should either (1) be actively warmed or (2) have a body temperature greater than or equal to 36°C within 30 min immediately before or 15 min after anesthesia end time.[18] In this study, we tested the hypothesis that SCIP Inf-10 compliance is associated with a decreased incidence of hospital-acquired infections and a reduced incidence of ischemic cardiovascular events, when compared with surgical cases that were SCIP Inf-10 noncompliant. We also sought to determine whether mortality and length of stay were reduced in SCIP-compliant patients.

Materials and Methods

After receiving approval from the institutional review board at the Johns Hopkins Medical Institutions (Baltimore, Maryland), we acquired electronic anesthesia records from the anesthesia information management system (Metavision®; iMdSoft, USA) for 46,683 inpatients who underwent noncardiac surgery between January 2010, and June 2014. Cardiac surgeries were not included because of the unique thermal perturbations with these surgeries. The anesthesia database includes information regarding use of active patient warming measures and body temperature data recorded in the operating room and on admission to the postanesthesia care unit (PACU) or intensive care unit (ICU) after surgery. These records were merged with a second database derived from the hospital's billing records (Datamart, Microsoft SQL server database software, USA), and a third database made available through a Web-based intelligence portal (IMPACT Online; Haemonetics Corp., USA). Our use of these databases and the quality control methods used have been described previously.[19,20] The Datamart database includes up to 29 preadmission comorbidities for each patient, and the IMPACT Online database includes hospital-acquired morbid events that are determined by *International Classification of Diseases*, ninth Revision (ICD-9) codes on discharge. Also included is the Charlson comorbidity index score derived from the preadmission comorbidities,[21] which we used in the risk-adjusted model described in Outcome Assessment and Statistical Analysis. After merging these databases, we excluded 1,379 patients who had surgical procedures that were less than 60 min in duration because these patients are exempt from the SCIP Inf-10 guideline for body temperature management. Thus, 45,304 patients were included in the analysis.

Intraoperative temperature measurements were taken according to the preference of the anesthesia team. At our institution, temperatures are typically measured by placing a thermistor probe (YSI, USA) in the oropharynx, nasopharynx, or proximal esophagus. Our institution does not use the "esophageal stethoscope" temperature probes that reach the distal esophagus. In 9,342 patients, the intraoperative temperature during the last 30 min of surgery (end of surgery) was not available. Either the probe was removed before the end of case (in 5,225 cases) or the temperature probe was removed from the patient and exposed to ambient temperature (in 4,117 cases). After surgery, the body temperature of each patient was measured on admission to the PACU or ICU with a temporal artery infrared thermometer (Exergen TAT-5000, USA), as it is the routine practice by the nursing staff.

Regarding the PACU/ICU admission temperature, 1,387 patients had missing measurements. All missing temperatures were treated as missing data, just as they would be when determining SCIP compliance according to the actual SCIP Inf-10 guideline. Only 96 patients (0.2%) were missing both end of surgery and PACU/ICU admission temperatures and thus were only defined as SCIP compliant if active warming was utilized.

Active warming measures at our institution typically include the forced-air method, with either an upper or lower body cover, or occasionally both upper and lower covers. Rarely, a circulating water mattress is used. All these methods are recorded in the electronic records that we used in the analysis to define active warming. Intravenous fluid warming alone was not defined as active warming.

Two groups were created based on the SCIP Inf-10 guideline, which we designated to be the "SCIP-compliant" and "SCIP-noncompliant" groups. If the highest of the two temperatures measured during (1) the last 30 min of surgery and (2) the first 15 min of postoperative care was greater than or equal to 36°C, or active patient warming was utilized, then the patient was deemed to be in the SCIP-compliant group. All other patients were deemed to be SCIP noncompliant.

Baseline characteristics in the two groups were compared. The primary outcomes were morbid events during the hospital stay, which are defined as (1) hospital-acquired infections and (2) ischemic cardiovascular events. Infections included postoperative wound infections, drug-resistant infections, sepsis, and *Clostridium difficile* infections. Ischemic cardiovascular events included myocardial infarction, cerebral vascular accident, and transient ischemic attack. The exact ICD-9 codes used to define each of these outcomes are shown in the appendix. Secondary outcomes included mortality during the hospital stay and hospital length of stay.

Outcome Assessment and Statistical Analysis

The two groups were compared by using two-tailed Student *t* tests for continuous variables, chi-square tests for dichotomous variables, and the Mann–Whitney *U* test for nonparametric analyses (comparing medians and ordinal data). We

analyzed the relationship between SCIP Inf-10 compliance and clinical outcomes in both an unadjusted and a risk-adjusted fashion, using univariable and multivariable logistic regressions, respectively; the odds ratios (ORs) and 95% CIs are reported.

In the multivariable models, we included the design variable of the study (SCIP Inf-10 compliance) and those variables from table 1 (baseline patient characteristics) that occurred with different frequency between groups ($P < 0.05$). To adjust for potential confounders, a propensity score was calculated from a logistic regression as the probability of being in the SCIP-noncompliant group, taking into account each of the baseline clinical characteristics in table 1. This propensity score was then forced in the logistic model. In addition, we included the calendar year of the surgery, duration of surgery, and receipt of an intraoperative blood transfusion, because these were considered potential confounding variables. The reported risk-adjusted ORs are from the multivariable logistic regression model with all covariates included.

Two additional multivariable models were constructed to determine (1) the independent association between active warming and outcomes and (2) the independent association between any body temperature greater than or equal to 36°C and outcomes. These models included the same methods described in the previous paragraph, except that the two components that comprise SCIP compliance: (1) use of active warming measures and (2) any temperature greater than or equal to 36°C, were substituted for "SCIP compliance" as independent variables in the model. To avoid the likelihood of a type 1 error, a Bonferroni *post hoc* correction was used in both univariable and multivariable analyses of composite outcomes.

Continuous variables that were normally distributed are reported as mean ± SD; those that were not normally distributed, as well as ordinal variables, are reported as median and interquartile range. *P* value less than 0.05 was used to define significance. Analyses were generated using JMP version 9.0.3 (SAS Institutes, Inc., USA), and R version 3.1.2 (http://www.r-project.org, accessed March 17, 2015).

Results

The SCIP-compliant and SCIP-noncompliant groups were compared for preoperative patient characteristics and prehospital admission comorbidities (table 1). The two groups were comparable for age; gender; the prevalence of diabetes, liver disease, and human immunodeficiency virus disease; presence of tumor; anemia; alcohol or drug abuse; and psychiatric conditions. The SCIP-noncompliant group had a greater incidence of congestive heart failure, valvular cardiac disease, peripheral vascular disease, hypertension, pulmonary disease, and renal insufficiency/failure. The SCIP-compliant group had a greater incidence of metastatic disease and obesity. The incidence of SCIP-noncompliance decreased over the 4-yr time period: year 2010, 3.7%; 2011, 3.0%; 2012, 2.1%; 2013, 1.8% ($P \leq 0.0001$). The distribution of patients in each group according to the surgical specialty service that performed the procedure is compared in table 2. The SCIP-compliant group had a greater percentage of general, spine, and plastic surgery cases than did the noncompliant group,

Table 1. Patient Characteristics

	SCIP Compliant (n = 44,064), No. (%)	SCIP Noncompliant (n = 1,240), No. (%)	*P* Value
Age (yr)	44 ± 24	44 ± 27	0.71
Gender (% male)	23,029 (52.3)	668 (53.9)	0.26
Charlson score, median (IQR)	1 (0–2)	1 (0–3)	0.0009
Comorbidities			
Congestive heart failure	1,236 (2.8)	68 (5.5)	<0.0001
Valvular cardiac disease	1,901 (4.3)	74 (6.0)	0.005
Peripheral vascular disease	1,684 (3.8)	116 (9.4)	<0.0001
Hypertension	12,758 (29.0)	396 (31.9)	0.023
Pulmonary	5,435 (12.3)	206 (16.6)	<0.0001
DM	4,484 (10.2)	139 (11.2)	0.24
Renal	2,562 (5.8)	102 (8.2)	0.0004
Liver	1,348 (3.1)	46 (3.7)	0.19
HIV	271 (0.6)	13 (1.1)	0.057
Metastatic disease	4,483 (10.2)	99 (8.0)	0.012
Tumor	10,198 (23.1)	271 (21.9)	0.29
Obesity	4,539 (10.3)	104 (8.4)	0.028
Anemia	4,275 (9.7)	122 (9.8)	0.87
Alcohol abuse	781 (1.8)	16 (1.3)	0.2
Drug abuse	789 (1.8)	16 (1.3)	0.19
Psychoses	852 (1.9)	25 (2.0)	0.84
Depression	2,598 (5.9)	59 (4.8)	0.093

DM = diabetes mellitus; HIV = human immune deficiency virus; IQR = interquartile range; SCIP = Surgical Care Improvement Project.

Table 2. Surgical Specialty Services

	SCIP Compliant (n = 44,064), No. (%)	SCIP Noncompliant (n = 1,240), No. (%)	Total (n = 45,304), No. (%)
General surgery	9,886 (22.5)	165 (13.4)	10,051 (22.3)
Gynecology	1,814 (4.1)	37 (3.0)	1,851 (4.1)
Neurosurgery	6,216 (14.2)	171 (13.9)	6,387 (14.2)
Spine	1,336 (3.0)	13 (1.1)	1,349 (3.0)
Orthopedics	1,801 (4.1)	46 (3.7)	1,847 (4.1)
Otolaryngology	2,692 (6.1)	66 (5.4)	2,758 (6.1)
Plastics	1,990 (4.5)	32 (2.6)	2,022 (4.5)
Pediatric surgery	8,732 (19.9)	334 (27.1)	9,066 (20.1)
Thoracic	1,586 (3.6)	103 (8.4)	1,689 (3.7)
Transplant	1,294 (3.0)	28 (2.3)	1,322 (2.9)
Urology	4,810 (11.0)	126 (10.2)	4,936 (10.9)
Vascular	1,405 (3.2)	105 (8.5)	1,510 (3.4)
Total	43,903 (97.3)	1,231 (2.7)	45,134 (100)

There is a discrepancy between the "n" in the top row and the "Total" in the bottom row, because 161 patients in the SCIP-compliant group and 9 patients in the SCIP-noncompliant group did not have an assigned surgical service.

SCIP = Surgical Care Improvement Project.

whereas the noncompliant group had a greater percentage of pediatric, thoracic, and vascular surgery cases.

Patients in the SCIP-compliant group had a mean body temperature measurement at PACU or ICU admission that was 1.1°C higher than that of patients in the SCIP-noncompliant group ($P < 0.0001$; table 3). Active warming was used in 64.1% of the SCIP-compliant patients, and, by definition of SCIP compliance, none of the SCIP-noncompliant patients had active warming. When forced-air warming was used, 36% of patients had an upper body cover, 41% had a lower body cover, and 22% had both. Duration of surgery was longer in the SCIP-compliant group (table 3). The percentage of patients receiving an intraoperative blood transfusion was higher in the SCIP-noncompliant group (15.4%) compared with the SCIP-compliant group (9.2%; $P < 0.0001$). At the end of surgery, mean body temperature was similar in the transfused patients (36.6° ± 1.2°C) and the nontransfused patients (36.6° ± 0.9°C; $P = 0.84$).

Clinical outcomes were initially compared in the two groups by univariable (nonrisk-adjusted) analysis (table 4). The incidence of hospital-acquired infection was lower in the SCIP-compliant group than in the SCIP-noncompliant group (3,312 [7.5%] *vs.* 160 [12.9%] events; $P < 0.0001$). This difference was attributed to a decreased occurrence of *C. difficile*, sepsis, and drug-resistant infections, as postoperative wound infections occurred with similar frequency in the two groups. Ischemic cardiovascular events occurred less frequently in the SCIP-compliant group than in the SCIP-noncompliant group (602 [1.4%] *vs.* 38 [3.1%] events; $P < 0.0001$). This difference was attributed to a lower frequency of both cerebral (transient ischemic attack or cerebral vascular accident) ischemic events and myocardial infarction. When compared with that in the SCIP-noncompliant group, the SCIP-compliant group exhibited a lower in-hospital mortality rate (617 [1.4%] *vs.* 60 [4.8%] events; $P < 0.0001$) and shorter median (interquartile range) length of stay (4 [2 to 8] *vs.* 5 [2 to 14] days; $P < 0.0001$).

We assessed the same clinical outcomes to determine the independent relationship between SCIP compliance and adverse outcomes using a multivariable analysis to risk adjust for confounding variables (table 5). SCIP compliance was associated with a reduced risk for hospital-acquired infection, ischemic cardiovascular events, and in-hospital mortality. By using the same independent variables as were used for

Table 3. Perioperative Temperature and Thermal Management

	SCIP Compliant (n = 44,064)	SCIP Noncompliant (n = 1,240)	*P* Value
End operating room temperature (°C)	36.3 ± 0.9	35.1 ± 0.5	<0.0001
10th percentile	34.0	34.0	
25th percentile	35.2	34.4	
50th percentile	36.4	35.2	<0.0001*
75th percentile	37.0	35.6	
90th percentile	37.4	35.8	
PACU/ICU admit temperature (°C)	36.6 ± 0.6	35.5 ± 0.5	<0.0001
10th percentile	36.0	34.9	
25th percentile	36.2	35.4	
50th percentile	36.5	35.7	<0.0001*
75th percentile	36.9	35.8	
90th percentile	37.3	35.9	
Duration of surgery (min)			
Mean ± SD	254 ± 147	224 ± 140	<0.0001
Median (IQR)	220 (147–322)	188 (123–279)	<0.0001
Active warming (% of patients)	64.1	0	<0.0001

* Comparison of median and percentile distribution temperature measures in the two groups by the Mann–Whitney U test.

ICU = intensive care unit; IQR = interquartile range; PACU = postanesthesia care unit; SCIP = Surgical Care Improvement Project.

Table 4. Primary and Secondary Outcomes by Univariable Analysis

	SCIP Compliant (n = 44,064), No. (%)	SCIP Noncompliant (n = 1,240), No. (%)	Univariable (Unadjusted) Effect for SCIP Compliance, OR (95% CI)	*P* Value
Any infection	3,312 (7.5)	160 (12.9)	0.55 (0.44–0.69)	<0.0001
Clostridium difficile	569 (1.3)	31 (2.5)	0.51 (0.32–0.82)	0.0008
Sepsis	1,350 (3.1)	93 (7.5)	0.39 (0.29–0.52)	<0.0001
Wound infection	1,673 (3.8)	44 (3.6)	0.93 (0.63–1.39)	0.7811
Drug-resistant infection	235 (0.5)	16 (1.3)	0.41 (0.21–0.80)	0.0016
Ischemic cardiovascular event	602 (1.4)	38 (3.1)	0.44 (0.28–0.68)	<0.0001
TIA or CVA	446 (1.0)	27 (2.2)	0.46 (0.29–0.72)	0.0005
MI	164 (0.4)	11 (0.9)	0.42 (0.21–0.84)	0.008
In-hospital mortality	617 (1.4)	60 (4.8)	0.28 (0.20–0.40)	<0.0001
Length of stay				
Mean LOS (d)	9.0 ± 19.1	13.6 ± 24.2		<0.0001
Median (IQR) LOS (d)	4 (2–8)	5 (2–14)		<0.0001

ORs and *P* values are reported after Bonferroni *post hoc* adjustment for multiple comparisons.

CVA = cerebral vascular accident; IQR = interquartile range; LOS = length of stay; MI = myocardial infarction; OR = odds ratio; SCIP = Surgical Care Improvement Project; TIA = transient ischemic attack.

Table 5. Primary and Secondary Outcomes by Multivariable Analysis

	Risk-adjusted Effect for SCIP Compliance, (OR (95% CI)	*P* Value	Risk-adjusted Effect for Temperature ≥36°C, OR (95% CI)	*P* Value	Risk-adjusted Effect for Active Warming, OR (95% CI)	*P* Value
Any infection	0.68 (0.54–0.85)	<0.0001	0.76 (0.66–0.88)	<0.0001	0.75 (0.68–0.83)	<0.0001
Clostridium difficile	0.63 (0.40–1.04)	0.021	0.66 (0.49–0.89)	0.0006	0.68 (0.55–0.85)	<0.0001
Sepsis	0.53 (0.40–0.72)	<0.0001	0.65 (0.53–0.80)	<0.0001	0.65 (0.57–0.76)	<0.0001
Wound infection	0.86 (0.56–1.24)	0.31	0.92 (0.75–1.14)	0.33	0.93 (0.82–1.06)	0.16
Drug-resistant infection	0.56 (0.31–1.17)	0.047	0.64 (0.45–0.96)	0.02	0.79 (0.57–1.11)	0.08
Ischemic cardiovascular event	0.60 (0.41–0.92)	0.008	0.57 (0.44–0.74)	<0.0001	0.79 (0.66–0.96)	0.008
TIA or CVA	0.61 (0.39–1.00)	0.026	0.57 (0.43–0.76)	<0.0001	0.78 (0.63–0.98)	0.015
MI	0.67 (0.34–1.52)	0.25	0.77 (0.47–1.13)	0.26	0.86 (0.60–1.25)	0.36
In-hospital mortality	0.41 (0.29–0.58)	<0.0001	0.36 (0.29–0.46)	<0.0001	0.64 (0.53–0.77)	<0.0001

OR and 95% CIs from the multivariable analysis are shown to illustrate the risk-adjusted effects of SCIP compliance, temperature ≥36°C, and active warming, on each of the adverse clinical outcomes. Each of these three parameters was associated with a reduced risk of any infection, ischemic cardiovascular events, and in-hospital mortality. OR and *P* values are reported after Bonferroni *post hoc* adjustment for multiple comparisons. Patient characteristics included as independent variables in the multivariable models were: Charlson score, congestive heart failure, valvular cardiac disease, peripheral vascular disease, hypertension, pulmonary disease, renal disease, metastatic disease, and obesity.

CVA = cerebral vascular accident; MI = myocardial infarction; OR = odds ratio; SCIP = Surgical Care Improvement Project; TIA = transient ischemic attack.

the outcomes assessment, SCIP compliance was associated with a reduced risk for a length of stay that was greater than the median for all patients (4 days; OR, 0.83; 95% CI, 0.74 to 0.94), in a multivariable analysis.

In subsequent analyses, we used the same multivariable model, except that we substituted the use of "any temperature greater than or equal to 36°C" and then "active warming" for "SCIP compliance" as the primary independent variable (table 5). Both temperature greater than or equal to 36°C and active warming were independently associated with reduced risk of all three adverse outcomes: hospital-acquired infection, ischemic cardiovascular events, and in-hospital mortality. Of note is the finding that the risk of wound infection and myocardial infarction alone (outside the defined composite outcome) were not significantly reduced with SCIP compliance, temperature greater than or equal to 36°C, or active warming.

Discussion

The primary findings in this study were that SCIP Inf-10 compliance was associated with a reduced risk for hospital-acquired infections, ischemic cardiovascular events, and mortality, as well as a decreased length of stay. These findings suggest that perioperative maintenance of normothermia according to the SCIP Inf-10 guideline is an important process measure that can be used as a perioperative quality measure. Our findings also support those of the original randomized clinical trials by Kurz *et al.*[16] and Frank *et al.*,[17] on which this SCIP measure was based, whereby preventing perioperative hypothermia–reduced infections[16] and ischemic cardiovascular morbidity.[17] An additional benefit of maintaining normothermia is reduced perioperative bleeding and transfusion requirements,[22] which further justifies the importance of this particular SCIP measure.

Although SCIP Inf-10 compliance was associated with reduced morbidity as defined by our primary outcome measures, it should be noted that the effect of SCIP compliance on postoperative wound infection alone was not significant and that the effect on myocardial infarction alone was significant only in the unadjusted analysis and not after risk adjustment. A possible explanation for these findings may be that we included all surgical inpatients in the analysis, and not just those at high risk for these particular morbid events, as was the case in the original clinical trials by Kurz *et al.*[16] and Frank *et al.*[17] It is likely that because the patient population was all-inclusive, we only recognized the reduced morbidity when the composite outcomes were considered. The very low incidence of myocardial infarction in our study is evidence that our population was an overall low-risk group of patients for this particular outcome. In addition, most perioperative myocardial infarctions are silent.[23] We also had a lower risk population for wound infection compared with the randomized trial by Kurz *et al.*,[16] where all patients had colorectal surgery. This may explain why in our study the composite infection outcome was significantly increased but wound infection by itself was not.

In simplified terms, body temperature is an important vital sign, and quality anesthetic care aims to control and maintain vital signs near normal baseline values. The physiologic effects of even mild hypothermia in awake humans have been well described. Intense vasoconstriction occurs as a result of the adrenergic response to core hypothermia,[24] which increases norepinephrine concentrations to 300 to 400% above baseline[25,26] and produces a smaller but substantial increase in epinephrine, about twofold.[25] This normal thermoregulatory response increases vasomotor tone, which reduces heat loss through the skin surface, thus increasing core temperature. The resulting decrease in skin blood flow has detrimental effects on oxygen delivery to the skin surface.[27] This reduction in oxygen may contribute to the increased risk of wound infection, as macrophages may be dysfunctional in hypoxemic tissues,[28] allowing bacteria to take hold in the wound surface. In addition, leukocytes become dysfunctional at lower temperature and have less ability to defend the body against infection.[29] The adrenergic response to hypothermia has also been implicated as the mechanism for cold-induced perioperative myocardial ischemia.[17]

The SCIP measures have been criticized in the literature primarily because they are process measures used as a surrogate for quality measures.[1,2] Furthermore, and with few exceptions, SCIP-measure compliance has been shown by previous investigators to be poorly correlated with clinical outcomes.[8–14] For hospital-acquired infections, Ingraham *et al.*[10] analyzed data from 200 hospitals and showed that giving antibiotics within 60 min of incision (SCIP Inf-1), discontinuing the antibiotic within 24 h after surgery (SCIP Inf-3), and appropriate hair removal from the surgical site (SCIP Inf-6) were all unrelated to the incidence of surgical site infection (SSI), even in a risk-adjusted analysis. Only the selection of the appropriate antibiotic (SCIP Inf-2) was a predictor of improved outcome. Maintaining normothermia was not assessed in that particular study.

Other poor correlations between SCIP compliance and outcomes have been reported. Nicholas *et al.*[14] assessed data from 2,000 U.S. hospitals and found that compliance did not correlate with reduced mortality, venous thrombosis rates, or SSI rates, even after risk adjustment. These authors focused on antibiotic start and stop times (SCIP Inf-1 and SCIP Inf-3), antibiotic choice (SCIP Inf-2), and venous thrombosis prophylaxis (SCIP VTE-1 and SCIP VTE-2) measures, but did not assess SCIP-10 because when the data were collected, SCIP-10 had not yet been added to the list of core measures. Recently, Tillman *et al.*[9] reported a before and after comparison study in which SCIP Inf-1 (antibiotic timing), SCIP Inf-2 (antibiotic selection), and SCIP Inf-10 (perioperative temperature management) were all implemented in 2010. Overall, they found no decrease in SSI rate (3.13% before *vs.* 2.96% after, $P = 0.72$). However, they did show a decrease in SSI for the colorectal subgroup (24.1% before *vs.* 11.5% after, $P = 0.03$). This finding suggests that in high-risk patients, the combination of SCIP measures is beneficial. These results are of interest because the original study by Kurz *et al.*[16] was performed in patients undergoing colorectal surgery and provided the evidence on which SCIP Inf-10 is based. Recently, Rasouli *et al.*[8] reported that implementing the entire group of SCIP measures in total joint arthroplasty patients was associated with an *increase* in rate of both superficial SSI and pulmonary embolus, but no change in venous thrombosis or deep SSI. These authors also did not describe specific compliance rates with SCIP-10.

In the 1990s, Sessler[30] conducted a large number of studies showing that virtually all anesthetic drugs and techniques render patients poikilothermic, whereby their body temperature drifts rapidly downward toward ambient temperature. This thermoregulatory impairment is likely due to both central and peripheral mechanisms. The anterior hypothalamus is the body's central "thermostat," but this function is blocked by general anesthetics. Peripheral cold defense mechanisms such as vasoconstriction and shivering are also impaired by general and neuraxial (spinal and epidural) anesthetic techniques.[24,31] In fact, all these anesthetic methods are associated with the development of intraoperative hypothermia.[24]

The advent of forced-air warming in the late 1980s was a true breakthrough in perioperative care. Studies have shown this to be the most effective method of maintaining normothermia.[32] Forced-air warming was used in virtually all patients who received active warming in this study. Considering the current cost of the forced-air "cover" (blanket) at approximately $6 USD, this may one of the simplest, most cost-effective methods of improving perioperative care. Given our current findings and the "quality-over-cost-equals-value" equation, forced-air warming is clearly a high-value method for improving perioperative care.

Limitations in this study may include the following. Some baseline preoperative patient characteristics differed between

groups, as is commonly seen in retrospective outcome studies addressing an intervention. These differences were only recognized for specific comorbidities, and we believe that we evaluated clinical outcomes in a risk-adjusted fashion in the multivariable analysis. Furthermore, we included a propensity score to further adjust for confounding variables. The risk adjustment also included duration of surgery, requirement for blood transfusions, and year of surgery, all of which could conceivably be related to adverse outcomes. Like other administrative database studies, we used ICD-9 codes from the hospital's billing database to assess morbid outcomes. This method may be less reliable than prospectively recorded outcomes.[33] However, the method we used offers less chance for investigator bias in determining morbidity. Another potential limitation is the reliance on "hand-entered" data, for example, to document the use of active warming. It was surprising that only 64% of the SCIP-compliant group was noted to be actively warmed, and it is likely that this percentage would be higher if the electronic record was 100% reliable. Finally, we recognize that the body temperature we measured on admission to the PACU or ICU may not represent a true core temperature. The temporal artery infrared thermometer that was used is known to be a somewhat unreliable indicator of true core temperature, with some studies supporting and some refuting its use as a core temperature monitor.[34–36] However, using a truly accurate core temperature measurement site (*e.g.*, distal esophagus) is not feasible in awake postoperative patients. Thus, temporal artery thermometry is typically used in many hospitals to satisfy the definition of SCIP compliance, which states that "body temperature," not true core temperature, should be greater than or equal to 36°C. We also recognize a limitation with reporting body temperature within the last 30 min of surgery, as it was not uncommon for the temperature probe to be removed from the patient near the end of the surgical procedure, thus rendering a missing value. This practice is also a "routine care" and representative of what is typically available for SCIP measure reporting. However, there were many fewer missing temperature measurements on admission to the PACU/ICU.

In conclusion, our findings show that compliance with the SCIP Inf-10 measure was associated with a reduced incidence of hospital-acquired infections, ischemic cardiovascular events, and mortality, as well as a reduced length of stay. Our findings support those from previous randomized trials showing improved outcomes when perioperative hypothermia is prevented. Furthermore, our results suggest that the process measure defined by SCIP Inf-10 can and should be used as a valid measure of perioperative care quality. Because active patient warming is an inexpensive perioperative intervention that can improve outcome, it is a high-value method of improving care.

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Competing Interests

The authors declare no competing interests.

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Appendix: ICD-9 Codes Used to Define Clinical Outcomes

Infection/Complication	ICD-9 Code	Diagnosis Description
C Diff	008.45	*Clostridium difficile*
Cerebral vascular accident	434.01	Cerebral Thrombosis W/Ci
Cerebral vascular accident	434.11	Cerebral Embolism W Ci
Cerebral vascular accident	434.91	Cerebral Artery Occlusion, Unspecified W/Ci
Cerebral vascular accident	997.02	Iatrogenic Cv Infarction
Drug-resistant antibiotic infection	V09.0	Penicillin Resistant Infection
Drug-resistant antibiotic infection	V09.1	Cephalosporin Resistant Infection
Drug-resistant antibiotic infection	V09.2	Macrolides Resistant Infection
Drug-resistant antibiotic infection	V09.3	Tetracyclines Resistant Infection
Drug-resistant antibiotic infection	V09.4	Aminoglycosides Resistant Infection
Drug-resistant antibiotic infection	V09.50	Quinolones/Fluoroq Resistant Infection
Drug-resistant antibiotic infection	V09.51	Quinolones/Fluoro Resistant Infection
Drug-resistant antibiotic infection	V09.6	Sulfonamides Resistant Infection
Drug-resistant antibiotic infection	V09.70	Antimycobacterial Resistant Infection
Drug-resistant antibiotic infection	V09.71	Other Antimycobacterial Resistant Infection
Drug-resistant antibiotic infection	V09.80	Spec Drug Resistant Infection
Drug-resistant antibiotic infection	V09.81	Multiple Drug Resistant Infection
Drug-resistant antibiotic infection	V09.90	Drug-Resistant Microorganism
Drug-resistant antibiotic infection	V09.91	Multiple Drug-Resistant Microorganism
Myocardial infarction	410.00	Ami A/L Wall/Unspecified Episode
Myocardial infarction	410.01	Ami A/L Wall/1st Episode
Myocardial infarction	410.02	Ami A/L Wall/Subsequent Episode
Myocardial infarction	410.10	Ami Ant Wall/Unspecified Episode
Myocardial infarction	410.11	Ami Ant Wall/1st Episode
Myocardial infarction	410.12	Ami Ant Wall/Subsequent Episode
Myocardial infarction	410.20	Ami I/L Wall/Unspecified Episode
Myocardial infarction	410.21	Ami I/L Wall/1st Episode
Myocardial infarction	410.22	Ami I/L Wall/Subsequent Episode
Myocardial infarction	410.30	Ami I/P Wall/Unspecified Episode
Myocardial infarction	410.31	Ami I/P Wall/1st Episode
Myocardial infarction	410.32	Ami I/P Wall/Subsequent Episode
Myocardial infarction	410.40	Ami Inf Wall/Unspecified Episode
Myocardial infarction	410.41	Ami Inf Wall/1st Episode
Myocardial infarction	410.42	Ami Inf Wall/Subsequent Episode
Myocardial infarction	410.50	Ami Other Wall/Unspecified Episode
Myocardial infarction	410.51	Ami Lat Wall/1st Episode
Myocardial infarction	410.52	Ami Lat Wall/Subsequent Episode
Myocardial infarction	410.60	Ami Pos Wall/Unspecified Episode
Myocardial infarction	410.61	Ami Pos Wall/1st Episode
Myocardial infarction	410.62	Ami Pos Wall/Subsequent Episode
Myocardial infarction	410.70	Subendocardial Ami/Unspecified Episode
Myocardial infarction	410.71	Subendocardial Ami/1st Episode
Myocardial infarction	410.72	Subendocardial Ami/Subsequent Episode
Myocardial infarction	410.80	Ami Other Site/Unspecified Episode
Myocardial infarction	410.81	Ami Other Site/1st Episode
Myocardial infarction	410.82	Ami Other Site/Subsequent Episode
Myocardial infarction	410.90	Ami Unspecified/Unspecified Episode
Myocardial infarction	410.91	Ami/Unspecified Site/1st Episode
Myocardial infarction	410.92	Ami/Unspecified Site/Subsequent Episode
Postoperative wound infection	998.51	Infected Postoperative Seroma
Postoperative wound infection	998.59	Other Postoperative Infection
Sepsis	038.9	Septicemia Nos
Sepsis	670.20	Puerperal Sepsis - Unspecified as to Episode of Care or Not Applicable
Sepsis	670.22	Puerperal Sepsis, Delivered, with Mention of Postpartum Complication

(*Continued*)

Appendix. Continued

Infection/Complication	ICD-9 Code	Diagnosis Description
Sepsis	670.24	Puerperal Sepsis—Postpartum Condition or Complication
Sepsis	771.81	Newborn Septicemia
Sepsis	995.91	Sepsis
Transient ischemic attack	435.0	Basilar Artery Syndrome
Transient ischemic attack	435.1	Vertebral Artery Syndrome
Transient ischemic attack	435.2	Subclavian Steal Syndrome
Transient ischemic attack	435.3	Vertebrobasilar Artery Syndrome
Transient ischemic attack	435.8	Transient Cerebral Ischemia Nec
Transient ischemic attack	435.9	Transient Cerebral Ischemia Nos

A/L = anterolateral; Ami = acute myocardial infarction; Ant = anterior; Ci = cerebral infarction; ICD-9 = *International Classification of Diseases*, ninth Revision; IL = inferolateral; I/P = inferoposterior; Lat = lateral; Nec = not elsewhere classified; Nos = not otherwise specified.