



## AHEAD OF PRINT PUBLICATION

## Postoperative Hypothermia in Patients Undergoing Major Abdominal Surgery: A Cohort Study

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ARTICLE INFORMATION	ABSTRACT
<b>KEYWORDS</b> <i>General Surgery;</i> <i>Hypothermia;</i> <i>Risk Factors</i>	<p><b>Introduction:</b> Up to 90% of patients undergoing surgery will present hypothermia in the perioperative period. Likewise, no study has reported the occurrence of postoperative hypothermia and variables associated with its occurrence only in patients undergoing major abdominal surgery.</p> <p><b>Objective:</b> To describe the proportion of patients undergoing major abdominal surgery who develop postoperative hypothermia, and the variables associated with its occurrence.</p> <p><b>Material and Methods:</b> We conducted a prospective cohort study in a tertiary care referral hospital in Mexico City to</p>
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describe the incidence of perioperative hypothermia and factors associated with postoperative hypothermia. Potential variables associated with hypothermia were evaluated with logistic regression analysis.

**Results:** A total of 110 patients were included in the analysis. Of them, 61% ( $n = 67$ ) were women. The mean age was 56.7 years (SD: 16.3, range: 75). The incidence of postoperative hypothermia in patients undergoing major abdominal surgery was 57.3%, while preoperative and intraoperative hypothermia occurred in 55.5% and 79.1%, respectively. An age over 60 years was the only variable associated with postoperative hypothermia after multivariable adjustment for sex, age, and time surgery (OR=18.4; 95% CI: 3.79-89.6;  $p<0.0001$ ).

**Conclusion:** Increasing age was the only variable associated with postoperative hypothermia in patients undergoing major abdominal surgery.

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**This is a preliminary edition, and the final version may undergo changes.**



## PUBLICACIÓN ADELANTADA

## Hipotermia posoperatoria en pacientes sometidos a cirugía abdominal mayor: un estudio de cohorte

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INFORMACIÓN ARTÍCULO	RESUMEN
<p><b>PALABRAS CLAVE</b>  <i>Cirugía General;</i>  <i>Factores de Riesgo;</i>  <i>Hipotermia</i></p> <p><b>Recibido:</b> abril 30 de 2024  <b>Aceptado:</b> agosto 28 de 2024</p> <p><b>Disponible en línea:</b> agosto 21 de 2025</p> <p><b>Correspondencia:</b> Ashuin Kammar-García; <a href="mailto:akammar@inger.gob.mx">akammar@inger.gob.mx</a></p>	<p><b>Introducción:</b> hasta el 90 % de los pacientes intervenidos quirúrgicamente presentan hipotermia en el perioperatorio. No se ha reportado la aparición de hipotermia postoperatoria y variables asociadas a su aparición únicamente en pacientes sometidos a cirugía abdominal mayor.</p> <p><b>Objetivo:</b> describir la proporción de pacientes sometidos a cirugía abdominal mayor que desarrollan hipotermia posoperatoria y las variables asociadas a su ocurrencia.</p>

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**Materiales y métodos:** estudio de cohorte prospectivo en un hospital de referencia de tercer nivel en la Ciudad de México. Las variables asociadas con hipotermia postoperatoria se evaluaron mediante regresión logística.

**Resultados:** se incluyeron un total de 110 pacientes. De ellos, 61 % ( $n = 67$ ) eran mujeres. La edad media fue de 56,7 años (DE: 16,3, rango: 75). La incidencia de hipotermia postoperatoria en pacientes sometidos a cirugía abdominal mayor fue del 57,3 %, mientras que la hipotermia preoperatoria e intraoperatoria se presentó en el 55,5 % y el 79,1 %, respectivamente. La edad mayor de 60 años fue la única variable asociada a hipotermia postoperatoria tras el ajuste multivariable por sexo, edad y tiempo de cirugía (OR=18,4; IC 95%:3,79-89,6;  $p<0,0001$ ).

**Conclusiones:** solo la edad se asoció a la hipotermia postoperatoria en pacientes sometidos a cirugía mayor abdominal.

## INTRODUCTION

Up to 90% of patients undergoing surgery will present hypothermia in the perioperative period (1). To improve the patient care, the Standards and Practice Parameters Committee of the American Society of Anesthesiologists (ASA) states: “Every patient receiving anesthesia shall have temperature monitored when clinically significant changes in body temperature are intended, anticipated, or suspected” (2). Postoperative hypothermia is defined as a decrease in body temperature below 35°C within the first 24 hours after surgery (3).

Anesthesia and the surgical procedure affect the thermoregulatory center, thereby contributing to adverse events during the perioperative period (4). The decrease in temperature affects processes going from drug metabolism to the healing process and immunoprotection during perioperative hypothermia, which increases morbidity and complications that may result in cardiovascular events, altered platelet activity, or postoperative infections (5).

As shown in Table 1, the occurrence of hypothermia can vary widely depending on the type of patients included in the study (5-12). Its occurrence has been associated with factors such as sex, type of surgery, duration, and age (13). Likewise, no study has reported the occurrence of postoperative hypothermia and variables associated with its occurrence only in patients undergoing major abdominal surgery, who may have different risk factors and frequency of occurrence of postoperative hypothermia than patients undergoing other types of surgery.

**Table 1. Representative studies conducted in the last 10 years that have reported the occurrence and/or risk factors associated with perioperative hypothermia**

Study	Type of surgery	Country	Hypothermia (%)	Identified Risk Factors
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Li, et al. (2021) <sup>6</sup>	all surgeries	China	6.32	ASA>II, general anesthesia (vs. regional anesthesia) and lower preoperative body temperature.
Karalapillai, et al. (2011) <sup>7</sup>	elective heart surgery	Australia and New Zealand	66	Not analyzed.
Karalapillai, et al. (2013) <sup>8</sup>	Non-cardiac elective surgery	Australia and New Zealand	46	Not analyzed.
Kleimeyer, et al. (2018) <sup>5</sup>	Orthopedic surgery	United States of America	72.5	Intraoperative hypothermia, lower preoperative body temperature, gender (female), lower body mass index, older age, reconstructive surgery, and hip or pelvic surgery.
Akers, et al. (2019) <sup>9</sup>	Abdominal and orthopedic surgery	United States of America	2.3	Older age and type of surgery (abdominal).
Motamed, et al. (2021) <sup>10</sup>	Oncological surgery (breast)	France	21	Not analyzed.
Tavares Mendonça, et al. (2019) <sup>11</sup>	all surgeries	Brazil	69.2	Older age, combined anesthesia, morphine, sufentanil, spinal anesthesia.
Assunção Peixoto, et al. (2021) <sup>12</sup>	non-cardiac surgery	Brazil	69.8	Older age.

Source: own creation

Considering the complications that can derive from hypothermia, determining the factors that can contribute to its development may lead to prevention strategies that ultimately increase patient safety. Therefore, the aim of this study was to describe the proportion of patients undergoing major abdominal surgery who develop postoperative hypothermia, as well as the variables associated with its occurrence in a tertiary care hospital.

## METHODS

## **Study design**

A prospective cohort study was conducted in patients undergoing major abdominal surgery between November 2021 and March 2022 in a tertiary care referral center in Mexico City. The inclusion criteria were patients with an age over 18 years who underwent scheduled or emergency major abdominal surgery lasting more than 2 hours. Patients with neuromuscular diseases, pregnant women, patients with prolonged advanced life support, as well as those who did not give their consent to participate in the study were not included. Patients who withdrew their consent at any time during the study were eliminated. The study was approved by the Ethics and Research Committee of “Centro Médico Nacional 20 de Noviembre ISSSTE” (approval number 459.2021) and all patients signed a written informed consent form to participate in the study.

## **Data Collection**

During the pre-anesthetic evaluation, patients who met the inclusion criteria were invited to participate in the study. After consenting to be enrolled, their baseline characteristics, surgical procedure data, and post-procedural data were collected. Clinical variables collected were sex, age, weight (in kilograms), body mass index (BMI), body temperature (°C), their physical status classification by the American Society of Anesthesiologists (ASA-PS, see below), and comorbidities (type-2 diabetes, hypertension, obesity, malnutrition, coronary artery disease, chronic kidney disease, peripheral venous disease, epilepsy, anxiety, illicit drug use, and current smoking). Data related to the surgical procedure were: type of surgery (urgent or elective), organ involved (kidney or urinary tract, liver and bile ducts or gallbladder, esophagus or stomach, small bowel, large bowel, exploratory laparotomy, or gynecological), duration of surgery (minutes from primary

incision to wound closure), anesthetic technique (balanced general or combined [balanced general + neuraxial]), duration of anesthesia (minutes from drug induction until the patient woke up), and room temperature during surgery.

Body temperature was measured using an electronic axillary skin thermometer and was reported in Celsius degrees ( $^{\circ}\text{C}$ ) during the pre-anesthetic evaluation (preoperative), during surgery (intraoperative), and after surgery (postoperative). Patients were classified as hypothermic when they presented a body temperature lower than or equal to  $35^{\circ}\text{C}$  (14). Postoperative pain and postoperative hypoxemia were also recorded. Hypoxemia was classified according to room-air peripheral arterial oxygen saturation ( $\text{SpO}_2$ ) as mild ( $\text{SpO}_2 = 86\%-90\%$ ), moderate ( $\text{SpO}_2 = 81\%-85\%$ ), severe ( $\text{SpO}_2 = 76\%-80\%$ ), or extreme ( $\text{SpO}_2 < 70\%$ ) hypoxemia. The presence of pain was determined with the visual analog pain scale. Patients were classified in stages 1 to 5 according to the 2020 ASA-PS classification (15) during the pre-anesthetic evaluation, considering ASA-PS 1 as normal healthy patient; ASA-PS 2, mild systemic disease; ASA-PS 3, severe systemic disease that is not life-threatening; ASA-PS 4, severe systemic disease that is a constant threat to life; and ASA-PS 5, moribund patient who is not expected to survive without the surgery.

The clinical evaluation of the patients was based on the diagnosis of malnutrition, detection of postoperative hypoxemia and pain during the stay in the post-anesthesia care unit (PACU). Patients with a BMI less than 18.5 were classified as having severe malnutrition according to the GLIM criteria for the diagnosis of malnutrition (10).

## **Outcome**

The main outcome was the presence of postoperative hypothermia, defined as a body temperature below  $35^{\circ}\text{C}$  during PACU stay after surgery (14).



### Sample size

Considering that the presence of variables under study could double the risk of hypothermia, the calculation was done considering a 0.5 probability of the presence of each variable in the study sample, with statistical power of 80% ( $1-\beta = 0.80$ ) and a type 1 error probability of 5% ( $\alpha=0.05$ ). The sample size obtained was 136 subjects. The following formula for estimating an odds ratio was applied:

*Patients per group*

$$= \frac{[Z\alpha\sqrt{2 * P * (1 - P)}] + Z\beta\sqrt{P1 * (1 - P1) + P2 * (1 - P2)}}{(P1 - P2)^2}$$

Where  $Z\alpha=1.96$ ,  $Z\beta=1.28$ ,  $P1=0.5$  (proportion of patients with the risk factor),  $P$ : weighted mean of  $P1$  and  $P2$ .  $P2$  was calculated according to the following formula:

$$P2 = \frac{(P1 * OR)}{[1 + P1 * (OR - 1)]}$$

Considering  $P1=0.5$  and  $OR=2.0$  (expected odds ratio due to any study factor).

### Statistical analysis

Descriptive data are presented as mean with standard deviation for quantitative variables, and as frequency and percentage for qualitative variables. Comparisons between patients who presented hypothermia and normal temperature during PACU stay were made using the Student's t-test for quantitative data and the Chi-square test or Fisher's exact test for qualitative data.

A repeated measures ANOVA (RM-ANOVA) model was performed to compare preoperative, intraoperative, and postoperative temperatures. The model is summarized in

a scatter plot showing the mean and 95% confidence intervals (95% CI). Once the assumptions of sphericity were verified by the Greenhouse-Geisser test and the assumption of dependence of observations, the p value of the model was obtained. When a significant value was found, the Bonferroni post-hoc test was performed to identify whether there was a difference between the intraoperative and postoperative moments compared to the preoperative moment.

The evaluation of potential variables associated with hypothermia was carried out by means of logistic regression analysis to determine the effect of each variable on the development of postoperative hypothermia. The variables were included in each univariate model by the Enter method. Variables associated with postoperative hypothermia were included in a multivariable model adjusted by sex, age, and duration of surgery. The results are summarized by means of the regression coefficient, Odds Ratio (OR) and 95% CI.

The quantitative variables (weight, age, preoperative temperature, intraoperative temperature, room temperature, surgery time, and anesthetic time) were included in linear regression models to determine the decrease or increase for every °C for every increase of one unit in the independent variable. The results of the models are summarized in regression coefficients, standard error, and 95% CI.

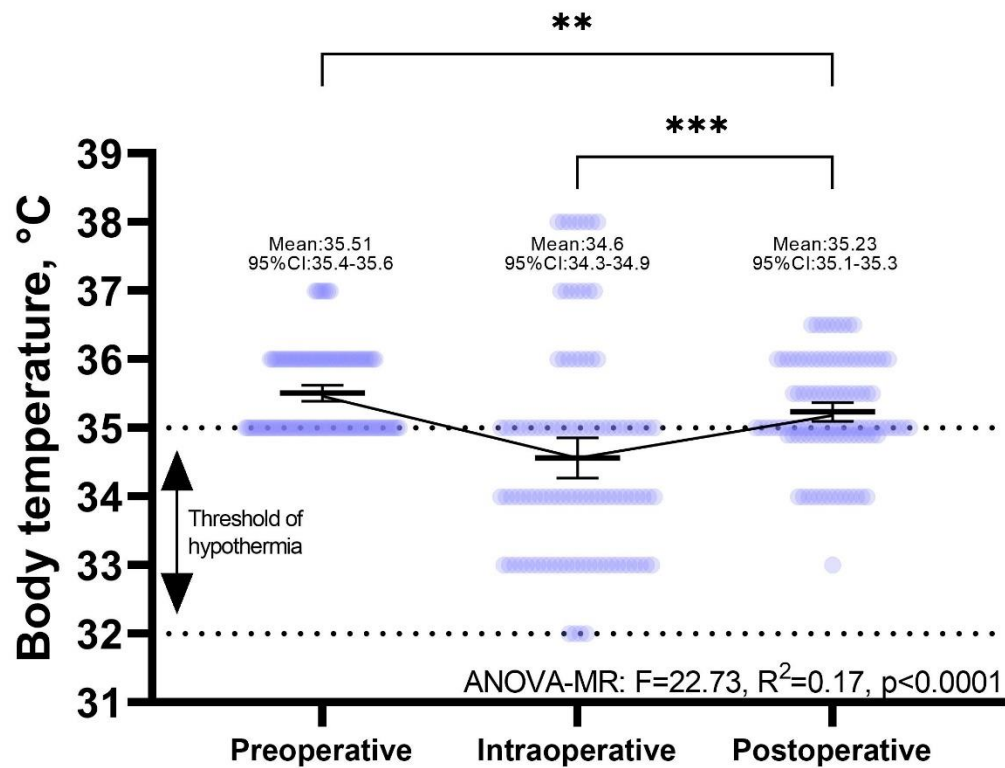
The assumptions of each statistical model were verified by residual analysis. A value of  $p < 0.05$  was considered as statistically significant. All analyses were performed using SPSS v.21 Software. The RM-ANOVA graph was built with GraphPad Prism v. 9.0.3.

## **RESULTS**

A total of 110 patients were included in the analysis. Of them, 61% (n=67) were women. The mean age was 56.7 years (SD: 16.3, range: 75), with the most frequent age range being

adults over 60 years (43.6%). The most frequent comorbidities were smoking (59.1%), arterial hypertension (40.0%), and type-2 diabetes (24.5%). The most frequently involved organ on which surgery was performed was kidney or urinary tract (21.8%), followed by large bowel (14.5%) and exploratory laparotomy (14.5%). The average duration of the surgeries was longer than 4 hours (mean: 298 minutes, SD: 166.5, range: 480). Most surgeries were elective (92.75%), with general balanced anesthetic techniques (95.5%), and most patients were in the ASA-PS III category (94.5%). Of the total number of patients in this category (n=104), 58.2% were women and 36.4% men. During recovery in the PACU, all patients presented some degree of hypoxemia, the majority (91.8%) being mild cases.

Hypothermia occurred in 61 patients (55.5%) prior to surgery (preoperative), while 87 (79.1%) presented intraoperative hypothermia, and 63 (57.3%) had postoperative hypothermia during PACU stay. Figure 1 shows the distribution of body temperature before, during and after surgery. Body temperature after surgery was lower than the temperature before surgery ( $p=0.009$ ), but the temperature during surgery was lower than that observed after surgery ( $p=0.0002$ ).



**Figure 1. Comparison of body temperature before, during and after surgery**

Data are presented as mean and 95% CI. Data compared by means of a repeated measures ANOVA (ANOVA-MR) model. \*\*:  $p<0.01$ , \*\*\*:  $p<0.001$

Source: own creation

Table 2 shows the comparisons of the main clinical and surgical characteristics and comorbidities, according to the occurrence of postoperative hypothermia or not during PACU stay. No significant differences were observed between the various characteristics, except for age categories where there was a higher frequency of subjects older than 60 years.

Table 3 shows the results of the univariate logistic regression analyses to identify the factors associated with postoperative hypothermia. Only advanced age (age over 60 years) was associated with a higher risk of postoperative hypothermia (OR=4.20, 95%CI: 1.45-12.18,  $p=0.01$ ). After multivariable adjustment for sex, age, and time surgery,

advanced age remained as a risk factor for postoperative hypothermia (OR=18.4; 95% CI: 3.79-89.6;  $p<0.0001$ ).

**Table 2. Comparisons of characteristics of patients who presented postoperative hypothermia against patients not experiencing the outcome**

	Total sample n=110	Normal temperature n=47	Hypothermia n=63	p value
<b>Sex, n (%)</b>				
Women	67 (60.9)	29 (61.7)	38 (60.3)	0.3
Men	43 (39.1)	18 (38.3)	25 (39.7)	
<b>Age, years</b>	56.7 (16.3)	54.8 (1.9)	58.1 (2.31)	0.3
<b>Age categories, n (%)</b>				
≤30 years	4 (3.6)	0 (0.0)	4 (6.3)	0.4
31-40 years	18 (16.4)	7 (14.9)	11 (17.5)	
41-50 years	18 (16.4)	12 (25.5)	6 (9.5)	
51-60 years	22 (20.0)	15 (31.9)	7 (11.1)	
>60 years	48 (43.6)	13 (27.7)	35 (55.6)	
<b>Weight, Kg</b>	73.3 (16.4)	73.5 (2.3)	73.1 (2.12)	0.9
<b>BMI classification, n (%)</b>				
<25	47 (42.7)	20 (42.6)	27 (42.9)	0.8
25-29.9	39 (35.5)	16 (34.0)	23 (36.5)	
31-34.9	15 (13.6)	7 (14.9)	8 (12.7)	
≥35	9 (8.2)	4 (8.5)	5 (7.9)	
<b>Comorbidities n (%)</b>				
Type 2 Diabetes	27 (24.5)	10 (21.3)	17 (27.0)	0.5
Systemic arterial hypertension	44 (40.0)	21 (44.7)	23 (36.5)	0.4
Coronary artery disease	18 (16.4)	8 (17.0)	10 (15.9)	0.8
Obesity	24 (21.8)	11 (23.4)	13 (20.6)	0.7
Malnutrition	8 (7.3)	2 (4.3)	6 (9.5)	0.3
Chronic kidney disease	9 (8.2)	5 (10.6)	4 (6.3)	0.4
Peripheral venous disease	12 (10.9)	5 (10.6)	7 (11.1)	0.9
Epilepsy	2 (1.8)	1 (2.1)	1 (1.6)	0.8
Anxiety	2 (1.8)	1 (2.1)	1 (1.6)	0.8
Illicit drug use	32 (29.1)	17 (36.2)	15 (23.8)	0.2
Smoker	65 (59.1)	32 (68.1)	33 (52.4)	0.09
<b>ASA-PS, n (%)</b>				
ASA-PS II	5 (4.5)	1 (2.1)	0 (0.0)	0.2
ASA-PS III	104 (94.5)	45 (95.7)	4 (6.3)	
ASA-PS IV	1 (0.9)	1 (2.1)	59 (93.7)	
<b>Urgent surgery, n (%)</b>	8 (7.3)	2 (4.3)	6 (9.5)	0.3
<b>Organ involved, n (%)</b>				
Kidney / urinary tract	24 (21.8)	10 (21.3)	14 (22.2)	0.4

Liver and bile ducts / gallbladder	15 (13.6)	9 (19.1)	6 (9.5)	
Esophagus / stomach	13 (11.8)	6 (12.8)	7 (11.1)	
Small bowel	5 (4.5)	3 (6.4)	2 (3.2)	
Large bowel	16 (14.5)	6 (12.8)	10 (15.9)	
Exploratory laparotomy	16 (14.5)	4 (8.5)	12 (19.0)	
Gynecological	9 (8.2)	4 (8.5)	5 (7.9)	
Other classification	12 (10.9)	5 (10.6)	7 (11.1)	
<b>Time surgery, minutes</b>	298.3 (166.5)	333.8 (26.0)	271.9 (19.31)	0.05
<b>Time anesthesia, minutes</b>	358.3 (166.5)	393.8 (26.0)	331.9 (19.31)	0.05
<b>Combined anesthetic technique, n (%)</b>	5 (4.5)	2 (4.3)	3 (4.8)	0.9
<b>Ambient temperature, °C</b>	24.2 (0.6)	24.2 (0.1)	24.2 (0.07)	0.8
<b>Forced air warming, n (%)</b>	38 (34.5)	18 (38.3)	20 (31.7)	0.5
<b>Body temperature preoperative, °C</b>	35.5 (0.6)	35.4 (0.1)	35.6 (0.08)	0.1
<b>Body temperature intraoperative, °C</b>	34.6 (1.5)	34.4 (0.2)	34.7 (0.21)	0.2
<b>Preoperative hypothermia</b>	61 (55.5)	29 (61.7)	32 (50.8)	0.3
<b>Intraoperative hypothermia</b>	87 (79.09)	39 (83.0)	48 (76.2)	0.4
<b>Postoperative pain, n (%)</b>	17 (15.5)	9 (19.1)	8 (12.7)	0.4
<b>Postoperative hypoxemia, n (%)</b>				
Mild	101 (91.8)	41 (87.2)	60 (95.2)	0.09
Moderate	8 (7.3)	5 (10.6)	3 (4.8)	
Severe	1 (0.9)	1 (2.1)	0 (0.0)	

Data presented as media (standard error) or frequency (%)

Comparison between groups were made by Student t-test, Chi-square or Fisher's exact test

BMI: Body mass index, ASA-PS: American Society of Anesthesiologists physical status classification system

Source: own creation

**Table 3. Results of the logistic regression analyzes for the identification of factors associated with the occurrence of postoperative hypothermia**

	$\beta$	OR	95%CI	p value
Sex, Man	0.06	1.06	(0.49-2.30)	0.88
Age, years	0.01	1.01	(0.99-1.04)	0.29
Advanced age	1.44	4.20	(1.45-12.18)	0.01
Weight, Kg	0.00	1.00	(0.98-1.02)	0.90
BMI classification				
<25		Reference		
25-29.9	0.06	1.06	(0.45-2.52)	0.89
31-34.9	-0.17	0.85	(0.26-2.72)	0.78

≥35	-0.08	0.93	(0.22-3.89)	0.92
Comorbidities				
Type 2 Diabetes	0.31	1.37	(0.56-3.34)	0.49
Systemic arterial hypertension	-0.34	0.71	(0.33-1.54)	0.39
Coronary artery disease	-0.08	0.92	(0.33-2.54)	0.87
Obesity	-0.16	0.85	(0.34-2.11)	0.73
Malnutrition	0.86	2.37	(0.46-12.30)	0.30
Chronic kidney disease	-0.56	0.57	(0.14-2.25)	0.42
Peripheral venous disease	0.05	1.05	(0.31-3.54)	0.94
Epilepsy	-0.30	0.74	(0.05-12.18)	0.83
Anxiety	-0.30	0.74	(0.05-12.18)	0.83
Illicit drug use	-0.60	0.55	(0.24-1.27)	0.16
Smoker	-0.66	0.52	(0.23-1.13)	0.10
Urgent surgery	0.86	2.37	(0.46-12.30)	0.30
Organ involved				
Kidney / Urinary tract	0.06	1.06	(0.42-2.65)	0.91
Liver and Bile ducts / gallbladder	-0.81	0.44	(0.15-1.35)	0.15
Esophagus / stomach	-0.16	0.85	(0.27-2.73)	0.79
Small bowel	-0.73	0.48	(0.08-3.00)	0.43
Large bowel	0.25	1.29	(0.43-3.84)	0.65
Exploratory laparotomy	0.93	2.53	(0.76-8.42)	0.13
Gynecological	-0.08	0.93	(0.24-3.66)	0.91
Other classification	0.05	1.05	(0.31-3.54)	0.94
Time surgery, minutes	-0.14	0.87	(0.76-1.00)	0.06
Time anesthesia, minutes	-0.14	0.87	(0.76-1.00)	0.06
Combined anesthetic technique	0.12	1.12	(0.18-7.02)	0.90
Ambient temperature, °C	-0.06	0.94	(0.50-1.76)	0.85

Forced air warming

Body temperature preoperative, °C	0.50	1.65	(0.87-3.15)	0.13
Body temperature intraoperative, °C	0.15	1.17	(0.90-1.50)	0.24
Preoperative hypothermia	-0.45	0.64	(0.30-1.38)	0.26
Postoperative hypothermia	-0.42	0.66	(0.25-1.71)	0.39
Moderate or severe hypoxemia	-1.07	0.34	(0.08-1.44)	0.14

β: Regression coefficient, OR: Odds Ratio, 95%CI: 95% confidence interval

Source: own creation

Table 4 shows the results of the linear regression analyses to determine the linear relationship of each of the quantitative variables with the change in body temperature after surgery. Only age was related to a decrease in temperature, considering that every one-year increase over 35.8 years lead to a decrease of 0.01 °C in the postoperative body temperature.

**Table 4. Linear regression analysis to identify the relationship of the various risk factors with the decrease in post-surgical body temperature**

	β0	SE of β0	β1	SE of β1	95%CI	p value
Age, years	35.823	0.248	-0.010	0.004	(-0.019 a -0.002)	0.01
Weight, Kg	34.974	0.321	0.004	0.004	(-0.005 a 0.012)	0.4
Ambient temperature, °C	34.219	2.828	0.042	0.117	(-0.190 a 0.273)	0.7
Body temperature preoperative, °C	40.098	4.028	-0.137	0.113	(-0.362 a 0.088)	0.2
Body temperature intraoperative, °C	35.765	1.580	-0.015	0.046	(-0.106 a 0.075)	0.7
Time surgery, minutes	35.098	0.144	0.027	0.025	(-0.023 a 0.077)	0.3
Time anesthesia, minutes	35.070	0.166	0.027	0.025	(-0.023 a 0.077)	0.3

β0: Regression constant, β1: Regression coefficient, SE: standard error, 95% CI: 95% confidence interval



## **DISCUSSION**

In this study, we sought to describe the proportion of patients subjected to major abdominal surgery who experience postoperative hypothermia, and to study potential variables associated to the occurrence of postoperative hypothermia. We found that the incidence of postoperative hypothermia in patients undergoing major abdominal surgery was 57.3%, while preoperative and intraoperative hypothermia occurred in 55.5% and 79.1%, respectively.

Although perioperative hypothermia occurs in up to 90% of patients (1), we found that preoperative hypothermia occurred in 1 out of 2 patients in our study. The causes of this can be very diverse, ranging from environmental conditions, room temperature, measurement methods, intravenous solutions, to patient-specific diseases, etc. (16,17). In the case of emergency surgeries, it is reported that two-thirds of patients present preoperative hypothermia (18) due to the severity of injury, wet clothing, low transport unit temperature, use of anesthesia, and prolonged surgery. Preoperative hypothermia should be monitored every 15 minutes, and measures should be taken to normalize body temperature, as this condition is associated with more perioperative complications (19). We found that the occurrence of hypothermia was higher in the intraoperative period, which could be attributable to situations happening during surgery, such as the induction of anesthesia or blood loss.

The incidence of postoperative hypothermia varies among studies. With 116 patients, a cross-sectional study performed in Mexico reported a similar proportion to ours

(55%) (1). Likewise, Zhang et al. reported an incidence of 21.3% in a retrospective cohort study with a larger study population (20). Regarding advanced age as a risk factor, it was hypothesized that modifiable and non-modifiable risk factors are associated with the presentation of hypothermia in the immediate postoperative period in patients undergoing major surgery. However, only age older than 60 years was found to be associated with hypothermia. This coincides with the literature where it has been reported as a risk factor in studies of patients undergoing orthopedic surgery (5,9), abdominal surgery (9), and surgeries in general without distinguishing the anatomical site (6,11,12).

Differences in thermoregulatory mechanisms between younger and older adults have been documented (21). Underlying mechanisms include alteration of three of the major protective mechanisms against hypothermia: 1) decreased sympathetic and vasomotor responses that attenuate cutaneous vasoconstriction, 2) decreased heat generation by metabolic activity, and 3) decreased cold perception (21).

Other studies have found that the anatomical site is associated with the presence of perioperative hypothermia, especially abdominal procedures when compared to surgeries of other types (9). Therefore, there was special interest in studying whether there was any association between the occurrence of postoperative hypothermia and the specific abdominal site of surgery. However, none of the specific surgical sites or organs were found to be associated with postoperative hypothermia. Therefore, there could be a common pathophysiological trigger for all abdominal surgeries that is not organ specific. In a study that compared the occurrence of perioperative hypothermia in patients undergoing colorectal surgery by open versus laparoscopic surgery, the occurrence of hypothermia was comparable to the rate reported in our study (67%) and while it was more frequent in the open surgical approach than in the laparoscopic approach (71.23% vs. 63.16%,  $p < 0.001$ ),

the type of surgical approach did not behave as a risk factor after adjusting for confounding variables (22).

Other variables such as comorbidities, body mass index, ASA-PS and sex were not associated with postoperative hypothermia in this study despite the fact that in other studies there has been an association (5,6). Notably, most patients in our study were ASA-PS III (94.5%), which limited our capacity to capture a broader perspective of what could be expected in patients under different ASA-PS categories. Although there is a possibility that in reality, these are not factors associated with postoperative hypothermia in patients undergoing major abdominal surgery exclusively, it is important to take into account that the sample size calculation for this study was made to detect variables that increased the risk of hypothermia by at least twice, so it is likely that larger sample sizes are required to detect smaller differences. Furthermore, we were unable to reach the final sample size calculated for this study due to administrative constraints, which may have resulted in our study being underpowered to detect those differences.

Our results of the incidence of hypothermia and age as a significant risk factor contribute to the existing literature by providing insights into a specific population of patients who underwent abdominal surgery. Our findings suggest that age is a crucial factor in assessing the risk of perioperative hypothermia, emphasizing the need for temperature monitoring in older adults. Current research identifies several risk factors for perioperative hypothermia, including operating room temperature, shock, type of surgery, and extremes of age (23). This underscores the importance of identifying potential predictors to mitigate the risk of adverse outcomes. Our research aligns with multiple studies that highlight the importance of temperature regulation to prevent complications like wound infections, coagulopathies, and myocardial injury, which predominantly affect the elderly and high-

risk patients (24,25). For instance, it is demonstrated that hypothermia impairs platelet function, which increases blood loss by about 20%, thereby raising the need for transfusions (26).

Nevertheless, it should be considered that our findings are from a sample of 110 patients undergoing abdominal surgery lasting longer than 2 hours from a single tertiary care referral hospital, which may not be generalizable to populations undergoing surgery at different kind of hospitals. Although our results are consistent with other studies, a further limitation to generalizability of our study is that we did not include pregnant women, patients under 18 years of age, or with neuromuscular problems. Future research could include these and other populations for a comprehensive understanding of the risk factors and mechanisms that lead to hypothermia during surgery.

Furthermore, we only assessed forced air maneuvers as a potential intervention done to manage perioperative hypothermia. Other warming devices (23) were not assessed due to their empirical low use in this center, but could have an important role in prevention and management of perioperative hypothermia. Likewise, variables such as drugs administered in the perioperative period (which could have a pathophysiological role in the triggering of hypothermia) were not collected (27).

It is important to acknowledge that in our study the temperature was measured with an axillar thermometer. While axillary temperature measurements are usually close to core temperature, they can deviate due to external factors and patient positioning (25). The most reliable monitoring sites are typically the esophagus, nasopharynx and the tympanic membrane (28,29). The tissue temperature varies considerably from region to region; thus, the selection of the measurement site can significantly influence the detection of hypothermia, potentially leading to an underestimation of its prevalence. This highlights

the need for careful consideration in the selection of temperature measurement in clinical settings. Extensive research shows that the esophagus and nasopharynx are the best practical sites for temperature monitoring during general anesthesia, while oral and axillary temperature can be suitable alternatives for neuraxial anesthesia and postoperative care (25). For future studies, employing other temperature monitoring sites could enhance the accuracy of detection of hypothermia and associated variables.

## **CONCLUSIONS**

The incidence of postoperative hypothermia in patients undergoing major abdominal surgery was 57.3%, while preoperative and intraoperative hypothermia occurred in 55.5% and 79.1%, respectively. An age over 60 years was associated with postoperative hypothermia. Prospective studies with a larger number of patients that include other types of surgery at different anatomical sites are required to continue characterizing the potential role of the anatomical site of surgery as a determinant of perioperative hypothermia.

## **CONFLICT OF INTEREST**

The authors declare that they have no conflict of interest.

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