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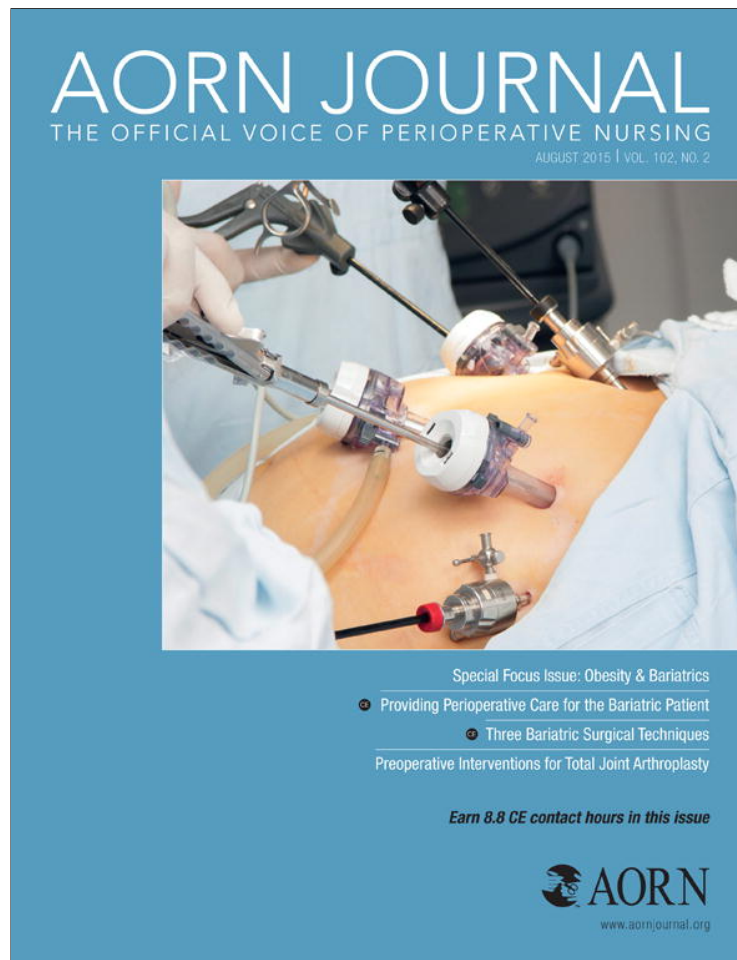
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Comparing New-Technology Passive Warming Versus Traditional Passive Warming Methods for Optimizing Perioperative Body Core Temperature

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ABSTRACT

Hypothermia puts surgical patients at risk for adverse outcomes. Traditional passive warming methods are mostly ineffective in reducing hypothermia. New-technology passive warming holds promise as an effective method for promoting and sustaining normothermia throughout surgery. The purpose of this retrospective cohort study was to compare the effectiveness of new-technology passive warming with traditional methods. We measured core body temperature at anesthesia induction and at the end of surgery for patients undergoing robotic-assisted prostatectomy/hysterectomy in the lithotomy position who received either new-technology passive warming ($n = 30$) or traditional linens and gel pads ($n = 35$). The traditionally warmed cohort had no change in temperature ($35.9^{\circ}\text{C} \pm 0.6^{\circ}\text{C}$ presurgery vs $35.9^{\circ}\text{C} \pm 0.7^{\circ}\text{C}$ postsurgery; $t = 0.47$; $P = .66$). The intervention cohort showed a significant increase in temperature ($35.75^{\circ}\text{C} \pm 0.52^{\circ}\text{C}$ presurgery vs $36.30^{\circ}\text{C} \pm 0.53^{\circ}\text{C}$ postsurgery; $t = 4.64$; $P < .001$). A repeated-measure analysis of variance adjusting for surgery duration and fluid administration confirmed the significance ($F = 17.254$; $P < .001$), suggesting that new-technology passive warming may effectively complement active warming to reduce perioperative hypothermia. *AORN J* 102 (August 2015) 183.e1–183.e8. © AORN, Inc, 2015. <http://dx.doi.org/10.1016/j.aorn.2015.06.005>

Key words: *hypothermia, perioperative, passive warming, lithotomy position, prostatectomy, hysterectomy.*

The OR environment has been considered an extreme environment for patients because of its cold temperature that contributes to patient heat loss and hypothermia.^{1,2} Hypothermia puts patients at risk for many adverse outcomes.^{3,4} Passive warming methods are used concomitantly with active warming methods to promote normothermia in patients during surgery.⁵ Passive

warming methods traditionally involve wrapping patient extremities with blankets, linens, and gel pads. However, these passive methods are mostly ineffective in reducing heat loss.⁶ Technological advances in passive warming materials and devices may improve their effectiveness in keeping patients warm and reducing the risk for hypothermia.

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STATEMENT OF PURPOSE

While technologically advanced warming devices show promise as an effective method for passive warming, limited evidence exists on which to base practice. The purpose of this study was to compare one new-technology passive warming device with traditional passive warming, consisting of gel pads and linens, for maintaining optimal core body temperature in the OR.

RESEARCH HYPOTHESIS

We hypothesized that patients with new-technology passive warming would have higher core body temperatures by the end of surgery than patients with traditional passive warming methods.

STATEMENT OF SIGNIFICANCE TO NURSING

Perioperative nurses are critical to promoting best practices for keeping patients safe during surgery.⁷ AORN has developed recommended practices for perioperative nurses to prevent unplanned hypothermia. These include the selection of appropriate equipment, appropriate uses of warming devices, and use of evidence in determining best practice.^{8,9} However, little evidence guides the effective use of passive warming methods to promote normothermia. Studies are needed to address this gap. The preliminary data from this study provide information to the perioperative nurse and OR surgical team when considering the most effective passive warming method to improve the patient experience and prevent the risk for adverse patient outcomes.

LITERATURE REVIEW

The cold temperature of the OR environment contributes to patient heat loss because of temperature gradient differences between the patient's body and the ambient temperature.^{10,11} Patient warming to maintain normothermia has become a standard part of the overall care of surgical patients to reduce complications attributed to perioperative hypothermia.⁴ However, maintaining normothermia is a challenge in certain clinical scenarios, such as surgeries on patients in lithotomy positions (prostate, colon resections, hysterectomy), liver transplantation surgery, and open heart and trauma surgeries. The risk for these patients is hypothermia, or a body temperature less than 36° C (96.8° F), which has been shown to occur in 50% to 90% of all surgeries.^{6,9} Hypothermia puts patients at risk for many adverse outcomes, including but not limited to prolonged postoperative recovery from anesthesia, suboptimal enzyme function, surgical site infection, increased perioperative blood loss, delayed wound healing, and increased cardiac morbidity events, including ventricular tachycardia.^{3,11-14} Perioperative hypothermia

results in part from patient skin surfaces that cannot be covered by active and passive warming methods in the OR. These peripheral thermal compartments, which can be 2° C to 4° C (3.6° F to 7.2° F) lower than core temperature, can rapidly dissipate total-body heat content up to 30% to 40% if not prevented or reduced.^{15,16} Other mechanisms of perioperative hypothermia include the cooling effect of anesthetic gases, IV fluids, and the patient's reduced heat production because of lowered metabolic activity.^{6,17}

To effectively maintain normothermia in surgical patients, both active and passive warming methods are typically used. Active methods include heated humidifiers, warmed IV fluids, circulating-water blankets and mattresses, and warming devices such as forced-air warmers that blow warm air into a blanket placed over the patient.^{3,6,18} These active heating methods are effective in maintaining normothermia and have few complications.¹¹ Passive warming methods involve wrapping patient extremities with blankets, linens, and gel pads. However, these methods have been found to function poorly because of the porous nature of the linens and because as gel pads cool, they begin to add to heat loss, rather than protect from it.⁶ This heat loss can be difficult to regain because of the limited skin surface available for active warming to rewarm the patient. The overall heat gain by active warming is usually inadequate to compensate for the greater heat loss via the extremities and the lower body.^{10,14,19}

New passive warming devices have been developed by the US military for transporting trauma patients in adverse conditions, which incorporate insulation, wind-proofing properties, and reinforced and composite fabrics.²⁰ These new-technology passive warming devices may provide superior passive warming by reducing or preventing the peripheral heat loss at the beginning of and throughout surgery by effectively covering and insulating the peripheral compartments to allow the heating mechanism of forced-air warming (active warming) to keep the core thermal compartments warm.

METHODS

We conducted a retrospective observational cohort study comparing core body temperature outcomes for patients receiving one of two types of passive warming methods: new-technology passive warming or traditional passive warming consisting of linens and gel pads.

Operational Definitions

Hypothermia is defined as a core body temperature less than 36° C (96.8° F).^{11,14}

Table 1. Patient Demographic Variables

Variable	Control		Intervention		Test ^a	P
	Count	%/SD	Count	%/SD		
Sample size n	35		30			
Age at discharge	54	± 12	58	± 9	1.50	.14
Gender					0.17	.68
Female	25	38.5	20	30.8		
Male	10	15.4	10	15.4		
Race					-	.87
Asian	3	4.6	2	3.1		
Black/African American	1	1.5	2	3.1		
Declined	2	3.1	1	1.5		
Other race	6	9.2	7	10.8		
White	23	35.4	18	27.7		
Ethnicity					-	.42
Unknown	1	1.5	3	4.6		
Hispanic or Latino or Spanish origin	6	9.2	4	6.2		
Not Hispanic or Latino or Spanish origin	28	43.1	23	35.4		
DRG					-	.60
Major male pelvic procedures	7	10.8	10	15.4		
Bladder procedures	2	3	0	0		
Myeloproliferative disorder or neoplasm with other OR procedure	2	3.1	0	0		
Pelvic evisceration, radical hysterectomy/vulvectomy with complications	0	0	1	1.5		
Unknown	9	13.8	6	9.2		
Uterine & adnexa procedure	15	23.1	13	20		

Abbreviations: SD = standard deviation; DRG = diagnostic-related group.
^a The test is t test for continuous variables, Pearson chi square for category variables with counts of more than 5 (statistic listed), or Fisher exact test for category variables with counts of less than 5 (no statistic to list).

Mild hypothermia is defined as a core temperature between 34° C and 36° C (93.2° F and 96.8° F).¹⁹

Standard passive warming in this study are linens from a warmed cabinet used to cover patient extremities and gel pads that were strategically placed to both warm patient extremities and provide cushioning.

New-technology passive warming is an interconnected device that included a double-layer base surface (nylon and polypropylene) that supported the patient's head and body, a double-layer foam pad combined with a layer of polypropylene that wrapped around each arm, and a split double-layer (nylon and polypropylene) surface that wrapped around each individual leg.

Ambient OR temperature is the temperature from the wall thermometer in the study OR that is documented daily in the OR log and serviced daily by facilities maintenance.

Time in the OR is defined as the time documented on the anesthesia record when the patient entered the OR.

Surgery start time is the time documented in the anesthesia record when the surgeon made the first incision.

Surgery end time is the time documented in the anesthesia record when the patient's skin closure was complete and dressing on the wound was applied.

Core body temperature is the temperature measured with a nasopharyngeal temperature probe inserted by the anesthesiologist at the time of anesthesia induction.

Presurgery patient core temperature is the temperature documented just after induction of anesthesia.

Postsurgery core temperature is the temperature documented just before emergence from anesthesia.

Table 2. Clinical and Surgical Variables

Clinical/Surgical Variables	Control		Intervention		t Statistic	P
	Count	%/SD	Count	%/SD		
Fluids during surgery (mL)	1,992	817	2,107	844	0.56	.63
OR temperature (° C)	19.5	0.7	19.7	0.4	1.20	.24
Time from entering OR to incision (minutes)	44.9	12.3	38.5	16.1	1.84	.07
Time from incision to end of surgery (minutes)	157.7	78.9	174.2	72.5	0.87	.38
Total time in OR (minutes)	202.6	81.0	212.7	73.6	0.52	.60

Abbreviation: SD = standard deviation.

Intravenous fluids are the total quantity of all IV fluids documented on the anesthesia record, in milliliters.

Population

The study population included patients who received a robotic-assisted prostatectomy or hysterectomy in the lithotomy position requiring a general anesthetic. We chose these specific patient surgeries because they are standardized, with minimal variation in patient preparation, anesthesia induction, surgery procedures, and time spent for each facet of surgery, from the patient entering the OR suite to transfer to the postoperative department.

Setting

The setting for this study was Sharp Memorial Hospital, a 368-bed community hospital that is one of the largest providers of acute care services to a diverse patient population in San Diego County, California. All study patients had surgery in the same OR, removing potential confounding effects of sample heterogeneity in terms of surgery environment.

Sample Size Calculation

Based on data that show a historical standard deviation of patient core temperature of 0.4° C (0.72° F) from previous active warming studies²¹ and 80% power, we calculated a sample size of 30 patients for each cohort as adequate to

detect 0.3° C (0.54° F) below the targeted patient core temperature of 36.0° C (96.8° F) at the end of surgery with 95% confidence.

Sampling Technique

We obtained all data for this study retrospectively from Sharp HealthCare's data warehouse and electronic medical record. Patients were initially identified for inclusion into the study using diagnostic-related group (DRG) codes for study surgeries between October 2013 and March 2014. The director of surgical services reviewed the anesthesia record of each eligible patient to determine which passive warming method was used. The principal investigator then reviewed the patient's history and physical examination results to identify inclusion and exclusion criteria. Included study patients had American Society of Anesthesiologists (ASA) physical status I to III; body mass index (BMI) range of 18.5 kg/m² to 38 kg/m², to isolate the passive warming materials from the potential protective effect of body fat against hypothermia; age 18 years to 80 years; and height of 5 ft 1 in to 6 ft 3 in. We excluded patients from the study if they had a break in skin integrity on the extremity, a history or family history of malignant hyperthermia or allergic skin conditions, intraoperative blood loss greater than 1,000 mL, fluid administration greater than 5,000 mL, or a history of bleeding disorders or coagulopathies. The director of surgical services and principal investigator extracted data from the OR log and electronic health record, which includes the anesthesia

Table 3. Core Body Temperature Before and After Surgery

	Anesthesia Induction		End of Surgery		t Statistic	P
	Average	SD	Average	SD		
Control (n = 35)	35.89	0.57	35.93	0.73	0.47	.64
Intervention (n = 30)	35.75	0.52	36.36	0.53	4.64	<.001

Temperature in degrees Celsius.
Abbreviation: SD = standard deviation.

Variable	Type III Sum of Squares	df	Mean Square	F	P	Partial Eta ²
Temperature	0.598	1	0.598	3.995	.050	0.065
Temp x Time in Surgery	0.007	1	0.007	0.046	.832	0.001
Temp x Fluids During Surgery	0.005	1	0.005	0.033	.856	0.001
Temp x Group	2.581	1	2.581	17.254	.000	0.232
Error	8.527	57	0.150			

record. The principal investigator extracted data from the data warehouse. The principal investigator reviewed and audited all data for accuracy and consistency.

Protection of Participants' Rights

Human subject approval was obtained from Sharp's Institutional Review Board (IRB) before commencing the study procedures (IRB #131086).

Procedure

Sharp HealthCare routinely tests new US Food and Drug Administration (FDA)-approved technology for potential clinical- and cost-effectiveness. Patient warming was considered an improvement priority by Sharp Memorial Hospital Ambulatory and Clinical Service Department. The vice president of the department and the director of surgical services approved testing of the new passive warming device. The OR department tested the new-technology passive warming device between October 2013 and March 2014. Patients undergoing study surgeries received either new-technology passive warming (intervention cohort) or traditional passive warming consisting of linens and gel

pads (control cohort), based on the choice of the OR team prepping the patient. The choice was left to the OR team so that testing would not alter the routines of OR teams that did not want to participate in the test. All other procedures and equipment used were similar between cohorts, including the same OR, the same standard practice for measuring and documenting patient core body temperature, and routine standard care for the patient's surgery, recovery, and discharge.

Variables

Patient demographic variables included age, gender, race, and surgery type. Clinical and surgical variables included quantity of IV fluid administered during surgery, ambient temperature of OR, time into OR, surgery start time, and surgery end time. Core body temperature was measured just after induction of anesthesia (presurgery) and just before emergence from anesthesia (postsurgery).

Analysis

We calculated descriptive statistics as mean and standard deviation for continuous variables and as frequency and percentage for categorical variables. Univariate analysis included *t* tests for continuous variables and either Pearson chi-square test (for variables with counts greater than five) or Fisher exact test (for variables with counts less than five) for categorical variables to determine significant differences between cohorts on demographic, clinical, and surgery variables. We conducted *t* tests on outcomes data to determine whether there was a significant difference between unadjusted presurgery and postsurgery core body temperatures for each cohort. We subsequently conducted a repeated-measure analysis of variance (ANOVA) to determine significant differences in presurgery and postsurgery core body temperatures between cohorts, controlling for surgery time and IV fluid volume delivered during surgery. We conducted Mauchly test to test for the assumption of sphericity of the data and used a Greenhouse-Geisser correction if the assumption was not met. We conducted all statistical analyses using SPSS, version 21 (IBM, New York).

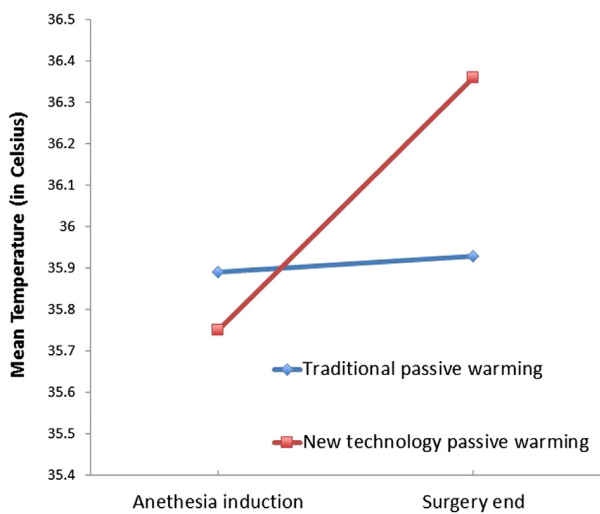


Figure 1. Core body temperatures of patients before and after surgery.

RESULTS

Total sample size was 35 control patients (traditional passive warming) and 30 intervention patients (new-technology passive warming). Demographically, there were no significant differences between cohorts in age, gender, race, ethnicity, or surgery type/DRG (Table 1). Clinically, there was no significant difference between cohorts in the quantity of IV fluids administered during surgery. Surgically, there was no significant difference between cohorts in the ambient OR temperature and time in the OR (Table 2).

There was a significant (unadjusted) difference between pre-surgical and postsurgical core body temperatures for the intervention, but not for the control cohort. For the control cohort, $35.89^{\circ}\text{C} \pm 0.57^{\circ}\text{C}$ presurgery versus $35.93^{\circ}\text{C} \pm 0.73^{\circ}\text{C}$ postsurgery ($t = 0.47$; $P = .66$); for the intervention cohort, $35.75^{\circ}\text{C} \pm 0.52^{\circ}\text{C}$ presurgery versus $36.30^{\circ}\text{C} \pm 0.53^{\circ}\text{C}$ postsurgery ($t = 4.64$; $P < .001$; Table 3). For the repeated-measure ANOVA, Mauchly test for assumption of sphericity was not met, so a Greenhouse-Geisser correction was used to adjust for nonassumption. The results of the repeated-measure ANOVA showed that core body temperatures before and after surgery were significantly different ($F = 4.0$; $P = .05$) between cohorts, controlling for surgery time and fluids during surgery (Table 4). There was no significant interaction between time in surgery or fluids during surgery. There was a significant interaction between cohort and temperature. The intervention cohort had significantly higher postsurgery temperatures than the control cohort ($F = 17.254$; $P < .001$); 6.5% of the variance between groups was associated with temperature, and 23%, with temperature by grouping (Figure 1).

DISCUSSION

The results confirm the study hypothesis. We found a significant difference between cohorts in patients' postoperative core body temperatures, with the intervention cohort showing a significant increase in core body temperature by the end of surgery compared with no change in core body temperature for the control cohort. The adjusted model controlling for surgery time and IV fluid quantity confirmed the difference between the cohorts. The intervention cohort had significantly greater postsurgery core body temperatures than the control group.

The OR ambient temperature is an important factor contributing to heat loss in surgical patients.^{1,2,10} Both active and passive warming are typically used for patient warming. The evidence shows that traditional passive warming methods using blankets or elastic bandages wrapped around the legs are

less effective in reducing the incidence or magnitude of hypothermia than active warming methods.⁶ Traditional passive warming devices such as surgical drapes may reduce heat loss by approximately 30%,² while newer technology passive warming materials may reduce heat loss up to 45% when applied to areas that cannot be actively warmed.²²

It is important to explore new-technology passive warming methods that can effectively maintain core body temperature at optimal levels. Even mild perioperative hypothermia, defined as a core temperature between 34°C and 36°C (93.2°F and 96.8°F),¹⁹ can initiate peripheral vasoconstrictor responses (thermoregulatory vasoconstriction) that decrease tissue oxygen levels and increase immunosuppression. This can increase patient susceptibility to adverse outcomes such as surgical wound infection and decreased wound healing.¹⁴ Mild hypothermia can also cause other complications, such as shivering, increased metabolic rates, prolonged medication duration, increased cardiac morbidity, and increased blood loss and transfusion requirement.¹⁴ This study showed that new-technology passive warming has the potential to reduce the risk for hypothermia above and beyond active warming methods.

LIMITATIONS AND RECOMMENDATIONS FOR RESEARCH

This was a retrospective design that used preexisting data from clinical records to examine passive warming methods at Sharp HealthCare. The use of preexisting data in an observational retrospective study design limits the generalizability of study findings because of the reduced internal validity of the study design and potential inaccuracies in the preexisting data. However, observational cohort studies have the ability to assess causality due to the temporal nature of the methodology,²³ and this study's findings confirm a temporal link between a passive warming method and subsequent outcome of interest. There were no significant differences between cohorts in a range of baseline demographic, clinical, and surgical variables, suggesting that we were comparing equal cohorts, but we do not know whether unmeasured variables had a confounding effect on the findings. For example, surgical teams that chose the new-technology passive warming device to test may be intrinsically different from surgical teams that chose to stay with traditional passive warming methods. It is therefore important to replicate these findings with research that includes prospective study designs, other surgery types (eg, open and laparoscopic surgeries), and different settings to improve the evidence base for new-technology passive warming in improving core body temperature.

KEY TAKEAWAYS FOR CLINICAL PRACTICE

Comparing New-Technology Passive Warming Versus Traditional Passive Warming Methods for Optimizing Perioperative Body Core Temperature

WHY DID WE DO THIS RESEARCH?

- This research project was undertaken to compare a new passive warming device with the traditional passive warming techniques of gel pads and linens, for maintaining optimal core body temperatures of patients in the OR. We measured the presurgery and postsurgery body temperatures of patients undergoing hysterectomy or prostatectomy.

WHAT DID WE FIND?

- We found a significant (unadjusted and adjusted) difference between presurgery and postsurgery core body temperatures for the cohort of patients using a new-technology passive warming device, but not for the cohort that experienced traditional passive warming techniques.

HOW CAN HEALTH CARE PROFESSIONALS USE THESE RESULTS?

- **Clinician:** Perioperative team members should be aware that traditional methods of warming are fairly ineffective at maintaining core body temperatures throughout surgery and that new-technology warming devices appear to better assist in maintaining patient body temperatures.
- **Manager:** Managers should keep abreast of new-technology warming devices and studies that evaluate their uses so that effective equipment can be ordered for use in the OR.
- **Educator:** Educators should be aware of the effectiveness of new-technology warming devices and ensure that nursing staff members are trained in their value and proper use.

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RECOMMENDATIONS FOR PRACTICE

The Centers for Medicare & Medicaid Services and The Joint Commission have recognized the importance of reducing perioperative hypothermia and have developed a national normothermia measure (Surgical Care Improvement Project [SCIP]-Inf-10) that requires hospitals to manage core body temperature during surgery as part of the SCIP.²⁴ Our study showed that both control and intervention patients were experiencing mild hypothermia at the time of anesthesia onset (Table 3), most likely due to the cold OR ambient temperature and anesthesia induction, which reduces core body temperature during the time needed to prepare the patient for surgery. Our study showed that patients with new-technology passive warming had normothermia (core

body temperature of 36° C or higher) by the end of surgery compared with continued mild hypothermia for control patients. This evidence suggests that changing the methods of passive warming can result in significant and clinically meaningful improvements in patient core body temperature, helping to ensure compliance with The Joint Commission SCIP measures and to improve patient safety outcomes.

CONCLUSION

In this study, new-technology passive warming resulted in significant increases in core body temperature by the end of surgery. An adjusted model confirmed this difference between cohorts. We conclude that new-technology passive warming

devices effectively complement active warming methods to result in significant heat gain in patients undergoing robotic-assisted prostatectomy/hysterectomy in the lithotomy position. The data from this study provide information that the professional nurse and OR surgical team can consider when deciding on the most effective passive warming method to improve the patient experience and to ameliorate the risks for adverse patient outcomes. ●

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Brandon Giap, MD, is director of the division of cardiac anesthesiology at Sharp Memorial Hospital in San Diego, CA. As chief executive officer and founder of BCG Medical, a company that produces and sells patented patient handling systems for surgical patients, Dr Giap has declared an affiliation that could be perceived as posing a potential conflict of interest in the publication of this article. BCG Medical provided the new-technology passive warming devices (Opt-Shield) that were investigated in this study.
