Research Square

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Intraoperative hypothermia during laparoscopic radical prostatectomy: incidence, timing, and associated preoperative factors—a retrospective cohort study

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Research Article

Keywords: Intraoperative hypothermia, Laparoscopic radical prostatectomy, Body mass index, Core temperature

Posted Date: November 3rd, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11397594/v1

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Additional Declarations: No competing interests reported.

Abstract

Background: Intraoperative hypothermia remains a concern during laparoscopic radical prostatectomy (LRP), but its timing and associated preoperative factors are unclear. We investigated the occurrence, timing, and preoperative factors associated with intraoperative hypothermia during LRP.

Methods: This single-center retrospective cohort study included 381 consecutive patients undergoing elective LRP between January 2022 and June 2024. Hypothermia was defined as any nasopharyngeal core temperature <36.0 °C, and early hypothermia as first detection within 2 h after anesthesia induction. Variables with P<0.10 in univariable analyses were entered into multivariable logistic regression. Early hypothermia was examined in an exploratory analysis.

Results: Overall, 103 patients (27.0%) developed intraoperative hypothermia, and 90 (87.4%) were first identified within 2 h. Greater preoperatively estimated blood loss (adjusted odds ratio [aOR] per 50 mL, 1.32; 95% confidence interval [CI], 1.05–1.66), lower body mass index (aOR per 1 kg/m², 0.88; 95% CI, 0.81–0.96), and C-reactive protein >5 mg/L (aOR, 5.73; 95% CI, 2.86–11.46) remained associated with overall hypothermia after adjustment. Baseline temperature was not significantly associated with the overall outcome (P=0.053). In the exploratory analysis, these three factors remained associated with early hypothermia, and higher baseline temperature was additionally associated with lower odds of this outcome (aOR per 0.1 °C, 0.913; 95% CI, 0.835–0.998).

Conclusions: Approximately one-quarter of patients developed intraoperative hypothermia, with most cases detected within 2 h after anesthesia induction. Routinely available preoperative factors were associated with hypothermia and may help identify patients requiring closer early temperature surveillance. Prospective multicenter studies are needed to confirm these findings.

Background

Inadvertent intraoperative hypothermia, commonly defined as a core temperature < 36.0°C, remains a clinically relevant perioperative complication and is associated with adverse outcomes, including impaired coagulation, surgical-site infection, delayed recovery, and prolonged hospitalization.[1–3] General anesthesia impairs thermoregulatory responses and promotes redistribution of body heat, particularly during the early intraoperative period.[1, 4] Although laparoscopic radical prostatectomy (LRP) is minimally invasive, prolonged pneumoperitoneum, steep Trendelenburg positioning, and restricted access to the body surface may complicate perioperative temperature management.[4–6]

Susceptibility to intraoperative hypothermia varies among patients. Age, body mass index, baseline temperature, duration of anaesthesia or surgery, fluid administration, and blood loss have been associated with hypothermia across adult laparoscopic and robotic surgical cohorts.[6–9] Whether routinely available nutritional, metabolic, and inflammatory markers provide additional information remains uncertain. Existing evidence has largely been derived from heterogeneous surgical populations

or broader laparoscopic and robotic cohorts.[6–9] Procedure-specific studies in radical prostatectomy have focused mainly on anaesthetic choice or warming strategies rather than the timing and preoperative correlates of hypothermia.[4, 5, 10] Although intraoperative temperature trajectories have been described, the timing of first detected hypothermia during LRP remains insufficiently characterised.[6, 7]

This study therefore aimed to determine the incidence and timing of intraoperative hypothermia and to identify preoperative factors independently associated with its occurrence in patients undergoing elective LRP. As a secondary exploratory objective, we examined factors associated with hypothermia first detected within the first 2 h after induction of anaesthesia.

Methods

Study design and participants

This single-centre retrospective cohort study was conducted at Ningbo Medical Center Lihuili Hospital, a tertiary academic medical centre in Ningbo, China. The study evaluated the occurrence, timing, and preoperative factors associated with intraoperative hypothermia in patients undergoing laparoscopic radical prostatectomy. Data were obtained from the electronic medical record, anaesthesia information management system, operating-room database, and laboratory information system. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology statement.

Consecutive adult patients who underwent elective laparoscopic radical prostatectomy for prostate adenocarcinoma between 1 January 2022 and 30 June 2024 were screened. Patients were eligible if surgery was performed under general anaesthesia and intraoperative core temperature was documented. Exclusion criteria were concurrent major abdominal surgery, preoperative temperature < 36.0°C or > 38.0°C, conversion to open surgery, or missing data required for outcome ascertainment or analysis. After application of these criteria, 381 patients were included. The sample size was determined by the number of eligible consecutive patients during the study period.

Data collection

Candidate factors were prespecified according to clinical relevance and data availability. Demographic and clinical variables included age, body mass index, hypertension, diabetes mellitus, Nutritional Risk Screening 2002 score, smoking history, alcohol consumption, previous abdominal surgery, baseline tympanic temperature, preoperative estimated blood loss, and estimated operative duration. Preoperative estimated blood loss was assessed by the operating surgeon before surgery, and estimated operative duration was documented during preoperative planning.

Laboratory variables comprised the most recent preoperative haemoglobin, C-reactive protein, blood glucose, and serum albumin measurements. Disease-related variables included Gleason score and total prostate-specific antigen. Elevated C-reactive protein was defined as > 5 mg/L. Values reported as < 0.5 mg/L were assigned a value of 0.25 mg/L. Total prostate-specific antigen values reported as < 0.04 or > 150.0 µg/L were assigned the corresponding boundary value. Data were extracted using a standardized form and de-identified before analysis.

Outcome definitions

The primary outcome was intraoperative hypothermia, defined as at least one recorded core temperature < 36.0°C. Core temperature was monitored using a nasopharyngeal probe and recorded routinely in the anaesthesia information management system. For each affected patient, the elapsed time from induction of anaesthesia to the first recorded core temperature < 36.0°C was used to determine the hour of first detection.

A secondary exploratory outcome was hypothermia first detected within the first 2 h after induction of anaesthesia. Patients whose hypothermia was first detected more than 2 h after induction were classified as not having the early outcome.

Statistical analysis

Continuous variables are presented as median and interquartile range, and categorical variables as number and percentage. Patients with and without intraoperative hypothermia were compared using the Mann–Whitney U test for continuous variables and Pearson’s chi-square test or Fisher’s exact test for categorical variables, as appropriate.

Associations with intraoperative hypothermia were examined using binary logistic regression. Each candidate factor was initially evaluated in a univariable model. Variables with $P < 0.10$ were entered simultaneously into the multivariable model. Odds ratios and 95% confidence intervals were reported.

Continuous effects were expressed per 10-year increase in age, 50-mL increase in anticipated blood loss, 0.1-°C increase in baseline temperature, 30-min increase in estimated operative duration, 10-g/L increase in haemoglobin, and 5-g/L increase in albumin. Other continuous variables were analysed per unit increase. Total prostate-specific antigen was log2-transformed, with its odds ratio representing a doubling.

The same analytical approach was applied to the secondary outcome of hypothermia first detected within the first 2 h after induction of anaesthesia. Among the 381 included patients, no candidate factor or outcome data were missing; therefore, no imputation was performed. All tests were two-sided, and $P < 0.05$ was considered statistically significant. Analyses were performed using Python version 3.12.

Ethical considerations

The study was approved by the Institutional Review Board of Ningbo Medical Center Lihuili Hospital (approval No. KY2025SL509-01). The requirement for informed consent was waived because of the retrospective design and use of anonymized data. The study was conducted in accordance with the Declaration of Helsinki and applicable national regulations.

Results

Study population

Baseline characteristics

Baseline characteristics are presented in Table 1. Patients with hypothermia had lower body mass index and blood glucose, greater estimated blood loss, and a higher prevalence of elevated C-reactive protein (> 5 mg/L) than normothermic patients (all $P \leq 0.007$). Baseline temperature was marginally lower ($P = 0.053$), while the remaining characteristics did not differ significantly.

Table 1
Baseline characteristics according to intraoperative hypothermia

Characteristic	Overall (n = 381)	Normothermia (n = 278)	Hypothermia (n = 103)	P value
Demographic and preoperative characteristics				
Age, years	72 (68, 76)	72 (67, 76)	72 (68, 76)	0.787
Body mass index, kg/m²	24.13 (21.91, 25.96)	24.37 (22.16, 26.19)	23.05 (21.07, 24.77)	< 0.001
Nutritional Risk Screening 2002 score	1 (0, 1)	1 (0, 1)	1 (0, 1)	0.416
Preoperative baseline temperature, °C	36.60 (36.40, 36.70)	36.60 (36.40, 36.77)	36.50 (36.30, 36.70)	0.053
Preoperative estimated blood loss, mL	50 (20, 50)	50 (20, 50)	50 (20, 100)	0.007
Estimated operative duration, min	175.0 (145.0, 205.0)	175.5 (145.8, 206.5)	173.0 (145.0, 203.0)	0.532
Medical history				
Hypertension, n (%)	201 (52.8)	149 (53.6)	52 (50.5)	0.589
Diabetes mellitus, n (%)	58 (15.2)	42 (15.1)	16 (15.5)	0.918
Smoking history, n (%)	111 (29.1)	78 (28.1)	33 (32.0)	0.447
Alcohol consumption, n (%)	78 (20.5)	59 (21.2)	19 (18.4)	0.551
Previous abdominal surgery, n (%)	57 (15.0)	42 (15.1)	15 (14.6)	0.895
Laboratory and disease characteristics				
Hemoglobin, g/L	136 (126, 143)	137 (126, 144)	133 (126, 141)	0.121
C-reactive protein, mg/L	0.60 (0.25, 2.20)	0.70 (0.25, 2.10)	0.50 (0.25, 5.80)	0.802
Elevated C-reactive protein (> 5 mg/L), n (%)	44 (11.5)	17 (6.1)	27 (26.2)	< 0.001
Blood glucose, mmol/L	5.20 (4.86, 5.86)	5.27 (4.93, 5.96)	5.05 (4.75, 5.50)	0.003
Serum albumin, g/L	40.60 (38.30, 42.90)	40.90 (38.50, 43.00)	39.90 (38.10, 42.05)	0.099
Gleason score	7 (7, 8)	7 (7, 8)	7 (7, 8)	0.801

Characteristic	Overall (n = 381)	Normothermia (n = 278)	Hypothermia (n = 103)	P value
Total prostate-specific antigen, μg/L	9.37 (5.82, 14.40)	9.30 (5.78, 14.00)	9.53 (6.39, 14.93)	0.513

Data are presented as median (interquartile range) or n (%). Percentages are calculated within columns.

Continuous variables were compared using the Mann-Whitney U test. Categorical variables were compared using Pearson's chi-square test or Fisher's exact test, as appropriate.

C-reactive protein values reported as < 0.5 mg/L were assigned 0.25 mg/L for continuous summaries. Elevated C-reactive protein was defined as > 5 mg/L.

Total prostate-specific antigen values reported as < 0.04 or > 150.0 μg/L were assigned the corresponding boundary value for analysis.

Timing of intraoperative hypothermia

Among the 103 patients who developed intraoperative hypothermia, it was first detected during the first, second, and third hours after induction of anaesthesia in 61 (59.2%), 29 (28.2%), and 13 (12.6%) patients, respectively. Overall, 90 cases (87.4%) were first detected within the first 2 h after induction (Fig. 2).

Preoperative factors associated with intraoperative hypothermia

In univariable analyses, greater preoperatively estimated blood loss, lower body mass index, lower baseline temperature, elevated C-reactive protein, and lower blood glucose were associated with intraoperative hypothermia. After multivariable adjustment, greater estimated blood loss (aOR per 50 mL, 1.32; 95% CI 1.05–1.66; P = 0.018), lower body mass index (aOR per 1 kg/m², 0.88; 95% CI 0.81–0.96; P = 0.006), and elevated C-reactive protein (> 5 mg/L; aOR, 5.73; 95% CI 2.86–11.46; P < 0.001) remained associated with hypothermia. Baseline temperature (P = 0.053) and blood glucose (P = 0.256) were not statistically significant after adjustment (Table 2; Fig. 3).

Table 2
Preoperative factors associated with intraoperative hypothermia

Factor	OR (95% CI)	P value
A Univariable logistic regression		
Age, per 10-year increase	0.99 (0.68–1.43)	0.947
Preoperative estimated blood loss, per 50-mL increase	1.31 (1.05–1.62)	0.015
Body mass index, per 1-kg/m² increase	0.88 (0.81–0.96)	0.002
Nutritional Risk Screening 2002 score, per point	1.16 (0.83–1.63)	0.385
Preoperative baseline temperature, per 0.1-°C increase	0.92 (0.85-1.00)	0.039
Estimated operative duration, per 30-min increase	0.95 (0.81–1.10)	0.468
Hypertension, yes vs no	0.88 (0.56–1.39)	0.589
Diabetes mellitus, yes vs no	1.03 (0.55–1.93)	0.918
Smoking history, yes vs no	1.21 (0.74–1.97)	0.448
Alcohol consumption, yes vs no	0.84 (0.47–1.49)	0.551
Previous abdominal surgery, yes vs no	0.96 (0.51–1.81)	0.895
Hemoglobin, per 10-g/L increase	0.90 (0.76–1.07)	0.242
Elevated C-reactive protein (> 5 mg/L), yes vs no	5.45 (2.82–10.54)	< 0.001
Blood glucose, per 1-mmol/L increase	0.75 (0.58–0.95)	0.020
Serum albumin, per 5-g/L increase	0.79 (0.57–1.09)	0.150
Gleason score, per point	1.06 (0.81–1.38)	0.675
Total prostate-specific antigen, per doubling	1.01 (0.87–1.16)	0.940
B Multivariable logistic regression		
Preoperative estimated blood loss, per 50-mL increase	1.32 (1.05–1.66)	0.018
Body mass index, per 1-kg/m² increase	0.88 (0.81–0.96)	0.006
Preoperative baseline temperature, per 0.1-°C increase	0.92 (0.84-1.00)	0.053
Elevated C-reactive protein (> 5 mg/L), yes vs no	5.73 (2.86–11.46)	< 0.001
Blood glucose, per 1-mmol/L increase	0.86 (0.67–1.11)	0.256

ORs and 95% CIs were estimated using binary logistic regression in the complete cohort (n = 381; 103 hypothermia events).

Continuous effects are reported per 10 years for age, 50 mL for estimated blood loss, 0.1°C for baseline temperature, 30 min for estimated operative duration, 10 g/L for hemoglobin, 5 g/L for albumin, and one unit unless otherwise stated.

C-reactive protein was categorized using the laboratory upper reference limit (> 5 vs < = 5 mg/L). Values reported as < 0.5 mg/L were assigned 0.25 mg/L during data preparation. Total prostate-specific antigen was log2-transformed; its OR represents a doubling.

Variables with P < 0.10 in univariable analysis were entered simultaneously into the multivariable model: preoperative estimated blood loss, body mass index, baseline temperature, elevated C-reactive protein, and blood glucose.

OR, odds ratio; CI, confidence interval.

Factors associated with hypothermia within 2 h after anaesthesia induction

Among 381 patients, 90 developed hypothermia within the first 2 h after induction of anaesthesia. In a secondary exploratory analysis, greater preoperative estimated blood loss, lower body mass index, lower baseline temperature, and elevated C-reactive protein (> 5 mg/L) were independently associated with this early outcome. Blood glucose was not independently associated with the outcome (Table 3).

Table 3
Preoperative factors associated with intraoperative hypothermia within 2 h after anaesthesia induction

Factor	Adjusted OR (95% CI)	P value
Preoperative estimated blood loss, per 50-mL increase	1.265 (1.003–1.597)	0.047
Body mass index, per 1-kg/m² increase	0.900 (0.821–0.986)	0.023
Preoperative baseline temperature, per 0.1-°C increase	0.913 (0.835–0.998)	0.045
Elevated C-reactive protein (> 5 mg/L), yes vs no	4.445 (2.253–8.767)	< 0.001
Blood glucose, per 1-mmol/L increase	0.864 (0.665–1.124)	0.276

Adjusted odds ratios and 95% confidence intervals were estimated using multivariable binary logistic regression in 381 patients, including 90 early hypothermia events. Hypothermia within the first 2 h was defined as the first recorded intraoperative core temperature < 36.0°C occurring within 2 h after induction of anaesthesia. Patients whose hypothermia was first detected more than 2 h after induction (n = 13) were classified as not having the early outcome. Variables with P < 0.10 in univariable analysis were entered simultaneously into the multivariable model. aOR, adjusted odds ratio; CI, confidence interval.

Discussion

In this cohort of patients undergoing elective laparoscopic radical prostatectomy, intraoperative hypothermia occurred in 27.0%, and most cases were first detected within the first 2 h after induction of anaesthesia. Greater preoperatively estimated blood loss, lower body mass index, and elevated C-reactive protein were independently associated with overall hypothermia. In the secondary exploratory analysis, lower baseline temperature was additionally associated with hypothermia within the first 2 h after induction. These findings suggest that preoperative susceptibility and the early intraoperative period are important considerations in temperature management.

The incidence in our cohort was slightly lower than the 34.9% reported in a recent large cohort of patients undergoing laparoscopic surgery.[11] The concentration of first detections within 2 h is compatible with redistribution hypothermia, in which anaesthesia-induced vasodilation and impaired thermoregulation promote heat transfer from core to peripheral tissues soon after induction.[12] Early perioperative temperature loss has also been documented during robotic-assisted surgery.[13] However, because first-detection times were analysed in hourly categories, the exact onset and mechanism could not be determined.

The associations of lower body mass index and lower baseline temperature with hypothermia are consistent with recent multicentre evidence.[14] Lower body mass index may reflect reduced insulation and thermal reserve, whereas a lower baseline temperature leaves a smaller margin before the 36.0°C threshold is reached. Baseline temperature was associated with early hypothermia but showed only a borderline association with overall hypothermia; this finding should therefore be interpreted cautiously. Greater surgeon-estimated anticipated blood loss may represent anticipated surgical complexity rather than the effect of actual blood loss. Elevated C-reactive protein showed the strongest association, but its relationship with thermoregulation remains uncertain. Given the small subgroup with elevated C-reactive protein and the wide confidence interval, this finding should be considered hypothesis-generating.

Current guidance recommends perioperative risk assessment, planned temperature management, and consistent temperature monitoring.[15] Patients with lower body mass index, lower baseline temperature, elevated C-reactive protein, or greater anticipated surgical complexity may therefore merit particular attention from anaesthetic induction. Recent randomised studies in robotic urological surgery, including patients undergoing radical prostatectomy, suggest that structured perioperative warming protocols can reduce hypothermia.[16, 17] Nevertheless, the present study did not compare warming interventions or develop a validated prediction model; therefore, no specific management strategy can be recommended from these findings alone.

This study included a homogeneous surgical cohort and evaluated both the occurrence and timing of hypothermia. However, its single-centre observational design limits causal inference and generalizability. Categorization of the time of first detection into hourly intervals limited temporal precision and did not permit determination of the exact onset of hypothermia. Potentially relevant intraoperative factors, including ambient temperature, fluid warming, anaesthetic management, and other warming practices, were not fully evaluated. In addition, the early-outcome analysis was exploratory, and the regression

models were not externally validated. Prospective multicentre studies with standardized temperature monitoring are required to confirm these findings.

Conclusions

Intraoperative hypothermia was common and predominantly detected within the first 2 h after induction of anaesthesia. Several readily available preoperative factors were associated with its occurrence. These findings support early temperature surveillance and prospective evaluation of risk-based thermal management strategies.

Abbreviations

aOR
Adjusted odds ratio
BMI
Body mass index
CI
Confidence interval
CRP
C-reactive protein
LRP
Laparoscopic radical prostatectomy
NRS-2002
Nutritional Risk Screening 2002
OR
Odds ratio.

Declarations

Ethics approval and consent to participate

This retrospective cohort study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Ningbo Medical Center Lihuili Hospital (Approval No. KY2025SL509-01). The requirement for informed consent was waived because of the retrospective design and the use of fully anonymized data.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This study was supported by the Medical Science and Technology Project of Zhejiang Province (2023KY237).

Acknowledgements

Not applicable.

Author Contribution

H L conceived and designed the study, performed the statistical analyses, and drafted the manuscript. Jj Z: collected and curated the data, contributed to data interpretation, and revised the manuscript. Y W: contributed to the study design, supervised the research, and critically revised the manuscript. All authors read and approved the final manuscript.

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Figures

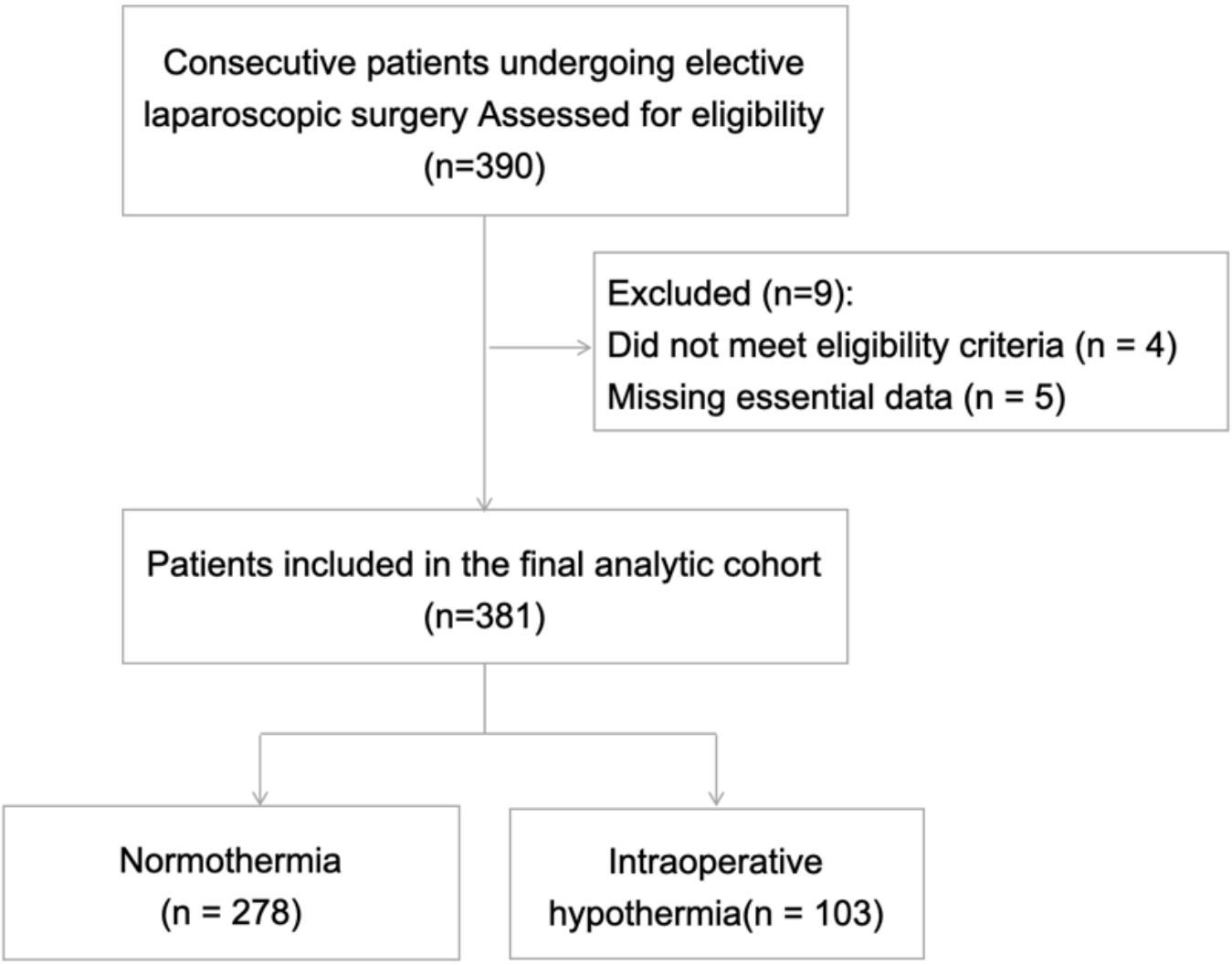


Figure 1

Flow diagram of patient selection and cohort formation.*A total of 390 consecutive patients undergoing elective laparoscopic radical prostatectomy were assessed for eligibility. Nine patients were excluded: four did not meet the eligibility criteria and five had missing essential data. The final analytic cohort comprised 381 patients, of whom 103 (27.0%) developed intraoperative hypothermia and 278 (73.0%) remained normothermic (Fig. 1).*

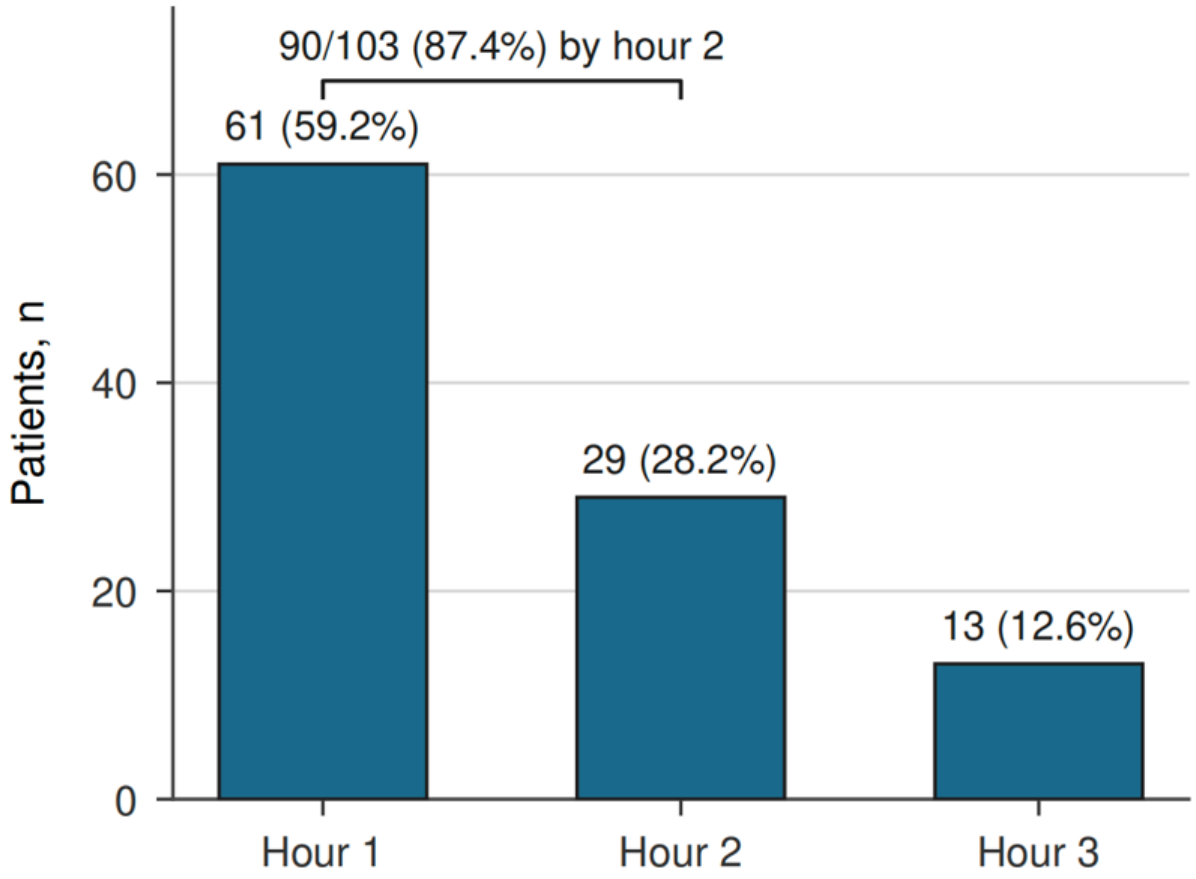


Figure 2

Distribution of first-recorded intraoperative hypothermia. *Bars show the number of patients in whom hypothermia was first recorded during each hour after induction of anaesthesia. Percentages were calculated among patients who developed intraoperative hypothermia (n = 103). Overall, 90 of 103 cases (87.4%) were first recorded within the first 2 h after induction.*

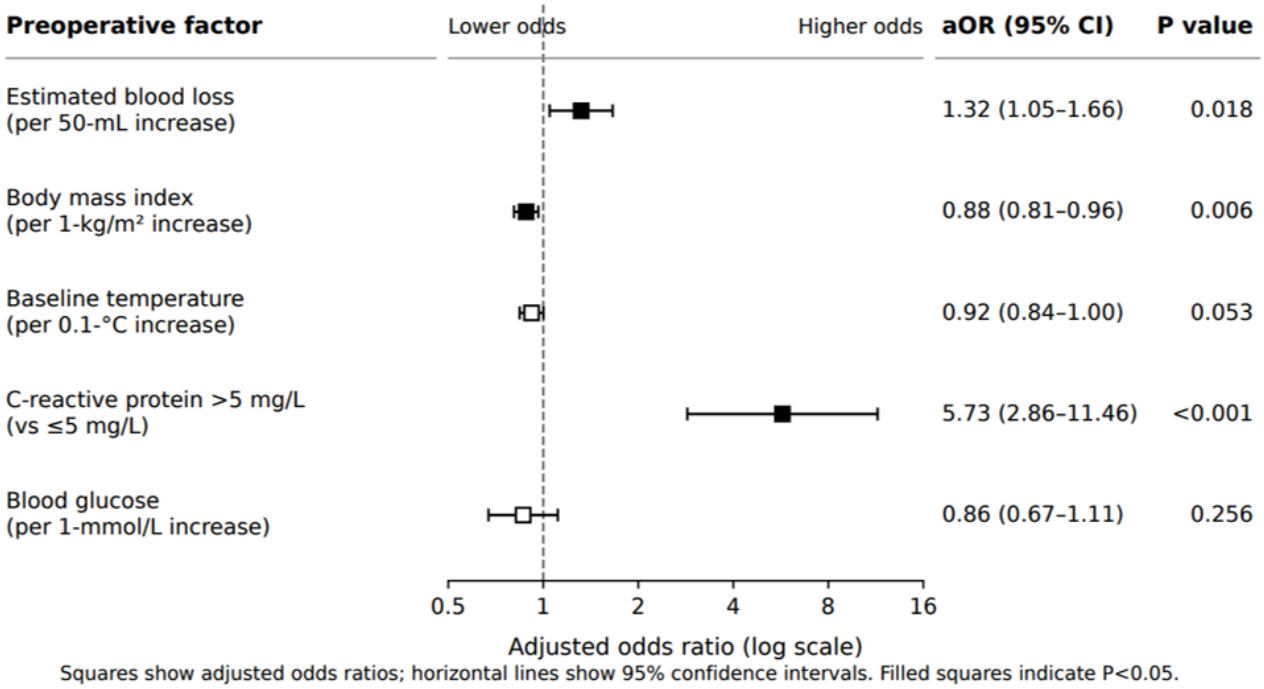


Figure 3

Adjusted associations between preoperative factors and intraoperative hypothermia. *Adjusted odds ratios and 95% confidence intervals were estimated using multivariable logistic regression. Variables with a univariable P value <0.10 were entered simultaneously into the adjusted model. Squares represent adjusted odds ratios and horizontal lines represent 95% confidence intervals. Filled squares indicate P<0.05. An adjusted odds ratio greater than 1 indicates higher odds of intraoperative hypothermia. aOR, adjusted odds ratio; CI, confidence interval; CRP, C-reactive protein.*