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Original Article

# Newborns are Prone to More Hypothermia in the Low Temperature of Operating Rooms

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**ABSTRACT**

**Aim:** Hypothermia (HT) is a common and serious problem during anesthesia. As the ratio of skin surface area to body volume is higher in neonates than in adults, heat loss and ultimately HT are more common in the intraoperative period. This study aimed to determine the incidence and independent risk factors of HT in the neonatal period.

**Materials and Methods:** This retrospective observational cohort study included 63 patients who underwent neonatal surgery within a one-year period. HT was defined as body temperature <36 °C and the patients were divided into two groups: Group I (body temperature <36 °C) and Group II (≥36 °C). Demographic data, ASA score, operative diagnosis, duration of surgery and anesthesia, amount of fluid, inotrope and vasopressor therapy, amount of bleeding, amount of blood transfusion, preoperative and postoperative temperatures, and the heating methods of the patients were recorded.

**Results:** The median age of the patients was 5 days (0-28 days) and their mean weight was 2,792±782 grams. The esophageal method was used for temperature monitoring in 88.9% (56 patients) and the rectal method in 10.1% (7 patients). HT developed in 54% of the patients. Caps and socks were used to prevent HT in 96.8% of the patients, forced-air warming blankets in 95.2%, warming gel mattresses in 27%, and fluid and blood warming devices in 17.5%. In the logistic regression model, the operating room temperature was identified as the only independent risk factor associated with neonatal HT.

**Conclusion:** Despite the use of active and passive warming methods, the incidence of HT in the neonatal period was found to be high. Cold operating rooms were found to be the only independent factor associated with neonatal HT.

**Keywords:** Neonate, hypothermia, pediatric anesthesia, body temperature, rewarmings

## Introduction

The neonatal (newborn) period refers to the first 28 days after the birth of a child. Neonates may undergo surgical procedures for a variety of reasons, many of which are emergency procedures. Maintaining a stable body temperature for patients in this age group during the perioperative period requires careful management of the balance between heat production and heat loss (1).

Hypothermia (HT) occurs in 70% of neonates during the intraoperative period, with several factors influencing body temperature, including vasodilating anesthetics, room temperature, systemic diseases, and/or intravenous cold fluids. Heat loss in neonates occurs by radiation, conduction, convection, evaporation, and respiration. Unlike adults, who can generate heat by shivering, neonates generate metabolic heat, relying primarily on brown adipose tissue. Premature infants have minimal brown fat, which affects

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their heat production. In response to cold stress, newborns release norepinephrine from nerves in their brown adipose tissues in their back, neck, kidneys, and adrenal glands. This triggers the oxidation of fatty acids, which initiates lipolysis. Consequently, chemical thermogenesis occurs in the form of fat catabolism, as opposed to thermogenesis induced by shivering (1,2).

If no measures are taken to prevent heat loss, a drop in body temperature is inevitable in newborns. Basal metabolic rate and oxygen consumption are increased in order to maintain temperature and increase heat production. This can lead to hypoxia in patients or hypoglycemia as a result of the depletion of glycogen stores. Metabolic acidosis, pulmonary hypertension, and/or apnea may develop as a result of hypoxia and peripheral vasoconstriction (3,4). Complications such as disseminated intravascular coagulation, intraventricular hemorrhage, hypotension, severe sinus bradycardia, and/or increased mortality may occur in hypothermic infants. Despite the implementation of various precautions, HT may still occur in neonates due to a variety of factors (4,5).

The aim of this study was to investigate the incidence of HT in neonates and to identify any independent risk factors associated with its development.

## Materials and Methods

From November, 2019 to November, 2020, a total of 82 procedures were performed on 52 neonatal patients in the pediatric surgery operating room. This retrospective cohort study received approval from the Ege University Clinical Research Ethics Committee (approval no.: 20-12.1T/28, date: 17/12/2020), and informed consent was obtained from the parents of the patients. All the procedures were conducted in accordance with the Helsinki Declaration-2013. Of these, 63 procedures met the criteria for inclusion in this retrospective cohort study. Some patients underwent a single surgery, while others underwent multiple surgeries. Patients who underwent temperature monitoring by methods other than esophageal and rectal measurements were excluded from this study.

HT was defined as a decrease in body temperature below 36 °C (5,6). The patients were divided into two groups: Group I (patients with a core body temperature <36 °C, hypothermia group) and Group II (≥36 °C, normothermia group). Demographic data (age, weight, height, body surface area), American Society of Anesthesiologists Physical Status (ASA score), diagnosis, type of anesthesia, duration of anesthesia and operation, amount of fluid administered, inotrope and vasopressor treatment, amount of bleeding, amount of blood transfused, and the preoperative and postoperative temperatures of the patients were documented on the case report forms of the patients. This study's hypothesis was formulated as "Hypothermia is still prevalent at high rates in neonates". The primary objective of this study was to determine the incidence of HT, while its secondary objective was to identify any independent risk factors associated with neonatal HT.

### Statistical Analysis

This research utilized SPSS 21 (Statistical Package for the Social Sciences, IBM®) for statistical analysis. The Kolmogorov-Smirnov test was used to assess the normal distribution of the data. Descriptive statistics are presented as numbers (n) and percentages (%) for categorical variables, while mean and standard deviation are described by numerical variables.

Pairwise and multiple comparisons for categorical variables employed the chi-squared test and the Fisher's exact test. Quantitative variables underwent analysis through the independent t-test, one-way ANOVA test, and the Mann-Whitney U test. Binary logistic regression analysis was conducted in order to identify independent risk factors, ensuring the exclusion of multicollinearity. Statistical significance was set at $p<0.05$, with significance determined at the 95% confidence interval.

## Results

This study included 82 procedures performed on 52 neonates in the pediatric surgery operating room over a one-year period. Nineteen patients were excluded from this study due to axillary or tympanic temperature monitoring, leaving 63 procedures which met the criteria (patients monitored by rectal or esophageal methods) for inclusion in this study (Figure 1).

Of the patients included, 57.1% (36 patients) were male and 42.9% (27 patients) were female ($p=0.344$). The average age, weight, height, and body surface area (BSA) of all of the patients were 8.75±8.9 days (median: 5 days, range: 0-28 days), 2.79±0.78 kg (median: 2.8 kg, range: 0.88-4.5 kg), 49±3.5 cm (median: 50 cm, range: 40-60 cm), and 0.19±0.03 $m^2$ (median: 0.2 $m^2$, range: 0.1-0.27 $m^2$), respectively. Age, weight, height, BSA, and ASA were comparable between the two groups (Table I).

HT occurred in 54% of the patients (34 patients). While the preoperative body temperature was 35.95±0.78 °C in all patients, the postoperative temperature was 35.2±1.12 °C ($p<0.001$). The number of patients with a postoperative body temperature below 35 °C (32.3-35 °C) was 33.3%

**Table I.** Demographic and preoperative data of the patients

| | All patients (n=63) | Hypothermia (n=34) | Normothermia (n=29) | p value |
|---|---|---|---|---|
| Age (day) | 5 (0-28) | 3 (0-26) | 6 (0-28) | 0.147 |
| Gender (male, %) | 36 (57.1) | 20 (58.8) | 16 (55.2) | 0.770 |
| BSA (m$^2$) | 0.2 (0.1-0.27) | 0.2 (0.14-0.26) | 0.2 (0.1-0.27) | 0.464 |
| ASA I/II/III | 19/20/24 | 10/19/5 | 9/11/9 | 0.532 |
| Preoperative temperature (°C) | 35.95±0.78 | 35.8±0.92 | 36.1±0.52 | 0.053 |
| Postoperative temperature (°C) | 35.2±1.12 | 34.42±0.88 | 36.1±0.52 | **<0.001** |
| Operating room temperature (°C) | 22.4±1.25 | 22.1±1.27 | 22.7±1.17 | 0.079 |
| Duration of operation (min) | 149±84 | 139±76 | 160±92 | 0.314 |
| Duration of anesthesia (min) | 169±85 | 156±70 | 183±99 | 0.212 |
| Amount of fluid (mL/kg/hr) | 15.5±7.2 | 16.9±6.4 | 13.9±7.7 | 0.108 |
| Urine output (mL/kg/hr) | 2.1±2.7 | 1.7±1.7 | 2.7±3.5 | 0.243 |
| Preoperative hematocrit (%) | 40.6±9 | 39.5±7.3 | 42.2±11.5 | 0.475 |
| Blood sugar level (mg/dL) | 79±44 | 75±42 | 85±46 | 0.500 |

Continuous data are given as mean ± standard deviation, median (minimum-maximum). Dichotomous data are given as numbers (n) and percentages (%)
m$^2$: Square meter, ASA: The American Society of Anesthesiologists physical status classification system, °C: Degree celsius, min: Minute, mL: Milliliter, kg: Kilogram, hr: Hour, dL: Deciliter

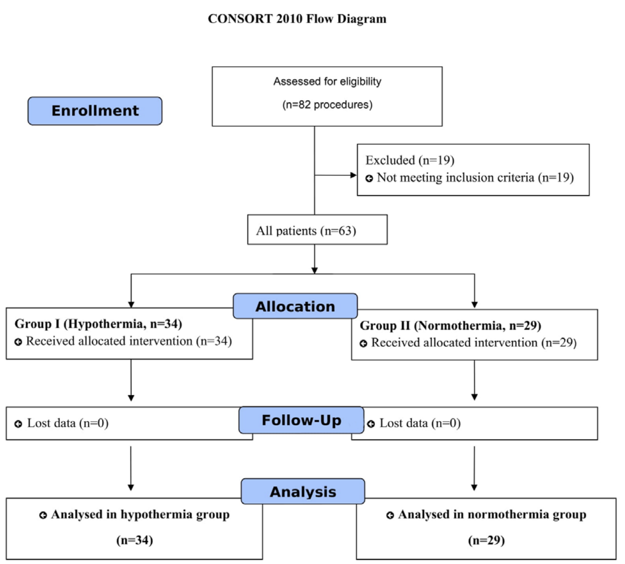


**Figure 1.** CONSORT flow chart of the data collection process

(21 patients), and there were no cases of hyperthermia (37.5 °C). Although basal (preoperative) body temperature was slightly lower in the HT group (35.8±0.92 °C vs. 36.1±0.52 °C), no statistical significance was observed (p=0.053). Temperature decreased in 68.3% of the patients, increased in 25.4%, and remained unchanged in 6.3%. Anesthesia and operating times were longer in the normothermic group, but these differences were not statistically significant (p>0.05). Although not statistically significant, the HT group showed a higher amount of fluid used (p=0.108). The perioperative characteristics of the patients are detailed in Table I.

**Table II.** Preoperative diagnoses and percentage rates of the patients

| | n | % |
|---|---|---|
| Tracheoesophageal fistula | 15 | 23.8 |
| Intestinal atresia | 10 | 15.9 |
| Omphalocele | 6 | 9.5 |
| Diaphragmatic hernia | 4 | 6.3 |
| Sacrococcygeal teratoma | 4 | 6.3 |
| Hirschsprung's disease | 3 | 4.8 |
| Necrotizing enterocolitis | 3 | 4.8 |
| Anorectal malformation | 2 | 3.2 |
| Exotropia vesica | 2 | 3.2 |
| Congenital lung malformation | 2 | 3.2 |
| Posterior ureteral valve | 2 | 3.2 |
| Others | 10 | 15.9 |
| Total | 63 | 100 |

Others: Ambiguous genitalia, biliary atresia, inguinal hernia + undescended testicle, June syndrome, colon perforation, meconium ileus, gastric malrotation, midgut volvulus, ovarian torsion and umbilical hernia.
Data are given as numbers (n) and percentages (%)

Some patients underwent intratracheal general anesthesia, most commonly for tracheoesophageal fistula (23.8%, 15 patients) and intestinal atresia (15.9%, 10 patients) (Table II). While open surgery was performed on 65.1% (41 patients), laparoscopic or thoracoscopic methods were used in 34.9% (22 patients). The choice of surgical method, such as open surgery, did not contribute to HT (p=0.550). Temperature monitoring was performed using the esophageal method in 88.9% (56 patients) and the rectal method in 11.1% (7 patients). To prevent HT, cap and socks were used in 96.8% of the patients, forced air warming blankets in 95.2%, table-top warming gel mattresses in 27%, and fluid and blood warming devices in 17.5%. No significant relationship was observed between the heating methods and HT occurrence (p>0.05) (Table III).

Erythrocyte suspension (16.3±12 mL/kg) was administered to 7 patients (11.1%) because of intraoperative bleeding, with the amount of bleeding varying by 6.2±9 mL/kg (range: 5-120 mL). Twenty-seven patients (42.9%) were intubated and received mechanical ventilation support in the intensive care unit. Hypotension occurred in 22 patients (34.9%) during the intraoperative period, and vasoconstrictors were required in 17.5% of these cases due to a lack of response to fluid therapy. A significant association was found between HT and the development of complications (p=0.048) (Table IV).

To identify the risk factors associated with HT, a logistic regression model was constructed including age, sex, BSA, preoperative temperature, duration of anesthesia, active or passive warming method, open or laparoscopic surgery, operating room temperature, patient fluid administration rate (mL/kg/hour), bleeding volume, and preoperative hematocrit. Among these variables, only operating room

**Table III.** Heating methods used to protect patients from hypothermia

| Heating methods | All patients (n=63) | Hypothermia (n=34) | Normothermia (n=29) | p value |
|---|---|---|---|---|
| Cap | 61 (96.8) | 34 (100) | 27 (93.2) | 0.120 |
| Socks | 61 (96.8) | 34 (100) | 27 (93.1) | 0.120 |
| Forced air warming blanket | 60 (95.2) | 32 (94.1) | 28 (96.6) | 0.651 |
| Warming gel mattresses | 17 (27) | 8 (23.5) | 9 (31) | 0.504 |
| Fluid and blood warming device | 11 (17.5) | 6 (17.6) | 5 (17.2) | 0.966 |

Data are given as numbers (n) and percentages (%)

**Table IV.** Complications developing in the patients in the intraoperative and the postoperative periods

| Complications (yes) | All patients, n (%) | Hypothermia, n (%) | Normothermia, n (%) | p value |
|---|---|---|---|---|
| At least one complication | 28 (44.4) | 19 (55.9) | 9 (31) | 0.048 |
| Hypotension | 22 (34.9) | 14 (41.2) | 8 (27.6) | 0.259 |
| Use of vasoconstrictors | 11 (17.5) | 6 (17.6) | 5 (17.2) | 0.966 |
| Arrhythmia | 1 (1.6) | 0 (0) | 1 (3.4) | 0.460 |
| Hypercapnia | 6 (9.5) | 3 (8.8) | 3 (10.3) | 1.000 |
| Postoperative apnea | 6 (9.5) | 4 (11.8) | 2 (6.9) | 0.678 |
| Delayed recovery | 6 (9.5) | 5 (14.7) | 1 (3.4) | 0.205 |
| Hypoxia | 3 (4.8) | 2 (5.9) | 1 (3.4) | 0.651 |
| Hypoglycemia | 1 (1.6) | 1 (2.9) | 0 (0) | 1.000 |

Data are given as numbers (n) and percentages (%)

**Table V.** Analysis of independent risk factors associated with hypothermia by logistic regression model

| | B | p value | OR | 95% CI |
|---|---|---|---|---|
| Age (day) | -0.038 | 0.248 | 0.963 | 0.903-1.027 |
| Weight (kg) | -0.384 | 0.308 | 0.681 | 0.325-1.425 |
| Preoperative temperature (°C) | -0.590 | 0.130 | 0.554 | 0.258-1.191 |
| Duration of anesthesia (min) | -0.005 | 0.152 | 0.995 | 0.998-1.002 |
| Operating room temperature (°C) | -0.563 | 0.028 | 0.569 | 0.345-0.941 |
| Constant | 36.314 | 0.022 | - | - |

Hosmer-Lemeshow test model fit chi-square=4.748, p=0.784; omnibus test model effectiveness chi-square=11.316, p=0.045
°C: Degree celsius, min: Minute, kg: Kilogram, B: Regression coefficients, CI: Confidence intervals, OR: Odds ratio

temperature showed a significant association with HT ($p=0.028$; odds ratio: 0.681; 95% confidence interval: 0.345-0.941) (Table V).

## Discussion

Despite early efforts by pediatric anesthesiologists to monitor, identify, and implement effective interventions for perioperative HT, neonates and young children still frequently experience HT during surgery. Deviation from normothermia is strongly associated with numerous complications and adverse outcomes in neonates and young children, particularly those at highest risk. A comprehensive perioperative warming strategy is essential, including maintenance of normothermia during transport, active warming before the induction of anesthesia, during anesthesia and surgery, and accurate measurements of the core temperature (7).

The aim of this study was to investigate the occurrence of intraoperative HT and its associated risk factors in 63 neonates meeting specific criteria. The results showed that intraoperative HT developed in 54% (34 patients) of the study participants, and a significant correlation was found between the operating room temperature and the incidence of HT. Comparing our results with similar studies, Görges et al. (8) reported a HT rate of 45% in 6,737 children, while Pearce et al. (5) found an incidence of 52% in 717 children, with core body temperature measured in only 74% of cases and active warming applied in only 50%. Sim et al. (9) observed an 85% incidence of perioperative HT in premature infants undergoing laparotomy for necrotizing enterocolitis, and Cui et al. (10) reported an 82% incidence in a retrospective study of neonates. Ongun et al. (11) found an 83% rate of HT in infants undergoing craniosynostosis repair. In contrast, Thompson et al. (12) found severe intraoperative HT in 22% and 26% of infants undergoing open and endoscopic craniectomy for craniosynostosis repair, respectively.

Some studies suggest that the use of an appropriate protocol can reduce the incidence of HT to less than 10%, even in preterm infants (13-17). Consequently, the prevalence of perioperative HT seems to depend more on the effectiveness of warming strategies, regardless of the age of the patient or the type of surgical procedure.

Tander et al. (18) found that maintaining an operating room temperature above 23 °C was the most important factor in preventing perioperative HT in neonates undergoing major bowel surgery. Correspondingly, Morehouse et al. (19) observed a higher incidence of HT during surgery in the operating room compared to the intensive care unit. Certain studies have reported that risk factors for the development of HT include the type and duration of surgery (such as major orthopedic surgery), low initial core temperature, significant blood loss, and transfusion requirements (5,15,20). Additionally, Sun et al. (21) suggested that adequate warming, older age, and longer durations of anesthesia were protective factors against postoperative HT.

In our study, the room temperature experienced by patients in the hypothermic group during the perioperative period was lower than that of the normothermic group. Although this difference did not reach statistical significance in individual analysis, it emerged as the only independent factor in regression analysis. In addition, the lower baseline (preoperative) body temperature in the HT group did not show statistical significance. Temperature values showed an increase with prolonged anesthesia and surgery. Although not statistically significant, the HT group had a higher volume of fluid intake. In addition, the type of surgical method, such as open surgery, did not contribute to the occurrence of HT.

HT in pediatric patients can lead to a spectrum of adverse events ranging from thermal discomfort to increased morbidity and mortality. Particularly in neonates, cold stress can activate several physiological pathways, including a catecholaminergic response, vasoconstriction, increased metabolism, and decreased surfactant synthesis (15,22,23). As a result, these pathways may lead to pulmonary hypertension, arterial hypotension, hypoperfusion of the vital organs, and tissue hypoxia resulting in metabolic acidosis and hypoglycemia. Potential consequences include arrhythmias, an increased risk of infection, impaired neurological outcomes, apnea, the need for mechanical ventilation, prolonged hospital stays, and mortality (15,18,24).

Morehouse et al. (19) observed a significantly higher incidence of respiratory adverse events associated with perioperative HT. They reported that cardiac complications were five times more common and respiratory complications were three times more common in infants who developed HT compared with the normothermic group. Pearce et al. (5) identified a correlation between HT and elevated blood loss, leading to an increased demand for blood transfusion. In a separate investigation conducted by Görges et al. (25), the implementation of prewarming was linked to elevated core temperatures and reduced blood transfusion requirements in children undergoing spinal surgery.

In our study, we found a significant association between HT and the occurrence of at least one complication. Among those patients who experienced HT, 55.9% developed at least one complication, with cardiac and respiratory problems being the most common. However, in contrast to the existing literature, our study did not yield statistically significant results. In particular, there was no significant difference in bleeding volumes between the groups, which contradicts the established findings.

As body temperature is one of the vital signs, anesthesiologists have the primary responsibility for perioperative monitoring (26). Monitoring neonatal body temperature is critical not only to prevent HT, but also to identify iatrogenic, drug-induced, or emergent hyperthermic conditions. Therefore, the use of an accurate method of measurement is essential for accurate temperature management. Peripheral measurements can be inaccurate in the perioperative setting because the operating room is 2-5 °C colder than the standard environment, especially for neonates who do not have adequate heat retention on their skin surfaces prior to surgery. To overcome this, esophageal or rectal temperature measurements provide the most accurate results (27). In our study, the esophageal method was used in 88.9% (56 patients), while the rectal method was used in 11.1% (7 patients). Patients monitored by axillary or skin measurements were excluded from this study due to these methods inability to accurately reflect core temperature.

Implementing active warming therapies in pediatric patients before and during surgery, coupled with measures to maintain body temperature, can prove effective in preventing HT (28,29). Specifically, dressing newborns in berets and socks, employing active blown warm heating, applying gel heating from below, warming liquid and blood products, and maintaining operating rooms at elevated temperatures are successful strategies in averting HT. Continuous active heating during surgery is crucial, and irrigation and infusion solutions should be kept at body temperature. Areas of the body which cannot be actively heated should be properly insulated in order to reduce heat loss. The use of humidifiers which retain heat and moisture is recommended in order to maintain a consistent temperature, which reduces the amount of heat lost through evaporation from the airways (30).

In our clinic, a comprehensive approach was adopted to safeguard patients from HT. Berets and socks were utilized in 96.8% of patients, active blown warm heating in 95.2%, tabletop-bottom gel heating in 27%, and warming of liquids and blood products in 17.5%. No correlation was identified between the choice of heating methods and the occurrence of HT. Preoperative heating was not feasible for those patients monitored in the ward, as is the case in the intensive care unit. The use of heat-humidifiers in the breathing circuit resulted in carbon dioxide retention, limiting their application. Nevertheless, a determined effort was made to apply passive heating methods, particularly berets and socks, to nearly all patients. In the pursuit of HT prevention, we endeavored to employ multiple heating methods on the same patient whenever possible, depending on the nature of the surgical procedures, rather than adhering to a singular approach.

### Study Limitations

This study had several limitations: Firstly, it was designed retrospectively and so lacked the control inherent in a prospective controlled trial. Secondly, the application of standard heat treatment was not consistent across all of the patients, as the focus was on presenting the results of specific applications. Thirdly, the patient groups were homogeneous and standardization was difficult due to the limited number of patients. Finally, this study did not include late postoperative complications, focusing instead on intraoperative and early postoperative complications.

## Conclusion

Neonates are at increased risk for intraoperative HT due to their fragile physiology, environmental exposures, and inadequate perioperative warming. The consequences of perioperative HT are significant, contributing in particular to an increased incidence of cardiac and respiratory complications. Despite the implementation of active and passive warming methods in our study, a high incidence of HT (54%) was observed during the neonatal period. Notably, ambient operating room temperature emerged as the only independent risk factor for neonatal HT. Our findings underscore the importance of initiating warming measures in the preoperative phase, heating the operating room, utilizing available facilities, and minimizing neonatal exposure to cold environments in order to reduce the risk of HT.

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### Ethics

**Ethics Committee Approval:** This study received ethical approval from the Ege University Faculty of Medicine Clinical Research Ethics Committee (president: Prof. Dr. Guzide Aksu) (approval no.: 20-12.1T/28, date: 17/12/2020).

**Informed Consent:** Informed consent was obtained from the parents of the patients.

### Authorship Contributions

Surgical and Medical Practices: E.G., C.Ş., C.B., M.U., Concept: E.G., C.Ş., C.B., M.U., Design: C.Ş., C.B., Data Collection and/or Processing: E.G., C.Ş., C.B., Analysis and/or Interpretation: E.G., M.U., Literature Search: E.G., C.Ş., Writing: E.G., C.Ş., C.B.

**Conflict of Interest:** The authors declare that there is no conflict of interest regarding the publication of this article.

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