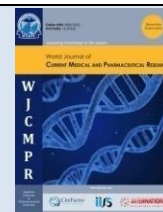




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INTRAOPERATIVE HYPOTHERMIA AND SURGICAL SITE INFECTION AFTER MAJOR ABDOMINAL SURGERY: A PROSPECTIVE COHORT STUDY

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ARTICLE HISTORY	ABSTRACT
Received on: 04-09-2026 Revised on: 26-09-2026 Accepted on: 18-10-2026 Keywords: Intraoperative hypothermia; surgical site infection; abdominal surgery; perioperative temperature; normothermia; wound infection. Corresponding Author Dr. Ramesh S. K	Background: Inadvertent perioperative hypothermia is common during major abdominal surgery and may adversely affect tissue perfusion, immune function and wound healing. Surgical site infection (SSI) remains an important postoperative complication and may prolong hospital stay and increase healthcare utilization. Objective: To evaluate the association between intraoperative hypothermia and the development of SSI following major abdominal surgery and to identify other perioperative factors associated with postoperative infection. Methods: This prospective cohort study included 286 adult patients undergoing major abdominal surgery under general anaesthesia. Core temperature was recorded before induction and at 30-minute intervals intraoperatively. Patients were classified according to whether their intraoperative core temperature fell below 36.0°C. Patients were followed prospectively for 30 days after surgery for development of SSI. Demographic, clinical, operative and postoperative variables were recorded. Multivariable logistic regression was performed to identify factors independently associated with SSI. Results: In the analysis, 143 patients (50.0%) experienced intraoperative hypothermia, while 143 (50.0%) remained normothermic. SSI developed in 34 patients (11.9%). The incidence of SSI was higher among patients with hypothermia than among normothermic patients (17.5% vs. 6.3%, $p=0.006$). Hypothermic patients had longer mean hospital stays (11.2 ± 3.2 vs. 9.3 ± 3.4 days, $p<0.001$). On multivariable analysis, hypothermia was not independently associated with SSI (adjusted OR 2.44, 95% CI 0.82–7.28; $p=0.109$), whereas diabetes mellitus, contaminated/dirty wound classification and blood transfusion remained independently associated with SSI. Conclusion: In this cohort, intraoperative hypothermia was associated with a higher incidence of SSI in unadjusted analysis, but the association was not statistically significant after multivariable adjustment. Routine temperature monitoring and active warming remain relevant perioperative considerations.

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INTRODUCTION

Surgical site infection (SSI) is one of the most frequent complications following operative procedures and is associated with prolonged hospitalization, increased healthcare expenditure, antimicrobial exposure and adverse postoperative outcomes [1, 2]. Major abdominal procedures are particularly relevant because they frequently involve prolonged anaesthesia, extensive tissue exposure, substantial fluid administration and physiological stress, all of which may contribute to postoperative infectious complications [3].

Inadvertent perioperative hypothermia is commonly defined as a core body temperature below 36°C [4]. General anaesthesia impairs normal thermoregulatory responses and promotes redistribution of heat from the core to peripheral tissues. Continued exposure, administration of unwarmed fluids and blood products, and prolonged operative duration can subsequently contribute to further heat loss [5, 6]. The relationship between perioperative temperature and postoperative infection has biological plausibility. Hypothermia can cause peripheral vasoconstriction and reduce tissue oxygen availability, while also affecting innate immune mechanisms and collagen

deposition [7]. In a landmark randomized study involving patients undergoing colorectal surgery, perioperative warming substantially reduced wound infection compared with routine thermal care [8].

Current SSI-prevention recommendations emphasize maintenance of perioperative normothermia. The WHO recommends the use of warming devices during surgery for the purpose of reducing SSI, while CDC guidance recommends maintaining perioperative normothermia [1,2]. NICE similarly recommends active warming during the intraoperative period and defines perioperative hypothermia as a core temperature below 36°C [4]. Nevertheless, the magnitude of the association between hypothermia and SSI remains incompletely established. A prospective cohort study of abdominal surgery found that repeated or prolonged exposure to temperatures below 36°C was associated with increased SSI risk, whereas previous meta-analyses have demonstrated heterogeneous findings, particularly among observational studies [9,10]. More recent evidence also suggests that the association may depend on the degree and duration of hypothermia [11]. Therefore, the present prospective cohort study was designed to evaluate the association between intraoperative hypothermia and SSI after major abdominal surgery while accounting for other clinically relevant perioperative risk factors.

AIM AND OBJECTIVES

Aim

To evaluate the association between intraoperative hypothermia and surgical site infection following major abdominal surgery.

Objectives

1. To determine the incidence of intraoperative hypothermia among patients undergoing major abdominal surgery.
2. To determine the incidence of SSI within 30 days following surgery.
3. To compare SSI rates between hypothermic and normothermic patients.
4. To evaluate the association between the duration/severity of hypothermia and SSI.
5. To identify factors independently associated with SSI using multivariable analysis.
6. To compare postoperative hospital stay between hypothermic and normothermic patients.

MATERIALS AND METHODS

Study Design and Setting

A prospective cohort study was designed to evaluate the relationship between intraoperative hypothermia and SSI in adult patients undergoing major abdominal surgery at a tertiary-care hospital.

Study Population

Adult patients undergoing elective or urgent major abdominal surgery under general anaesthesia were eligible.

Study sample size calculation: The sample size was estimated to compare the proportion of surgical site infection (SSI) between patients with intraoperative hypothermia and those maintaining normothermia.

Table 01:

Parameter	Value	Description
P_1	0.173 (17.3%)	Expected SSI proportion in hypothermia group
P_2	0.066 (6.6%)	Expected SSI proportion in normothermia group
α	0.05	Two-sided significance level
Power	80%	Statistical power
$Z_{\alpha/2}$	1.96	Standard normal deviate for $\alpha = 0.05$
Z_{β}	0.84	Standard normal deviate for 80% power

Formula

$$n = \left[\frac{Z_{\alpha/2} \times \sqrt{\{2P(1-P)\}} + Z_{\beta} \times \sqrt{\{P_1(1-P_1) + P_2(1-P_2)\}}}{P_1 - P_2} \right]^2$$

where:

$$P = (P_1 + P_2) / 2$$

$$P = (0.173 + 0.066) / 2 = 0.1195$$

Therefore: $n \approx 143.08$ participants per group.

Required sample size: Approximately 143 participants per group, giving a total sample size of 286 participants.

Sample size was calculated using a two-sided comparison of two independent proportions. Based on an anticipated SSI proportion of 17.3% among patients with intraoperative hypothermia and 6.6% among patients with normothermia, with a two-sided α of 0.05 and 80% power, the estimated sample size was approximately 143 participants per group, corresponding to a total sample size of 286 participants. The study therefore planned to include 286 participants, with equal allocation to the hypothermia and normothermia groups.

Inclusion criteria

- Age ≥ 18 years
- Major abdominal surgery under general anaesthesia
- Expected operative duration ≥ 60 minutes
- Availability of intraoperative core-temperature measurements
- Consent for participation and postoperative follow-up

Exclusion criteria

- Pre-existing infection at the operative site
- Therapeutic/intentional hypothermia
- Procedures involving deliberate cooling
- Patients transferred to another institution before adequate postoperative surveillance
- Incomplete temperature documentation

Exposure Definition

Intraoperative hypothermia was defined as a core temperature $< 36.0^\circ\text{C}$ at any recorded intraoperative measurement, consistent with commonly used perioperative definitions and NICE guidance.^{4,5}

Patients were divided into:

- Hypothermia cohort: at least one intraoperative core temperature $< 36.0^\circ\text{C}$
- Normothermia cohort: all recorded intraoperative temperatures $\geq 36.0^\circ\text{C}$

For secondary analysis, hypothermia could additionally be categorized according to duration:

Table 02:

Hypothermia duration	Category
None	Normothermia
<30 min	Mild exposure
30–60 min	Moderate exposure
>60 min	Prolonged exposure

Temperature was proposed to be documented before induction and every 30 minutes during surgery, consistent with perioperative temperature-monitoring recommendations [4].

Surgical Site Infection

SSI was assessed during hospitalization and after discharge up to postoperative day 30.

SSI was classified as:

1. Superficial incisional SSI
2. Deep incisional SSI
3. Organ/space SSI

These categories correspond to established CDC/NHSN surveillance definitions [12].

Perioperative Variables

The following variables were recorded:

- Age
- Sex
- BMI
- Diabetes mellitus
- Smoking
- ASA grade
- Preoperative haemoglobin
- Preoperative serum albumin
- Elective/emergency surgery
- Type of abdominal procedure
- Wound classification
- Duration of surgery
- Duration of anaesthesia
- Estimated blood loss
- Blood transfusion
- Intraoperative temperature
- Number of hypothermic episodes
- Duration of hypothermia
- Postoperative ICU admission
- Duration of hospital stay
- SSI occurrence

Statistical Analysis

Continuous variables were expressed as mean $\pm$ standard deviation or median with interquartile range, depending on distribution. Categorical variables were presented as frequencies and percentages. The chi-square test or Fisher's exact test was used for categorical variables, while the independent-samples t-test or Mann–Whitney U test was used for continuous variables.

Variables showing clinical relevance or statistical association with SSI were entered into multivariable logistic regression. Results were reported as adjusted odds ratios (aORs) with 95% confidence intervals.

The planned sample size was 286 participants, comprising 143 patients in the hypothermia cohort and 143 in the normothermia cohort.

A two-sided $p < 0.05$ was considered statistically significant. Because 34 SSI events were observed, the multivariable model should be interpreted cautiously, particularly because the number of events per covariate remains limited.

RESULTS

Patient Characteristics

A total of 286 patients were included in the cohort.

Of these, 143 (50.0%) developed at least one intraoperative hypothermic episode, while 143 (50.0%) remained normothermic.

Table 01: Baseline characteristics of the study population

Variable	Hypothermia (n=143)	Normothermia (n=143)	p-value
Age, years	54.8 $\pm$ 12.2	57.6 $\pm$ 13.7	0.067
Male sex	82 (57.3%)	84 (58.7%)	0.905
BMI, kg/m ²	24.7 $\pm$ 3.7	24.4 $\pm$ 3.5	0.484
Diabetes mellitus	40 (28.0%)	27 (18.9%)	0.094
ASA III/IV	56 (39.2%)	43 (30.1%)	0.136
Emergency surgery	19 (13.3%)	9 (6.3%)	0.073
Preoperative Hb, g/dL	11.7 $\pm$ 1.6	11.9 $\pm$ 1.8	0.280
Albumin, g/dL	3.5 $\pm$ 0.4	3.6 $\pm$ 0.5	0.106
Operative duration, min	194.3 $\pm$ 50.3	172.5 $\pm$ 44.5	<0.001
Anaesthesia duration, min	223.7 $\pm$ 50.6	200.2 $\pm$ 44.8	<0.001
Blood loss, mL	429.3 $\pm$ 175.9	360.9 $\pm$ 176.7	0.001

The hypothermia group had longer operative and anaesthesia durations and greater mean blood loss, while the difference in mean albumin concentration was not statistically significant.

Intraoperative Temperature

The mean lowest intraoperative temperature was 35.1 $\pm$ 0.5°C in the hypothermia group compared with 36.4 $\pm$ 0.3°C in the normothermia group ($p < 0.001$).

Among hypothermic patients:

- 29 (27.9%) had hypothermia for <30 minutes
- 34 (32.7%) had hypothermia for 30–60 minutes
- 41 (39.4%) had hypothermia for >60 minutes

Surgical Site Infection

Overall, 34/286 patients (11.9%) developed SSI.

The SSI rate was:

- 25/143 (17.5%) in the hypothermia cohort
- 9/143 (6.3%) in the normothermia cohort

The difference was statistically significant ($p = 0.006$).

Table 02: SSI according to intraoperative temperature status

Outcome	Hypothermia (n=143)	Normothermia (n=143)	p-value
SSI, n (%)	25 (17.5%)	9 (6.3%)	0.006
Superficial	16 (11.2%)	4 (2.8%)	0.011
Deep incisional	4 (2.8%)	4 (2.8%)	1.000
Organ/space	5 (3.5%)	1 (0.7%)	0.216
Mean hospital stay, days	11.2±3.2	9.3±3.4	<0.001

Surgical site infection according to temperature status
Comparison of SSI incidence between patients with and without intraoperative hypothermia in the updated 286-patient dataset.

0%5%10%15%20%

Hypothermia

Normothermia

Hypothermia Duration and SSI

SSI incidence was higher in each hypothermia-duration category than in the normothermia group, but the pattern was not strictly progressive: 10.0% with <30 minutes, 20.8% with 30–60 minutes and 20.0% with >60 minutes; the formal trend analysis was not statistically significant (Spearman $\rho=0.096$, $p=0.252$).

Table 03: SSI according to duration of hypothermia

Temperature exposure	Patients	SSI, n (%)
Normothermia	143	9 (6.3%)
Hypothermia <30 min	40	4 (10.0%)
Hypothermia 30–60 min	48	10 (20.8%)
Hypothermia >60 min	55	11 (20.0%)

SSI incidence by duration of hypothermia

SSI incidence according to duration of intraoperative hypothermia in the updated dataset.

0%7.5%15%22.5%30%

Normothermia

<30 min

30–60 min

>60 min

Risk-Factor Analysis

Table 04: Factors associated with SSI

Variable	SSI (n=34)	No SSI (n=252)	p-value
Age ≥60 years	13 (38.2%)	96 (38.1%)	1.000
Diabetes mellitus	21 (61.8%)	46 (18.3%)	<0.001
Hypothermia	25 (73.5%)	118 (46.8%)	0.006
Emergency surgery	11 (32.4%)	17 (6.7%)	<0.001
Contaminated/dirty wound	19 (55.9%)	17 (6.7%)	<0.001
Contaminated/dirty wound	19 (55.9%)	17 (6.7%)	<0.001
Operative duration >180 min	20 (58.8%)	125 (49.6%)	0.408
Blood transfusion	14 (41.2%)	37 (14.7%)	<0.001

Table 05: Multivariable logistic regression for SSI

Predictor	Adjusted OR	95% CI	p-value
Intraoperative hypothermia	2.44	0.82–7.28	0.109
Diabetes mellitus	26.13	6.81–100.23	<0.001
Contaminated/dirty wound	53.80	11.36–254.74	<0.001
Operative duration >180 min	3.00	1.00–9.04	0.051
Emergency surgery	2.05	0.45–9.37	0.353
Blood transfusion	4.18	1.49–11.77	0.007

After adjustment, intraoperative hypothermia was not independently associated with SSI (adjusted OR 2.44, 95% CI 0.82–7.28; $p=0.109$).

DISCUSSION

The prospective cohort demonstrates an association between intraoperative hypothermia and SSI following major abdominal surgery in unadjusted analysis. Patients experiencing temperatures below 36°C had a higher incidence of SSI than those who remained normothermic.

The biological basis for this association is plausible. Hypothermia causes peripheral vasoconstriction, which may impair tissue oxygen delivery. Adequate tissue oxygenation is important for oxidative bacterial killing and wound healing. In addition, hypothermia can influence immune function and coagulation, potentially contributing to postoperative complications [7].

The findings are consistent with the landmark randomized trial by Kurz et al., in which patients undergoing colorectal surgery who received active warming had a substantially lower wound infection rate than patients receiving routine thermal care [8]. The study provided important experimental evidence linking maintenance of perioperative normothermia with reduction in wound infection.

More directly comparable to the present study, a prospective cohort of patients undergoing abdominal surgery found that temperatures below 36°C for more than five hypothermic episodes or more than 75 minutes were associated with increased SSI risk, with a reported relative risk of 1.89 [9], in the present dataset, SSI incidence was higher in each hypothermia-duration category than in the normothermia group, but the formal trend analysis was not statistically significant. However, the literature is not completely uniform. A meta-analysis of perioperative hypothermia found that the pooled association differed between randomized and observational studies, and the authors concluded that additional high-quality trials were required [10]. A more recent 2025 meta-analysis involving 25 studies and 28,761 patients also reported substantial heterogeneity and found that the overall association between intraoperative temperature and SSI was not statistically significant, although temperatures ≤35°C were associated with higher SSI risk in subgroup analysis [11]. These findings emphasize that the severity, duration, timing and clinical context of hypothermia may be important. The updated analysis also demonstrates that SSI is multifactorial. Diabetes, contaminated or dirty wounds, and blood transfusion remained independently associated with SSI in

the multivariable model, whereas the adjusted association between hypothermia and SSI was not statistically significant.

The WHO recommends warming patients during surgery to reduce SSI, although it characterizes the evidence supporting warming specifically for SSI prevention as moderate and the recommendation as conditional [2]. The CDC guideline recommends maintaining perioperative normothermia as part of SSI prevention [1]. NICE similarly recommends active intraoperative warming and regular core-temperature monitoring [4].

The observed association between prolonged surgery and hypothermia is also clinically important. Longer procedures provide greater opportunity for heat loss through exposure, anaesthetic-related thermoregulatory impairment, administration of fluids and irrigation solutions, and the open operative field. Therefore, temperature monitoring should be integrated into routine perioperative management rather than considered only after hypothermia develops [12].

CLINICAL IMPLICATIONS

The findings support several practical considerations:

- Routine core-temperature monitoring during major abdominal surgery.
- Early identification of patients at increased risk of hypothermia.
- Active warming during prolonged procedures.
- Appropriate warming of intravenous fluids and blood products.
- Minimization of unnecessary patient exposure.
- Continued postoperative temperature surveillance.
- Integration of temperature management with established SSI-prevention measures.

These approaches are consistent with existing perioperative recommendations [1,2,4].

LIMITATIONS

This study has several potential limitations. First, as an observational cohort, residual confounding cannot be completely excluded. Hypothermia may occur more frequently in patients undergoing longer or more complex operations, making it difficult to completely separate the effect of temperature from operative complexity. Second, the use of a single threshold of 36°C may not fully capture the importance of the depth and duration of hypothermia. Third, SSI surveillance after discharge may result in under-detection if follow-up is incomplete.

CONCLUSION

In this updated prospective cohort, intraoperative hypothermia was associated with a higher incidence of SSI following major abdominal surgery in unadjusted analysis. SSI incidence increased descriptively across longer categories of hypothermic exposure, although no formal trend test was statistically significant. After adjustment for important clinical and operative factors, intraoperative hypothermia was not independently associated with SSI.

Routine intraoperative temperature monitoring and timely active warming should therefore be considered important components of comprehensive perioperative care.

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Nil

CONFLICT OF INTEREST

Not Declared

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Not Declared.

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