Impact of Intraoperative Hypothermia on Incidence of Infection in Implant-Based Breast Reconstruction

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Background: Infection following implant-based breast reconstruction can lead to devastating complications. Risk factors for infection include smoking, diabetes, and obesity. Intraoperative hypothermia may represent another modifiable risk factor. This study analyzed the effect of hypothermia in postmastectomy immediate implant-based reconstruction on postoperative surgical-site infection (SSI).

Methods: This was a retrospective review of 122 patients with intraoperative hypothermia, defined as less than 35.5°C, and 106 normothermic patients who underwent postmastectomy implant-based reconstruction between 2015 and 2021. Demographics, comorbidities, smoking status, hypothermia (and its duration), and length of surgery were collected. The primary outcome was SSI. Secondary outcomes included reoperation and delayed wound healing.

Results: A total of 185 patients (81%) underwent staged reconstruction with tissue expander placement and 43 patients (18.9%) had a direct-to-implant procedure. Over half (53%) of the patients experienced intraoperative hypothermia. In the hypothermic group, a higher proportion of patients had SSIs (34.4% versus 17% of normothermic patients; $P < 0.05$) and wound healing complications (27.9% versus 16%; $P < 0.05$). Intraoperative hypothermia predicted SSI (OR, 2.567; 95% CI, 1.367 to 4.818; $P < 0.05$) and delayed wound healing (OR, 2.023; 95% CI, 1.053 to 3.884; $P < 0.05$). Longer duration of hypothermia significantly correlated with SSI, with an average 103 minutes versus 77 minutes ($P < 0.05$).

Conclusions: This study demonstrates that intraoperative hypothermia is a significant risk factor for postoperative infection in postmastectomy implant-based breast reconstruction. Maintaining strict normothermia during implant-based breast reconstruction procedures may improve patient outcomes by reducing the risk of postoperative infection and delayed wound healing. *(Plast. Reconstr. Surg.* 153: 35, 2024.)

CLINICAL QUESTION/LEVEL OF EVIDENCE: Risk, II.

The number of breast reconstruction procedures has grown significantly over the past few decades, with an estimated 137,808 cases in 2020, according to the American Society of Plastic Surgeons.[1] Most procedures involve placement of an implant (75%) and are performed in the immediate postmastectomy setting (77%).[1] As with all surgical procedures, implant-based breast reconstruction carries a risk of postoperative surgical-site infection (SSI), but its incidence

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A Video Discussion by Pat McGuire, MD, accompanies this article. Go to PRSJournal.com and click on "Video Discussions" in the "Digital Media" tab to watch.

can be quite high: 5% to 35%.[2,3] Studies have shown that the incidence of infection is higher in immediate postmastectomy implant placement, which is thought to be because of colonization of the implant by native flora of the breast nipple and ducts.[3,4]

SSI can have a devastating impact on breast reconstruction. In addition to systemic illness and the potential need for prolonged antibiotic therapy, these infections can significantly increase hospital-associated costs, delay oncologic treatments, and even lead to implant loss.[3,5,6] Subclinical SSI has also been implicated in the pathogenesis of capsular contracture, which is a leading cause of revision surgery.[3,7] Many risk factors for SSI have been identified in implant-based reconstruction, including smoking, radiation therapy, chemotherapy, diabetes, and obesity.[8,9] However, one common risk factor that has not been evaluated extensively in implant-based breast reconstruction is intraoperative hypothermia.

Perioperative normothermia has been shown to decrease SSI in colorectal cancer operations and in general surgery patients, including those undergoing breast surgery.[8,10] Close intraoperative temperature regulation has become part of the definition of high-quality surgical care and is recommended in the World Health Organization Guidelines for Safe Surgery to reduce the risk of coagulopathy and SSI.[11] Mechanisms for hypothermia-related SSI have been evaluated and are thought to be related to anesthesia-induced central thermoregulatory center depression followed by compensatory peripheral vasoconstriction to shunt blood centrally. This reduces blood flow at the surgical site, impedes wound healing and immune system function, and ultimately contributes to an increased risk of postoperative wound infections.[12–15] This motivated our present study, which aimed to clarify the relationship between intraoperative hypothermia and SSI in implant-based breast reconstruction.

PATIENTS AND METHODS

Following institutional review board approval, a retrospective chart review of 228 consecutive patients undergoing mastectomy with immediate implant-based breast reconstruction at our institution from 2015 to 2021 was performed. These cases were performed by six plastic surgeons and four surgical oncologists at our institution. Inclusion criteria were women older than 18 years undergoing mastectomy and immediate implant-based reconstruction, those who had general anesthesia, and those who had intraoperative temperature data available. Exclusion criteria included patients for whom temperature was not recorded, patients with follow-up less than 90 days, inmates, and patients younger than 18 years.

Demographic information was collected, including age at surgery, body mass index (BMI), cancer stage at surgery, smoking status, hypertension, diabetes, American Society of Anesthesiologists (ASA) physical status classification, and indication for mastectomy. Operative data, including type of reconstruction, laterality, length of operation, perioperative warming devices, perioperative prophylactic antibiotics, surgical drains, lowest recorded intraoperative temperature, and length of time below 35.5°C. Intraoperative hypothermia was defined as less than 35.5°C for any period. The primary outcome evaluated was the incidence of postoperative infection, defined as any need for oral or intravenous antibiotics within 90 days after index surgery. The Centers for Disease Control and Prevention defines SSI as an infection that occurs within 30 days or up to 90 days when an implant is involved, which explains our use of the 90-day SSI timeline.[16] Secondary outcomes included reoperation within 90 days, wound healing complications defined as dehiscence and/or delayed healing, mastectomy skin necrosis, seroma, and hematoma.

Data were analyzed using SPSS (IBM Corp., Armonk, NY). Clinical outcomes and demographic data between the hypothermic and normothermic cohorts were compared by means of univariate analysis using the *t* test and analysis of variance. The chi-square test and Fisher exact test were used for categorical variables. A Firth-type logistic regression model was constructed to elucidate the impact of covariate factors (eg, age, BMI, smoking) on postoperative outcomes. Odds ratios, 95 percent confidence intervals (CIs), and *P* values were calculated for each comparison. For all analyses, significance was defined as $P < 0.05$.

RESULTS

A total of 228 consecutive patients met inclusion and exclusion criteria, and 122 (53%) were found to have experienced intraoperative hypothermia (Fig. 1). Patient demographics and clinical characteristics are summarized in Table 1. Overall, the average age of this patient population was 50 ± 12.2 years, with a range of 23 to 79 years, and most patients identified as white (53.9%) or black/African American (37.3%). The average BMI was 29.3 ± 6.5 kg/m^2, with a range of 18.0 to 49.3 kg/m^2. Fourteen percent of patients had

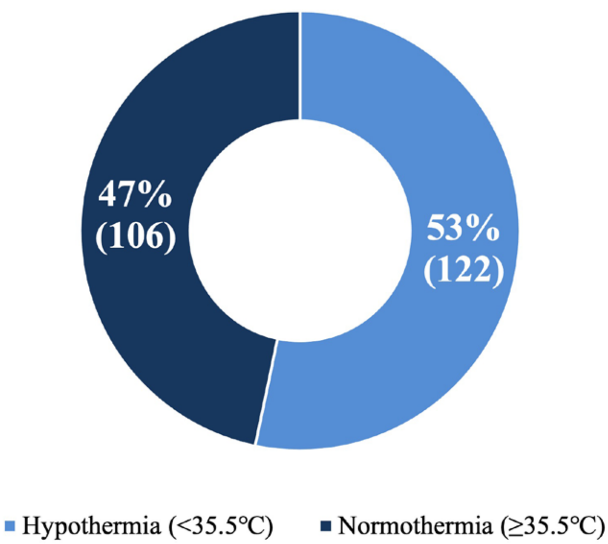

Fig. 1. Percentage of patients experiencing intraoperative hypothermia.

a diagnosis of type 1 or type 2 diabetes mellitus, 35.5% had a diagnosis of hypertension, and 61.8% of patients were never smokers; however, 15.8% were current smokers and 22.4% were former smokers, defined as cessation at least 4 weeks before surgery. In addition, 60.1% had an ASA class of 1 or 2. With 39.9% of our patient population having an ASA class of 3 or 4, it highlights that our patient population lends itself to having more uncontrolled disease. Our large academic center is also in an urban area with a high percentage of underserved patients, which contributes to a patient population with a higher incidence of moderate to severe uncontrolled diseases.

Most patients included in the study had a documented diagnosis of breast cancer (96.5%). Breast cancer type (ductal carcinoma in situ, invasive ductal carcinoma, invasive lobular carcinoma), breast cancer stage, chemotherapy, and radiation therapy were recorded and were not significantly different between the two cohorts (Table 1). Apart from smoking status, which was significantly lower in the normothermic group ($P = 0.004$), there were no significant differences in baseline characteristics between those who experienced intraoperative hypothermia and those who did not. There was a trend for older age (51.47 years versus 48.55 years) and lower BMI (28.52 kg/m^2 versus 30.12 kg/m^2).

Table 2 summarizes operative characteristics. Most patients underwent bilateral reconstruction (61.8%), and 81.1% of patients received tissue expanders. Acellular dermal matrix (ADM) was also used in most cases (93%). All patients received over-body forced-air warming and preoperative antibiotics according to our institution's policy. All patients who had drains placed intraoperatively (222 of 228 patients) continued to receive postoperative antibiotics until drains were removed. The average length of surgery was 277.8 ± 92.0 minutes (range, 79 to 546 minutes). There were no significant differences in these variables between hypothermic and normothermic cohorts. However, mean length of surgery was slightly longer in the hypothermic cohort (mean ± SD, 288.1 ± 92.8 minutes; range, 79 to 546 minutes) compared with the normothermic cohort (266.0 ± 90.0 minutes; range, 110 to 523 minutes). In the hypothermic cohort, the average length of time spent hypothermic (<35.5°C) was 86 ± 54.7 minutes (range, 5 to 300 minutes).

Outcomes data are summarized in Table 3. A significantly higher proportion of patients with hypothermia had SSIs (34% versus 17%; $P < 0.05$) and delayed wound healing (27.9% versus 16%; $P < 0.05$) (Figs. 2 and 3). Both groups had a similar incidence of hematoma (6.6% versus 11.3%; $P > 0.05$), seroma (12.3% versus 16%; $P > 0.05$), mastectomy skin flap necrosis (12.3% versus 9.4%; $P > 0.05$), and unplanned reoperation within 90 days (13.1% versus 13.2% for both; $P > 0.05$).

A Firth-type logistic regression model was constructed for univariate and multivariate analysis (Table 4). In the univariate analysis, intraoperative hypothermia predicted SSI (OR, 2.567; 95% CI, 1.367 to 4.818; $P < 0.05$). This model was statistically significant [chi-square (1), 4.658; $P < 0.05$). Intraoperative hypothermia also predicted wound healing complications (OR, 2.023; 95% CI, 1.053 to 3.884; $P < 0.05$), which was also a statistically significant model [chi-square (1), 9.131; $P < 0.05$]. A univariate analysis demonstrated that smoking status predicted intraoperative hypothermia (OR, 2.406; 95% CI, 1.231 to 4.702; $P < 0.05$) in a statistically significant model [chi-square (1), 8.387; $P < 0.05$]. A multivariate logistic regression was performed to ascertain the effects of hypothermia, age, BMI, smoking status, and delayed wound healing on postoperative SSI. The model was statistically significant [chi-square (6), 39.888; $P < 0.05$]. In the model, patients experiencing hypothermia were 2.4 times more likely to present with postoperative infection, patients with increasing BMI had a slightly higher likelihood of presenting with postoperative infection, and patients with delayed wound healing were 5.4 times more likely to present with postoperative

Table 1. Baseline Demographics

Characteristic	All Patients (%)	Hypothermia (<35.5°C) (%)	Normothermia (≥35.5°C) (%)	*P*
No. of patients	228 (100)	122 (100)	106 (100)	
Age at day of surgery, yr				0.071
Mean ± SD	50.11 ± 12.2	51.47 ± 12.3	48.55 ± 11.9	
Median	50.50	51.00	48.50	
Range	23–79	24–79	23–77	
Race				0.470
White	123 (53.9)	60 (49.2)	63 (59.4)	
Black	85 (37.3)	52 (42.6)	33 (31.1)	
Unknown/other	16 (7.0)	8 (6.6)	8 (7.5)	
Asian	4 (1.8)	2 (1.6)	2 (1.9)	
Ethnicity				0.444
Hispanic	12 (5.3)	6 (4.91)	6 (5.7)	
Non-Hispanic	215 (94.3)	116 (95.1)	99 (93.4)	
Unknown/other	1 (0.4)	0 (0)	1 (0.93)	
BMI, kg/m²				0.066
Mean ± SD	29.26 ± 6.5	28.52 ± 6.0	30.12 ± 6.9	
Median	28.54	28.14	29.06	
Range	18.03–49.3	19.1–46.32	18.03–49.3	
Chronic medical conditions				
Diabetes (type 1 or type 2)	32 (14.0)	15 (12.3)	17 (16.0)	0.419
Hypertension	81 (35.5)	41 (33.6)	40 (37.7)	0.518
Smoking status				0.004[a]
Current	36 (15.8)	24 (19.7)	12 (11.3)	
Former	51 (22.4)	34 (27.9)	17 (16.0)	
Never	141 (61.8)	64 (52.5)	77 (72.6)	
ASA class				0.724
1 or 2	137 (60.1)	72 (59.0)	65 (61.3)	
3 or 4	91 (39.9)	50 (41.0)	41 (38.7)	
Breast cancer diagnosis	220 (96.5)	119 (97.5)	101 (95.3)	0.358
Chemotherapy				0.662
No	93 (42.3)	52 (43.7)	41 (40.6)	
Yes, before mastectomy	85 (38.6)	45 (37.8)	40 (39.6)	
Yes, after mastectomy	40 (18.2)	21 (17.6)	19 (18.8)	
Unknown	2 (0.9)	1 (0.8)	1 (1.0)	
Radiation therapy				0.925
No	124 (56.4)	68 (57.1)	56 (55.4)	
Yes, before mastectomy	7 (3.2)	3 (2.5)	4 (4.0)	
Yes, after mastectomy	86 (39.1)	46 (38.7)	40 (39.6)	
Unknown	3 (1.4)	2 (1.7)	1 (1.0)	
Breast cancer type				0.537
DCIS	45 (20.5)	24 (19.7)	21 (20.8)	
IDC	153 (69.5)	84 (68.9)	69 (68.3)	
ILC	18 (8.2)	11 (9.0)	7 (6.9)	
Other	4 (1.8)	0 (0)	4 (4.0)	
Breast cancer stage				0.369
1	68 (39.8)	33 (34.7)	35 (46.1)	
2	72 (42.1)	45 (47.4)	27 (35.5)	
3	29 (17.0)	16 (16.8)	13 (17.1)	
4	2 (1.2)	1 (1.1)	1 (1.3)	

DCIS, ductal carcinoma in situ; IDC, intraductal carcinoma; ILC, intralobular carcinoma.
[a]Statistically significant, $P < 0.05$.

infection. In this model, age and smoking status did not significantly contribute.

Further analysis on the hypothermic cohort demonstrated that longer duration of hypothermia significantly correlated with SSI (Table 5). Patients who had a postoperative SSI were hypothermic for an average of 103 ± 55.0 minutes versus 77 ± 52.7 minutes for

Table 2. Intraoperative Details

Characteristic	All Patients (%)	Hypothermia (<35.5°C) (%)	Normothermia (≥35.5°C) (%)	P[a]
No. of patients	228 (100)	122 (100)	106 (100)	
Laterality of breast reconstruction				0.275
Unilateral	87 (38.2)	45 (36.9)	42 (39.6)	
Bilateral	141 (61.8)	77 (63.1)	64 (60.4)	
Type of breast reconstruction				0.501
Direct-to-implant	43 (18.9)	25 (20.5)	18 (17.0)	
Tissue expander	185 (81.1)	97 (79.5)	88 (83.0)	
Use of ADM	212 (93.0)	111 (91.0)	101 (95.3)	0.197
Warming device				
Over-body	228 (100)	122 (100)	106 (100)	1.000
Under-body	0 (0)	0 (0)	0 (0)	
Perioperative antibiotics	228 (100)	122 (100)	106 (100)	1.000
Postoperative antibiotics				0.542
First 24 hr	5 (2.2)	2 (1.6)	3 (2.8)	
Until drain removal	223 (97.8)	120 (98.4)	103 (97.2)	
Length of surgery, min				0.071
Mean ± SD	277.8 ± 92.0	288.1 ± 92.8	266.0 ± 90.0	
Median	270.0	291	259.0	
Range	79-546	79-546	110-523	
Drains placed	222 (97.4)	118 (96.7)	104 (98.1)	0.515

[a]Statistical significance defined as $P < 0.05$.

Table 3. Surgical Outcomes

Characteristic	All Patients (%)	Hypothermia (<35.5°C) (%)	Normothermia (≥35.5°C) (%)	P
Complications				
SSI	60 (26.3)	42 (34.4)	18 (17.0)	0.002[a]
Hematoma	20 (8.8)	8 (6.6)	12 (11.3)	0.214
Seroma	32 (14.0)	15 (12.3)	17 (16.0)	0.419
Skin necrosis	25 (11.0)	15 (12.3)	10 (9.4)	0.493
Wound healing complications	51 (22.4)	34 (27.9)	17 (16.0)	0.030[a]
Reoperation within 90 days	30 (13.2)	16 (13.1)	14 (13.2)	0.984

[a]Statistically significant, $P < 0.05$.

patients who did not have a postoperative SSI ($P < 0.05$).

DISCUSSION

This study was motivated by current surgical literature indicating that maintenance of normothermia can significantly decrease the incidence of SSI by two- to three-fold.[10,17] To our knowledge, this is the first study to date to examine the impact of patient intraoperative temperature on patient outcomes in implant-based breast reconstruction. Intraoperative hypothermia nearly doubled the incidence of SSI (34% versus 18%; $P < 0.05$) and wound healing complications (28% versus 16%; $P < 0.05$). In the hypothermic cohort, patients who had a postoperative SSI were hypothermic for a longer length of time compared with patients who did not have a postoperative SSI (103 minutes versus 77 minutes; $P < 0.05$). Rates of hematoma ($P = 0.9134$), seroma ($P = 0.4362$), mastectomy skin flap necrosis ($P = 0.4773$), and unplanned reoperation within 90 days ($P = 0.9445$) were unaffected. A multivariate analysis was performed to analyze the effects of covariate factors: wound healing complications, hypothermia, smoking status, age, and BMI on postoperative SSI. The model was statistically significant and demonstrated that BMI (OR, 1.057; 95% CI, 1.005 to 1.112; $P < 0.05$), wound healing complications (OR, 5.426; 95% CI, 2.689 to 10.950; $P < 0.05$), and intraoperative hypothermia (OR, 2.416; 95% CI, 1.192 to 4.898; $P < 0.05$) were predictors for SSI in this patient population. Smoking status and age were not predictors for SSI in this patient population.

Although many of the baseline characteristics and demographic variables collected did

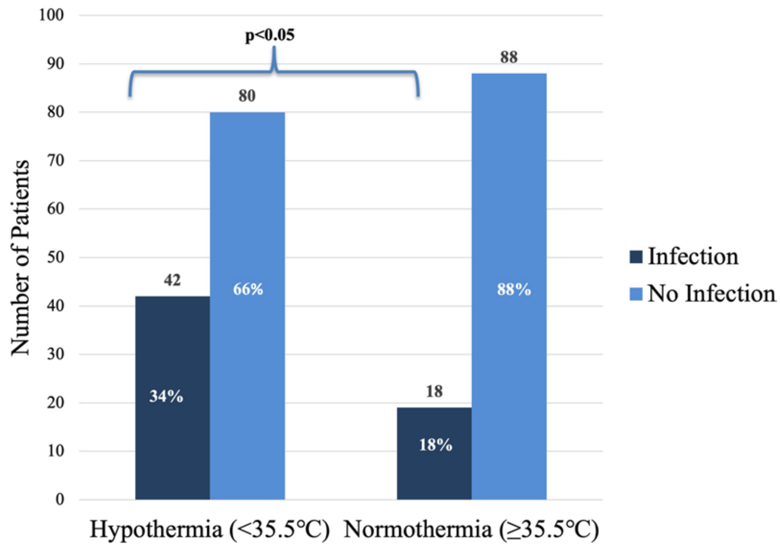

Fig. 2. Effect of intraoperative hypothermia on postoperative SSI.

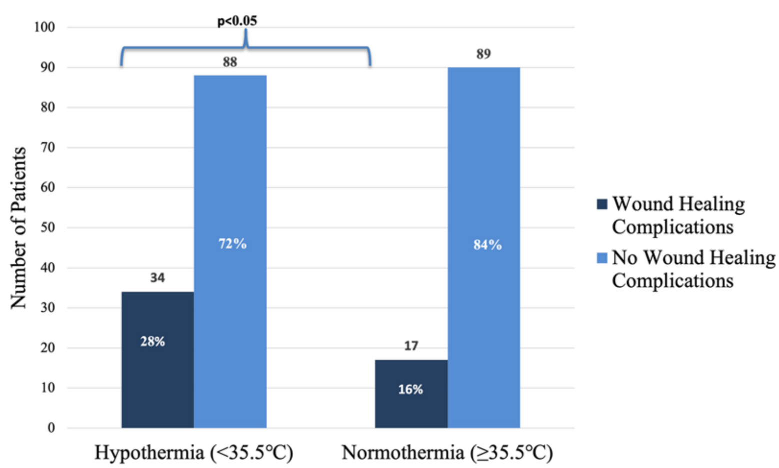

Fig. 3. Effect of intraoperative hypothermia on postoperative wound healing complications.

not significantly differ between the hypothermic and normothermic cohorts, smoking status did demonstrate a statistically significant difference between the two groups ($P = 0.0004$). Patients in the hypothermic group were more likely to be current smokers (19.7% versus 11.3%) and former smokers (27.9% and 16.0%). Univariate analysis demonstrated that current smokers were 2.4 times more likely to be hypothermic (OR, 2.406; 95% CI, 1.231 to 4.702; $P < 0.05$). Sagiroglu et al. also identified that smoking was a risk factor for perioperative hypothermia during major abdominal operations.[18]

In the general surgery literature, hypothermia is associated with increased SSI and other complications. Specifically, patients who experienced intraoperative hypothermia in trauma laparotomies were two times more likely to experience postoperative SSI.[19] This is supported by a prospective study of 290 surgical patients conducted by Flores-Maldonado et al., which demonstrated that perioperative hypothermia was associated with SSI.[20] Furthermore, a randomized controlled trial conducted to determine the effect of preoperative warming on postoperative SSI after clean surgery found that those patients who were assigned to the nonwarmed group were more likely to present with postoperative SSI.[17] Aside from SSI, there are studies that demonstrate that perioperative hypothermia is also associated with increased blood loss, increased incidence of adverse myocardial outcomes, impaired wound healing, prolonged recovery, and increased hospital length of stay.[10,21,22] These studies support the

Table 4. Univariate and Multivariate Analyses

Variable	OR	95% CI	*P*
Univariate analysis			
SSI	2.567	1.367–4.818	0.003[a]
Wound healing complications	2.023	1.053–3.884	0.034[a]
Multivariate analysis			
Hypothermia (<35.5°C)	2.416	1.192–4.898	0.014[a]
Wound healing complications	5.426	2.689–10.950	<0.001[a]
Age (OR per 1-year increase)	1.008	0.980–1.035	0.588
Smoking status	1.089	0.708–1.675	0.697
BMI (OR per 1-kg/m^2 increase)	1.057	1.005–1.112	0.03[a]

[a]Statistically significant, $P < 0.05$.

Table 5. Duration of Hypothermia and Infection

Characteristic	All Patients (%)	Infection (%)	No Infection (%)	*P*
No. of patients	122 (100)	42 (34.4)	80 (65.6)	
Hypothermia duration, min				
Mean ± SD	85.93 ± 54.7	102.95 ± 55.0	77.00 ± 52.7	0.014[a]
Median	75.00	84.50	62.50	
Range	5–300	30–300	5–210	

[a]Statistically significant, $P < 0.05$.

results of our study and support the idea that strict normothermia should be maintained intraoperatively, especially within the first hour after anesthetic induction. Studies show that hypothermia tends to occur within the first hour after induction largely because of redistribution of body heat during that time, which provides an actionable period in which to be vigilant that normothermia is maintained.[23] Prewarming patients should also be pursued preoperatively based on the results of these studies.

A review of the literature demonstrates that unintentional intraoperative hypothermia is a relatively common intraoperative complication and has been estimated as occurring in up to 50% to 90% in the perioperative period.[24–27] At our institution, our preoperative temperature management protocol includes transportation of all patients with one cotton blanket and maintaining preoperative ambient room temperature at or above 24°C (75°F), with the option to consider preoperative warming to reduce the risk of perioperative hypothermia. For patients who are determined to be hypothermic preoperatively (<35.5°C), a forced-air warming blanket is used for active preoperative warming in addition to the one cotton blanket mandated for all patients. Intraoperative temperature management protocol at our institution includes mandatory use of forced-air warmers and/or underbody warmers to maintain intraoperative temperature with continuous monitoring of the patient's body temperature by the anesthesia team. It is also recommended by our institution that the intraoperative temperature remains between 20° and 24°C (68° and 75°F).

Despite these protocols, over 50% of the patients in this study developed intraoperative hypothermia. When comparing the literature to our institution's policy, the high incidence of intraoperative unintentional hypothermia is likely because all patients are not required to undergo preoperative warming. Our institution's protocol requires appropriate preoperative identification of patients needing preoperative warming by means of temperature monitoring rather than all patients undergoing preoperative warming by default. Finally, our institution tolerates intraoperative temperatures down to 20°C, which is below the literature's recommendation of 21°C.

Although there are no studies specifically examining the effect of hypothermia in breast reconstruction, there are recent studies examining the impact of hypothermia in breast cancer surgery and in elective plastic surgery. In breast cancer surgery, a study conducted by Motamed et al. showed no difference in complication/infection, nor did it show a delay to adjuvant radiation therapy or chemotherapy for patients who experienced hypothermia.[28] There are also studies that link the use of ADM and radiation therapy to increased likelihood of SSI in the breast cancer reconstruction patient population; however, in our study, we found no significant difference between the two cohorts with respect to the use of ADM or rates of chemotherapy/radiation therapy, making it unlikely that these variables impacted the results of our study, indicating that hypothermia increased the likelihood of SSI in this population.[9,29]

Another potential, anecdotal source of SSI in this patient population is the use of forced-air warmers; however, the literature is conflicting on the use of forced-air warmers and SSI. A study was conducted to evaluate forced-air warmers as a potential source of microbial contamination and found that when the warmers were used in conjunction with the appropriate perforated blanket, as recommended by the manufacturer, no organisms were detected.[30] Furthermore, a systematic review of the orthopedic literature demonstrated no increased risk for SSI with the use of forced-air warmers.[31,32] However, other studies note that forced-air warmers have the potential to be a source of operating room air contamination with the potential to increase the risk of SSI; however, without a clear link between forced-air warming and SSI, these studies continue to recommend the use of forced-air warming for maintenance of intraoperative normothermia.[33] Given the fact that all patients in both the hypothermic and normothermic group received forced-air warming, this is a controlled variable in our study.

In the context of elective plastic surgery, particularly in body contouring, there is controversy in the literature, as some studies demonstrate that hypothermia has no effect on postoperative outcomes and others indicate that hypothermia increases the risk of seroma formation and increases recovery time, pain, and opioid requirement.[34–37] Cavallini et al. examined the effect of hypothermia on coagulation in elective plastic surgery cases and demonstrated that there was significant prolongation of bleeding time and activated partial thromboplastin times in patients who developed intraoperative hypothermia.[35] A retrospective study in an aesthetic outpatient plastic surgery setting found that intraoperative normothermia resulted in reduced use of intraoperative analgesia, shortened recovery time, and greater patient comfort.[36] This is supported by the anesthesia literature, which has linked intraoperative hypothermia to increased recovery times and is also supported by a study conducted by Bayter-Marin et al., which demonstrated that patients undergoing body contouring procedures who experienced intraoperative hypothermia also have increased time spent in the recovery area, intensity of pain, cold perception, and opioid requirement.[38,39] Although not seen in our patient population, a 2012 study correlated intraoperative hypothermia and seroma formation in patients undergoing body contouring procedures. This 2012 study also supported other surgical literature linking intraoperative hypothermia to increased blood loss and need for transfusion.[40]

As demonstrated by the numerous aforementioned studies, hypothermia is a ubiquitous problem in surgical patients who receive both general and regional anesthesia, and rates of hypothermia range from 4% to 70%.[41–43] In addition to heat loss from exposed surface area and open wounds, general anesthesia causes redistribution of blood, vasodilation, decreased metabolism, and decreased vasoconstriction threshold.[44] Regional anesthesia also causes vasodilation, decreases shivering, and decreases vasoconstriction below the level of the block.[44] Longer operative times also increase the risk of hypothermia.[43] Intraoperative temperature regulation represents an important modifiable risk factor in the prevention of complications.

Studies in both the general surgery and plastic surgery literature have sought to find ways to improve or prevent hypothermia using multiple active warming methods, including approximately 1 hour of warming preoperatively, warm intravenous fluids, forced-air warming, maintaining intraoperative ambient temperature at 70°F minimum, and aggressively treating postoperative hypothermia.[14,37,45,46] In a 2015 review of 24 randomized controlled trials, Campbell et al. noted that giving warm fluids (37° to 41°C) increases patient temperature by half a degree.[45] Despite these measures, patients can still become hypothermic, and surgeons need to implement multiple methods of patient warming to achieve normothermia.[43,47]

Limitations of this study include the retrospective nature, a relatively small study population, and the examination of a single health system's surgical data. At our institution, protocols in immediate implant-based breast reconstruction include forced-air warming intraoperatively with variable use of adjuncts such as preoperative warming and administration of warmed fluids. Our institution does not mandate preoperative warming, which is supported in the literature to reduce the incidence of unintentional intraoperative hypothermia. Our institution's policy also tolerates ambient temperatures to 20°C, which is below the literature's recommendation of 21°C. Our rates of hypothermia in implant-based breast reconstruction exceed 50%, which is consistent with the literature's rates of unintentional hypothermia; however, further studies to prevent unintentional perioperative hypothermia with the use of standardized protocols are needed. Future research should include consistent use of multiple perioperative warming techniques.

CONCLUSIONS

This study demonstrates that intraoperative hypothermia less than 35.5°C is a significant risk factor for postoperative infection in postmastectomy implant-based breast reconstruction. Breast reconstruction patients are at significant risk of intraoperative hypothermia given the need to have a significant amount of their body surface area exposed intraoperatively and the longer duration of these combined procedures. Our results demonstrate that maintaining strict normothermia during implant-based breast reconstruction procedures can significantly improve patient outcomes and reduce morbidity by reducing the risk of surgical-site infection and wound healing complications.

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DISCLOSURE

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REFERENCES

1. American Society of Plastic Surgeons. 2020 Plastic surgery statistics report. Available at https://www.plasticsurgery.org/documents/News/Statistics/2020/plastic-surgery-statistics-full-report-2020.pdf. Accessed January 25, 2022.
2. Reish RG, Damjanovic B, Austen WG Jr, et al. Infection following implant-based reconstruction in 1952 consecutive breast reconstructions: salvage rates and predictors of success. *Plast Reconstr Surg.* 2013;131:1223–1230.
3. Washer LL, Gutowski K. Breast implant infections. *Infect Dis Clin North Am.* 2012;26:111–125.
4. Patel SU, Osborn R, Rees S, Thornton JM. Structural studies of Impatiens balsamina antimicrobial protein (Ib-AMP1). *Biochemistry* 1998;37:983–990.
5. Olsen MA, Chu-Ongsakul S, Brandt KE, Dietz JR, Mayfield J, Fraser VJ. Hospital-associated costs due to surgical site infection after breast surgery. *Arch Surg.* 2008;143:53–60; discussion 61.
6. Momoh AO, Ahmed R, Kelley BP, et al. A systematic review of complications of implant-based breast reconstruction with prereconstruction and postreconstruction radiotherapy. *Ann Surg Oncol.* 2014;21:118–124.
7. Dancey A, Nassimizadeh A, Levick P. Capsular contracture—what are the risk factors? A 14 year series of 1400 consecutive augmentations. *J Plast Reconstr Aesthet Surg.* 2012;65:213–218.
8. Barr SP, Topps AR, Barnes NL, et al; Northwest Breast Surgical Research Collaborative. Infection prevention in breast implant surgery—a review of the surgical evidence, guidelines and a checklist. *Eur J Surg Oncol.* 2016;42:591–603.
9. Ooi ASH, Song DH. Reducing infection risk in implant-based breast-reconstruction surgery: challenges and solutions. *Breast Cancer (Dove Med Press)* 2016;8:161–172.
10. Kurz A, Sessler DI, Lenhardt R. Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization. Study of Wound Infection and Temperature Group. *N Engl J Med.* 1996;334:1209–1215.
11. World Health Organization. *WHO Guidelines for Safe Surgery 2009: Safe Surgery Saves Lives.* Geneva: World Health Organization; 2009. Available at: https://www.ncbi.nlm.nih.gov/books/NBK143243/. Accessed January 25, 2022.
12. Leeds IL, Wick EC, Melton GB. Does close temperature regulation affect surgical site infection rates? *Adv Surg.* 2014;48:65–76.
13. Sumer BD, Myers LL, Leach J, Truelson JM. Correlation between intraoperative hypothermia and perioperative morbidity in patients with head and neck cancer. *Arch Otolaryngol Head Neck Surg.* 2009;135:682–686.
14. Vanni SM, Braz JR, Modolo NS, Amorim RB, Rodrigues GR Jr. Preoperative combined with intraoperative skin-surface warming avoids hypothermia caused by general anesthesia and surgery. *J Clin Anesth.* 2003;15:119–125.
15. Sessler DI. Perioperative heat balance. *Anesthesiology* 2000;92:578–596.
16. Horan TC, Andrus M, Dudeck MA. CDC/NHSN surveillance definition of health care-associated infection and criteria for specific types of infections in the acute care setting. *Am J Infect Control* 2008;36:309–332.
17. Melling AC, Ali B, Scott EM, Leaper DJ. Effects of preoperative warming on the incidence of wound infection after clean surgery: a randomised controlled trial. *Lancet* 2001;358:876–880.
18. Sagiroglu G, Ozturk GA, Baysal A, Turan FN. Inadvertent perioperative hypothermia and important risk factors during major abdominal surgeries. *J Coll Physicians Surg Pak.* 2020;30:123–128.
19. Seamon MJ, Wobb J, Gaughan JP, Kulp H, Kamel I, Dempsey DT. The effects of intraoperative hypothermia on surgical site infection: an analysis of 524 trauma laparotomies. *Ann Surg.* 2012;255:789–795.
20. Flores-Maldonado A, Medina-Escobedo CE, Rios-Rodriguez HM, Fernandez-Dominguez R. Mild perioperative hypothermia and the risk of wound infection. *Arch Med Res.* 2001;32:227–231.
21. Reynolds L, Beckmann J, Kurz A. Perioperative complications of hypothermia. *Best Pract Res Clin Anaesthesiol.* 2008;22:645–657.
22. Rajagopalan S, Mascha E, Na J, Sessler DI. The effects of mild perioperative hypothermia on blood loss and transfusion requirement. *Anesthesiology* 2008;108:71–77.
23. Matsukawa T, Sessler DI, Sessler AM, et al. Heat flow and distribution during induction of general anesthesia. *Anesthesiology* 1995;82:662–673.

24. Burger L, Fitzpatrick J. Prevention of inadvertent perioperative hypothermia. *Br J Nurs.* 2009;18:1114–1119.
25. Vaughan MS, Vaughan RW, Cork RC. Postoperative hypothermia in adults: relationship of age, anesthesia, and shivering to rewarming. *Anesth Analg.* 1981;60:746–751.
26. Yang F, Wang J, Cui J, Zhuan J, Hu X, Chen S. An overview of the implications for perianesthesia nurses in terms of intraoperative changes in temperature and factors associated with unintentional postoperative hypothermia. *J Healthc Eng.* 2022;2022:6955870.
27. Cooper S. The effect of preoperative warming on patients' postoperative temperatures. *AORN J.* 2006;83:1073–1076, 1079.
28. Motamed C, Weil G, Dridi C, Bourgain JL. Incidence of severe hypothermia and its impact on postoperative surgical complications and time delay to adjunct treatments in breast surgery cancer patients: a case-controlled study. *J Clin Med.* 2021;10:3702.
29. Sobti N, Liao EC. Surgeon-controlled study and meta-analysis comparing FlexHD and AlloDerm in immediate breast reconstruction outcomes. *Plast Reconstr Surg.* 2016;138:959–967.
30. Avidan MS, Jones N, Ing R, Khoosal M, Lundgren C, Morrell DF. Convection warmers—not just hot air. *Anaesthesia* 1997;52:1073–1076.
31. Haeberle HS, Navarro SM, Samuel LT, et al. No evidence of increased infection risk with forced-air warming devices: a systematic review. *Surg Technol Int.* 2017;31:295–301.
32. Wood AM, Moss C, Keenan A, Reed MR, Leaper DJ. Infection control hazards associated with the use of forced-air warming in operating theatres. *J Hosp Infect.* 2014;88:132–140.
33. Brock-Utne JG, Ward JT, Jaffe RA. Potential sources of operating room air contamination: a preliminary study. *J Hosp Infect.* 2021;113:59–64.
34. Constantine RS, Kenkel M, Hein RE, et al. The impact of perioperative hypothermia on plastic surgery outcomes: a multivariate logistic regression of 1062 cases. *Aesthet Surg J.* 2015;35:81–88.
35. Cavallini M, Baruffaldi Preis FW, Casati A. Effects of mild hypothermia on blood coagulation in patients undergoing elective plastic surgery. *Plast Reconstr Surg.* 2005;116:316–321; discussion 322–323.
36. Lista F, Doherty CD, Backstein RM, Ahmad J. The impact of perioperative warming in an outpatient aesthetic surgery setting. *Aesthet Surg J.* 2012;32:613–620.
37. Young VL, Watson ME. Prevention of perioperative hypothermia in plastic surgery. *Aesthet Surg J.* 2006;26:551–571.
38. Bayter-Marin JE, Cardenas-Camarena L, Duran H, Valedon A, Rubio J, Macias AA. Effects of thermal protection in patients undergoing body contouring procedures: a controlled clinical trial. *Aesthet Surg J.* 2018;38:448–456.
39. Lenhardt R, Marker E, Goll V, et al. Mild intraoperative hypothermia prolongs postanesthetic recovery. *Anesthesiology* 1997;87:1318–1323.
40. Coon D, Michaels J, Gusenoff JA, Chong T, Purnell C, Rubin JP. Hypothermia and complications in postbariatric body contouring. *Plast Reconstr Surg.* 2012;130:443–448.
41. Burns SM, Piotrowski K, Caraffa G, Wojnakowski M. Incidence of postoperative hypothermia and the relationship to clinical variables. *J Perianesth Nurs.* 2010;25:286–289.
42. Long KC, Tanner EJ, Frey M, et al. Intraoperative hypothermia during primary surgical cytoreduction for advanced ovarian cancer: risk factors and associations with postoperative morbidity. *Gynecol Oncol.* 2013;131:525–530.
43. Alfonsi P, Bekka S, Aegerter P; SFAR Research Network investigators. Prevalence of hypothermia on admission to recovery room remains high despite a large use of forced-air warming devices: findings of a non-randomized observational multicenter and pragmatic study on perioperative hypothermia prevalence in France. *PLoS One* 2019;14:e0226038.
44. Riley C, Andrzejowski J. Inadvertent perioperative hypothermia. *BJA Educ.* 2018;18:227–233.
45. Campbell G, Alderson P, Smith AF, Warttig S. Warming of intravenous and irrigation fluids for preventing inadvertent perioperative hypothermia. *Cochrane Database Syst Rev.* 2015;2015:CD009891.
46. Lauronen SL, Makinen MT, Annila P, Huhtala H, Yli-Hankala A, Kalliomaki ML. Thermal suit connected to a forced-air warming unit for preventing intraoperative hypothermia: a randomised controlled trial. *Acta Anaesthesiol Scand.* 2021;65:176–181.
47. Tyvold SS. Preventing hypothermia in outpatient plastic surgery by self-warming or forced-air-warming blanket: a randomised controlled trial. *Eur J Anaesthesiol.* 2019;36:843–850.