Original Research Article

PROSPECTIVE ASSESSMENT OF PERIOPERATIVE HYPOTHERMIA PREVENTION PROTOCOLS IN MAJOR ABDOMINAL SURGERIES

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ABSTRACT

Background: Inadvertent perioperative hypothermia (<36.0 °C) remains common during major abdominal surgery due to anaesthesia-induced thermoregulatory impairment, core-to-peripheral heat redistribution, and environmental heat loss. Multi-component prevention bundles—combining pre-warming, continuous intra-operative active warming, warmed fluids/irrigation, conditioned gases, and ambient temperature targets—are promoted to maintain normothermia, yet real-world adherence and its impact on patient-centred outcomes are variably reported. **Aim:** To prospectively evaluate adherence to a standardized perioperative hypothermia-prevention bundle in major abdominal surgeries at a tertiary care hospital and to compare thermal and recovery outcomes between high- and lower-adherence groups.

Materials and Methods: This prospective, single-centre observational study enrolled 50 adults undergoing elective major abdominal surgery under general anaesthesia. The institutional bundle comprised pre-warming, operating-room ambient temperature ≥21 °C during induction, continuous forced-air warming, warmed crystalloids/blood products, warmed irrigation fluids, and heated humidification when applicable. Adherence to each element was recorded to derive a 0–6 bundle score, classified as high adherence (≥5/6) or lower adherence (≤4/6). Core temperature was measured with oesophageal or nasopharyngeal probes intra-operatively and tympanic thermometry pre-/post-operatively at prespecified intervals. Primary outcome was hypothermia incidence; secondary outcomes included nadir temperature, time-weighted exposure <36 °C, PACU shivering, time to normothermia, thermal comfort, and complications.

Results: Baseline characteristics were comparable between high (n=32) and lower (n=18) adherence groups. Overall hypothermia occurred in 14/50 (28.00%); incidence was lower with high adherence (18.75%) than with lower adherence (44.44%; p=0.048). High adherence yielded a higher nadir temperature (36.2 ± 0.3 °C vs 35.9 ± 0.5 °C; p=0.02) and less time below 36 °C (8.6 ± 12.4 vs 19.1 ± 25.3 min; p=0.04). In PACU, any-grade shivering was reduced (12.50% vs 38.89%; p=0.03), time to normothermia was shorter (18.2 ± 7.8 vs 27.1 ± 10.3 min; p=0.01), and thermal comfort was higher (8.5 ± 1.0 vs 7.5 ± 1.3; p=0.004) with high adherence. Complications were infrequent and not statistically different. On multivariable analysis, lower adherence independently predicted hypothermia (adjusted OR 3.72; 95% CI 1.01–13.71; p=0.048).

Conclusion: In major abdominal surgery, higher adherence to a perioperative warming bundle was associated with lower hypothermia incidence, higher nadir core temperatures, reduced hypothermic exposure, and improved PACU recovery metrics. These findings support disciplined, protocolized thermal care as routine practice and justify larger multicentre evaluations to confirm effects on complications and resource utilization.

Keywords: Perioperative hypothermia; forced-air warming; pre-warming; abdominal surgery; patient outcomes.

INTRODUCTION

Inadvertent perioperative hypothermia—commonly defined as a core temperature below 36.0 °C—remains a frequent and clinically consequential problem across major surgical populations. Despite widespread availability of active warming technologies and clear recommendations to monitor and maintain normothermia, patients continue to experience early intra-anaesthetic temperature drops driven by anaesthesia-induced thermoregulatory impairment, core-to-peripheral heat redistribution, conductive and convective losses from exposed skin, and the thermal burden of cold infusions and insufflation gases.[1] In major abdominal operations—often lengthy, highly exposed, and fluid-intensive—the combination of redistribution after induction and ongoing environmental losses makes temperature management particularly challenging; consequently, targeted bundles that integrate pre-warming, intra-operative forced-air warming, warmed fluids and irrigation, humidified gases, and attention to ambient conditions are increasingly advocated as standard care.[2]

Mechanistically, general anaesthesia reduces the thresholds for vasoconstriction and shivering and produces marked vasodilation, promoting a net transfer of heat from the core to the periphery within minutes of induction. A landmark physiological study quantified this redistribution: core temperature fell by approximately 1.6 ± 0.3 °C in the first hour of anaesthesia, with ~81% of that decline attributable to core-to-peripheral heat flow.[2] This early, redistribution-driven nadir is directly relevant to the design of prevention protocols; brief pre-warming can "fill" peripheral thermal compartments and blunt the initial gradient, while continuous intra-operative warming and warmed fluids mitigate subsequent environmental losses.[1,3]

The clinical consequences of even mild hypothermia (often 1–2 °C below normal) are broad. Hypothermia impairs platelet function and enzymatic coagulation, increasing surgical blood loss and transfusion needs; it augments susceptibility to surgical-site infection through vasoconstriction-related tissue hypoxia; it triggers shivering and discomfort that degrade recovery quality; and it can precipitate morbid cardiac events in high-risk patients.[1] Early randomized data demonstrated the stakes: maintaining normothermia during noncardiac surgery reduced morbid cardiac events from 6.3% to 1.4% and shortened recovery times, underscoring that temperature management is not merely a comfort measure but a determinant of hard outcomes.[3] Complementing these trial data, a meta-analysis quantified the haemostatic impact of modest temperature reductions, estimating ~16% greater blood loss and ~22% higher transfusion risk with mild hypothermia—effects large enough to influence perioperative resource use and patient safety.[4]

At the system level, infection-prevention frameworks increasingly embed temperature management within perioperative bundles. The World Health Organization's Global Guidelines for the Prevention of Surgical Site Infection recommend maintaining normothermia as part of integrated pre-, intra-, and postoperative strategies, reflecting evidence that thermal homeostasis improves tissue perfusion and oxygenation—key biological defenses against infection.[5,6] Yet, translating guidance into routine practice remains uneven. Observational work in actively warmed patients shows hypothermia is still "routine" during the first hour of anaesthesia, with average temperatures rising only later in the case as warming overcomes redistribution and environmental losses.[7] These patterns suggest that single-intervention approaches may be insufficient and that adherence to multi-component protocols—initiated before induction and sustained throughout the procedure—matters.

Major abdominal surgery is an ideal testbed for assessing real-world effectiveness of such bundles. These procedures commonly entail broad exposure of the abdomen, high evaporative and convective losses, and substantial fluid administration; laparoscopic approaches add the thermal load of insufflated gas, whereas open approaches often prolong exposure and heighten heat loss from large wound surfaces. Against this backdrop, a comprehensive protocol should, in principle, raise nadir temperature, reduce time spent below 36 °C, and improve recovery-room endpoints such as shivering and time to normothermia. Our prospective assessment therefore focuses on pragmatic bundle adherence in a tertiary-care setting and its association with thermoregulatory trajectories and patient-centred outcomes.

A central premise of our work is that process reliability underpins thermal outcomes. Even well-validated measures (e.g., forced-air warming) can underperform when started late, paused for positioning or access, or applied with suboptimal blanket coverage. Likewise, warmed crystalloid and blood require both functional warming devices and procedural discipline to avoid inadvertent administration of cold fluids during busy operative phases. By explicitly measuring adherence to each bundle element and relating adherence tiers to outcomes, we aim to clarify whether incremental compliance translates into clinically meaningful reductions in hypothermia incidence, shorter hypothermic exposure, and better PACU recovery metrics. This approach aligns with contemporary views that perioperative thermoregulation is a continuous process—beginning pre-induction, extending through incision and closure, and continuing into early recovery—rather than a single device choice.[6,7]

MATERIALS AND METHODS

This was a prospective, single-centre observational study conducted in the operating theatres and post-anaesthesia care unit (PACU) of a tertiary care teaching hospital. The aim was to assess adherence to, and effectiveness of, a standardized perioperative hypothermia-prevention protocol ("warming bundle") among adults undergoing major abdominal surgery, with data collected in real time by trained investigators using predefined case-record forms.

Participants

Adults aged 18 years or older scheduled for elective major abdominal procedures (open or laparoscopic) under general anaesthesia, with or without neuraxial techniques, and classified as American Society of Anesthesiologists (ASA) physical status I–III were eligible following informed consent. Patients were excluded for emergency surgery, pre-existing fever or hypothermia on arrival to the pre-operative area (core temperature <36.0 °C or >38.0 °C), known thyroid dysfunction affecting thermoregulation, active sepsis, pregnancy, severe haemodynamic instability prior to induction, contraindication to active warming devices, or inability to obtain reliable core temperature measurements. A total of 50 consecutive eligible patients were enrolled using convenience sampling without interim analyses, representing the full cohort used for all descriptive and comparative evaluations of the protocol.

Methodology

All patients were managed according to the institutional warming bundle that included pre-warming in the pre-operative area with convective forced-air devices and passive insulation, maintenance of operating room ambient temperature at or above 21 °C during induction with minimization of unnecessary exposure, continuous intra-operative active warming with upper- or lower-body forced-air blankets, warming of intravenous crystalloids (approximately 37–40 °C) and blood products when administered, warming of irrigation fluids to a similar range when used, and conditioning of inspired gases with heated humidification for intubated cases when available and not contraindicated. Adherence to each component was prospectively recorded, protocol interruptions or device malfunctions were documented with reasons, and a per-patient bundle adherence score (0–6) was derived and further categorized as high adherence (≥5/6) versus lower adherence (≤4/6) for analysis.

Perioperative management

Anaesthetic conduct—including induction and maintenance agents, airway strategy, regional or neuraxial adjuncts, analgesia, and intra-operative fluid and transfusion practices—followed departmental standards at the discretion of the attending team and was contemporaneously recorded. Use of vasopressors, antibiotic prophylaxis and redosing, and surgical factors such as approach (open, laparoscopic, or converted), procedure category, operative duration, and estimated blood loss were captured to contextualize thermal management.

Temperature measurement and data collection

Core temperature was monitored intra-operatively using an oesophageal probe for intubated patients or a nasopharyngeal probe when oesophageal placement was not feasible; axillary temperature was reserved for instances in which core probes were contraindicated and such cases were flagged for sensitivity analysis. Tympanic membrane temperatures were obtained in duplicate in the pre-operative area and in the PACU, with the mean recorded at each time point. Temperatures were recorded at baseline prior to induction and pre-warming, immediately after induction, at skin incision, every 15 minutes intra-operatively, at the end of surgery, on PACU arrival, and at 30 and 60 minutes in PACU or until discharge, whichever occurred first. Monitoring devices were used per manufacturer instructions and departmental calibration schedules; any out-of-range quality checks prompted device replacement. Additional variables included demographics, body mass index, ASA class, comorbidities, smoking status, ambient temperature at induction and hourly thereafter, volume of fluids and blood products, PACU shivering grades (4-point scale), thermal comfort (0–10 numeric rating), arrhythmias or bleeding events, wound classification, and any early surgical-site concerns prior to hospital discharge.

Outcomes

The primary outcome was the incidence of perioperative hypothermia, defined as any recorded core temperature <36.0 °C from induction of anaesthesia until PACU discharge. Secondary outcomes included nadir intra-operative core temperature, time-weighted average temperature below 36.0 °C (area under threshold), PACU shivering incidence and severity, time to normothermia (first core or tympanic temperature ≥36.0 °C in PACU), intra-operative blood loss and allogeneic transfusion, unplanned ICU admission, arrhythmias, and patient-reported thermal comfort in PACU; exploratory analyses summarized early surgical-site concerns documented before discharge.

Statistical Analysis

Analyses were performed in IBM SPSS Statistics v26.0. Continuous data were summarized as mean ± SD or median (IQR), and categorical data as n (%). The primary outcome (incidence of hypothermia) was reported with 95% CI; high vs lower adherence groups were compared with χ^2/Fisher's exact and t-test/Mann–Whitney U, and temperature trajectories with repeated-measures ANOVA (Greenhouse–Geisser) or linear mixed-effects models. Exploratory logistic regression for hypothermia included prespecified covariates (age, BMI, ASA class, operative duration, approach, ambient temperature at induction, warmed fluids, adherence); missing data used complete-case analysis (≤5%) or multiple imputation (>5%); two-tailed $p < 0.05$ and effect sizes with 95% CIs were reported.

RESULTS

Baseline characteristics (Table 1):
The study enrolled 50 patients with a mean age of 52.4 ± 11.8 years. The distribution of sex, BMI, ASA status, surgical approach, and operative duration was comparable between the high adherence group (n=32) and the lower adherence group (n=18). Specifically, 56.25% in the high adherence group and 55.56% in the lower adherence group were males, with no significant difference (p=0.96). Similarly, mean BMI values (25.2 vs. 24.5 kg/m²; p=0.53), proportion of ASA II–III patients (65.63% vs. 72.22%; p=0.63), open procedures (59.38% vs. 61.11%; p=0.91), and operative duration (165.4 vs. 173.1 minutes; p=0.54) showed no statistically significant differences. Thus, the two groups were demographically and clinically comparable, minimizing confounding by baseline factors.

Incidence of perioperative hypothermia (Table 2):
Overall, 14 out of 50 patients (28.00%) developed perioperative hypothermia. The incidence was significantly lower in the high adherence group (18.75%) compared to the lower adherence group (44.44%, p=0.048). The nadir core temperature was higher in patients receiving high adherence to the protocol (36.2 ± 0.3 °C vs. 35.9 ± 0.5 °C, p=0.02), and the time-weighted average duration spent below 36 °C was also shorter (8.6 ± 12.4 minutes vs. 19.1 ± 25.3 minutes, p=0.04). These findings demonstrate that greater adherence to the warming bundle was associated with significantly better maintenance of normothermia.

PACU outcomes (Table 3):
In the recovery phase, shivering of any grade was reported in 22.00% of patients, with significantly fewer events in the high adherence group (12.50%) compared to the lower adherence group (38.89%, p=0.03). Although higher grade shivering (grade ≥2) was more common in the lower adherence group (22.22% vs. 6.25%), this did not reach statistical significance (p=0.09). Importantly, patients in the high adherence group achieved normothermia faster in PACU (18.2 ± 7.8 minutes vs. 27.1 ± 10.3 minutes, p=0.01). Furthermore, patient-reported thermal comfort scores were higher with high adherence (8.5 ± 1.0) compared to lower adherence (7.5 ± 1.3), with a significant difference (p=0.004). These results indicate that the protocol not only reduced hypothermia but also improved patient comfort and recovery quality.

Perioperative complications (Table 4):
Although perioperative complications were infrequent, they tended to be more common in the lower adherence group. Blood loss greater than 500 mL occurred in 14.00% overall, with higher frequency in the lower adherence group (22.22% vs. 9.38%, p=0.20). Similarly, transfusion requirements (16.67% vs. 3.13%, p=0.13), arrhythmias (11.11% vs. 3.13%, p=0.29), and unplanned ICU admissions (11.11% vs. 0%, p=0.09) were more frequent among patients with lower adherence, though differences did not reach statistical significance. This suggests a possible clinical benefit of adherence, but the small sample size limited statistical power for complications.

Predictors of hypothermia (Table 5):
In multivariable logistic regression, lower adherence to the warming bundle (≤4/6 components) emerged as a significant independent predictor of hypothermia (adjusted OR: 3.72; 95% CI: 1.01–13.71; p=0.048). Other variables, including age, BMI, ASA status, operative duration greater than 180 minutes, and surgical approach (open vs. laparoscopic), were not significantly associated with hypothermia. This highlights that adherence to the prevention protocol was the most important determinant of maintaining normothermia, independent of patient or surgical characteristics.

Table 1: Baseline characteristics of study population (N = 50)

Variable	Overall (n=50)	High adherence (n=32)	Lower adherence (n=18)	p-value
Age, mean ± SD (years)	52.4 ± 11.8	51.8 ± 11.2	53.5 ± 12.7	0.66
Male sex, n (%)	28 (56.00%)	18 (56.25%)	10 (55.56%)	0.96
BMI, mean ± SD (kg/m²)	24.9 ± 3.6	25.2 ± 3.5	24.5 ± 3.8	0.53
ASA II–III, n (%)	34 (68.00%)	21 (65.63%)	13 (72.22%)	0.63
Open procedure, n (%)	30 (60.00%)	19 (59.38%)	11 (61.11%)	0.91
Operative duration, mean ± SD (min)	168.2 ± 42.5	165.4 ± 39.6	173.1 ± 47.1	0.54

Table 2: Incidence of perioperative hypothermia

Outcome	Overall (n=50)	High adherence (n=32)	Lower adherence (n=18)	p-value
Hypothermia (<36.0 °C), n (%)	14 (28.00%)	6 (18.75%)	8 (44.44%)	0.048*
Nadir temperature, mean ± SD (°C)	36.1 ± 0.4	36.2 ± 0.3	35.9 ± 0.5	0.02*
Time-weighted average <36 °C (min)	12.3 ± 18.7	8.6 ± 12.4	19.1 ± 25.3	0.04*

****Statistically significant***

Table 3: Post-anaesthesia care unit (PACU) outcomes

Outcome	Overall (n=50)	High adherence (n=32)	Lower adherence (n=18)	p-value
Shivering, any grade, n (%)	11 (22.00%)	4 (12.50%)	7 (38.89%)	0.03*
Shivering grade ≥2, n (%)	6 (12.00%)	2 (6.25%)	4 (22.22%)	0.09
Time to normothermia, mean ± SD (min)	21.4 ± 9.6	18.2 ± 7.8	27.1 ± 10.3	0.01*
Thermal comfort score, mean ± SD	8.1 ± 1.2	8.5 ± 1.0	7.5 ± 1.3	0.004*

Table 4: Perioperative complications

Complication	Overall (n=50)	High adherence (n=32)	Lower adherence (n=18)	p-value
Blood loss >500 mL, n (%)	7 (14.00%)	3 (9.38%)	4 (22.22%)	0.20
Transfusion required, n (%)	4 (8.00%)	1 (3.13%)	3 (16.67%)	0.13
Arrhythmias, n (%)	3 (6.00%)	1 (3.13%)	2 (11.11%)	0.29
Unplanned ICU admission, n (%)	2 (4.00%)	0 (0.00%)	2 (11.11%)	0.09

Table 5: Multivariable logistic regression for predictors of hypothermia

Variable	Adjusted OR	95% CI	p-value
Age (per 10 years)	1.12	0.85 – 1.49	0.42
BMI (per 1 kg/m²)	0.94	0.83 – 1.08	0.39
ASA II–III vs I	1.41	0.38 – 5.18	0.61
Operative duration >180 min	2.67	0.74 – 9.57	0.13
Open vs laparoscopic	1.85	0.48 – 7.15	0.36
Lower adherence (≤4/6)	3.72	1.01 – 13.71	0.048*

Statistically significant

DISCUSSION

Our findings show that adherence to a structured perioperative warming bundle was associated with better thermal control without baseline imbalances between groups, which aligns with guideline expectations that adult surgical patients should maintain core temperature ≥36.0 °C through pre-, intra- and post-operative warming and consistent monitoring. In our cohort, overall hypothermia occurred in 28.00%, but only 18.75% with high adherence versus 44.44% with lower adherence, supporting guideline-driven bundles that emphasize pre-warming, active intra-operative warming, warmed fluids and ambient-temperature targets.[8]

The hypothermia incidence in our high-adherence group (18.75%) compares favorably with reports in major abdominal surgery where conventional warming alone can still permit substantial temperature decline. For example, Hasegawa et al. reported end-of-surgery core temperatures of 36.2 ± 0.9 °C with forced-air warming and 36.0 ± 0.6 °C with resistive heating, both lower than circulating-water systems (36.9 ± 0.7 °C), highlighting that routine methods may be insufficient during prolonged laparotomy; our nadir of 36.2 ± 0.3 °C in the high-adherence group and 35.9 ± 0.5 °C in the lower-adherence group is consistent with those challenges.[9]

Short-duration pre-warming has repeatedly demonstrated large reductions in hypothermia incidence and shivering. Horn et al. randomized 200 patients and found hypothermia at end of anaesthesia in 69% with no pre-warming versus 13%, 7% and 6% after 10, 20 and 30 min of pre-warming, respectively; shivering fell from 18.18% (10/55) without pre-warming to 5.77% (3/52), 6.98% (3/43) and 2.00% (1/50). Our bundle—of which pre-warming is a core element—yielded hypothermia in 18.75% with high adherence, substantially lower than the 44.44% seen with lower adherence, in the context of longer and more invasive major abdominal procedures.[10]

Similarly, Andrzejowski et al. showed that adding 60 min of pre-warming (plus intra-operative forced-air warming in both arms) kept ≥36 °C in 68% versus 43% of controls and limited the post-induction temperature drop by ~0.3 °C at multiple time points. In our study, high adherence reduced time-weighted exposure below 36 °C (8.6 ± 12.4 vs 19.1 ± 25.3 min; p = 0.04) and raised nadir temperatures (36.2 ± 0.3 °C vs 35.9 ± 0.5 °C), paralleling the temperature-trajectory benefits observed with robust pre-warming.[11]

Post-anaesthesia outcomes in our cohort also tracked with the evidence base. We observed any-grade shivering in 12.50% with high adherence versus 38.89% with lower adherence (p = 0.03) and higher thermal comfort scores (8.5 ± 1.0 vs 7.5 ± 1.3; p = 0.004). The Cochrane meta-analysis by Madrid et al. found that active body-surface warming reduced shivering (RR 0.39; 95% CI 0.28–0.54) and improved thermal comfort (SMD 0.76), mirroring our direction and magnitude of benefit on recovery-room experience.[12]

Our faster return to normothermia in PACU with high adherence (18.2 ± 7.8 vs 27.1 ± 10.3 min; p = 0.01) is consistent with randomized data showing that warming early in the anaesthetic course improves downstream temperatures. Yoo et al. reported that peri-induction forced-air warming reduced intra-operative hypothermia from 57.1% to 19.0% and immediate PACU hypothermia from 16.9% to 3.3%, with higher intra-operative core temperatures despite similar comfort scores—complementing our observation that targeted bundle adherence shortens time to normothermia.[13]

Regarding warming configurations, our lower time-weighted hypothermia in the high-adherence group aligns with evidence that device choice and coverage matter. In a propensity-matched analysis of 978 patients (489 pairs), Sumida et al. found end-of-surgery hypothermia in 6.75% (33/489) with underbody forced-air blankets versus 12.88% (63/489) with other blankets (OR 0.49; 95% CI 0.31–0.76), underscoring how effective convection and surface area coverage can shift temperature trajectories—an effect captured by our bundle's emphasis on continuous active warming.[14]

Although our study was not powered for hard complications, the pattern we observed—numerically fewer transfusions (3.13% vs 16.67%), arrhythmias (3.13% vs 11.11%) and ICU admissions

(0.00% vs 11.11%) with high adherence—converges with landmark data linking normothermia to improved outcomes. Kurz et al. randomized 200 colorectal patients and showed surgical-site infections fell from 19% to 6% and length of stay decreased by ~2.6 days when intra-operative normothermia (36.6 ± 0.5 °C) was maintained versus hypothermia (34.7 ± 0.6 °C), supporting the clinical importance of preventing even mild hypothermia. [15] Finally, our multivariable analysis identified lower bundle adherence (≤4/6 components) as an independent predictor of hypothermia (adjusted OR 3.72; 95% CI 1.01–13.71; $p = 0.048$). Taken together with the randomized and observational literature above, these results suggest that consistent delivery of multiple warming elements—early pre-warming, continuous intra-operative forced-air warming, warmed fluids, and appropriate ambient control—offers additive protection against hypothermia and shivering, with plausible downstream benefits for recovery and complications.

CONCLUSION

In this prospective cohort of 50 major abdominal surgery patients, higher adherence to a perioperative warming bundle was associated with a lower hypothermia incidence (18.75% vs 44.44%), higher nadir core temperatures, and reduced hypothermic exposure. Improved adherence also translated into better recovery metrics, including less PACU shivering, faster return to normothermia, and higher thermal comfort. Complication rates trended favorably with high adherence, though the study was not powered to detect differences in rare outcomes. Lower bundle adherence independently predicted hypothermia, underscoring that consistent, protocolized thermal care should be standard practice in major abdominal procedures and merits evaluation in larger, multi-centre trials.

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