Original Article / *Özgün Araştırma*

DOI: 10.4274/haseki.galenos.2018.4784
Med Bull Haseki 2019;57:225-231

Comparison of Forced-air Warming Systems and Intravenous Fluid Warmers in the Prevention of Pediatric Perioperative Hypothermia

Çocuklarda Perioperatif Hipoterminin Önlenmesinde Sıcak Hava Üfleme Sistemleri ile İntravenöz Sıvı Isıtıcıların Karşılaştırılması

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Abstract

Aim: We aimed to compare the efficacy of intravenous blood-fluid warming and forced-air warming systems for the prevention of perioperative hypothermia in pediatric patients under six years of age.

Methods: Two-hundred children aged 0-6 years, who underwent elective surgery, were included in the study. Group 1 patients were warmed with forced-air warming system at the operating room. Group 2 patients were warmed with intravenous fluid and blood warming systems at the operating room. During the entire operation, heart rate, SpO_2, end Tidal CO_2 and esophagus temperature values were recorded at 10-minute intervals. The number of patients, who needed rescue warming, the starting time and duration of rescue warming were recorded. The duration of the anesthesia, the duration of the operation, and the time of recovery were recorded.

Results: The groups were compared in terms of mean operating room temperature and body temperature and no statistically significant difference was found between the groups. There was no statistically significant difference between the groups for additional rescue warming need and time to rescue warming. The time to recovery was longer in the patients who needed rescue warming. There was a statistically significant positive correlation between the duration of the operation and the duration of the need for rescue warming with a confidence of 99%.

Conclusion: In pediatric patients, i.v. fluid warming systems are as effective as forced-air warming systems in avoiding perioperative hypothermia.

Keywords: Forced-air warming, fluid warming, pediatric patient, perioperative hypothermia

Öz

Amaç: Altı yaş altı çocuk hastalarda intravenöz kan-sıvı ısıtma ve zorlamalı hava ısıtma sistemlerinin perioperatif hipoterminin önlenmesinde etkinliğini karşılaştırmayı amaçladık.

Yöntemler: Elektif cerrahi geçiren 0-6 yaş arası 200 çocuk çalışmaya alındı. Grup 1 hastaları ameliyathanede zorlamalı hava ısıtma sistemi ile ısıtıldı. Grup 2 hasta operasyon odasında intravenöz sıvı-kan ısıtma sistemleri ile ısıtıldı. Operasyon süresince Kalp atış hızı, SpO_2, Tidal CO_2 ve özofagus sıcaklığı değerleri 10 dakikalık aralıklarla kaydedildi. Kurtarma ısıtıcısı gereken hasta sayısı, başlangıç ısısı ve kurtarıcı ısıtıcı süresi kaydedildi. Anestezi süresi, operasyon süresi, iyileşme zamanı kaydedildi.

Bulgular: Gruplar ortalama ameliyathane sıcaklığı ve vücut ısısı açısından karşılaştırıldı ve gruplar arasında istatistiksel olarak anlamlı bir fark bulunmadı. Ek kurtarıcı ısıtıcı ihtiyacı ve kurtarıcı ısıtıcı ihtiyacının zamanı için gruplar arasında istatistiksel olarak anlamlı bir fark yoktu. Kurtarıcı ısıtıcıya ihtiyaç duyan hastalarda iyileşme süresi uzadı ve bu ilişki istatistiksel olarak anlamlıydı. Operasyon süresi ile kurtarıcı ısıtıcı ihtiyacının süresi arasında % 99'luk bir güven ile pozitif korelasyon vardı ve istatistiksel olarak anlamlıydı.

Sonuç: Pediyatrik hastalarda i.v. sıvı ısıtma sistemleri, perioperatif hipotermiden kaçınmak için zorlamalı hava ısıtma sistemleri kadar etkilidir.

Anahtar Sözcükler: Zorlamalı hava ısıtma, sıvı ısıtma, çocuk hasta, perioperatif hipotermi

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Received/Geliş Tarihi: 20 October 2018 **Accepted/Kabul Tarihi:** 02 December 2018

This study was presented in TARK (50th National Congress of Turkish Anesthesiology and Reanimation Society) in 2016 as an oral presentation

Introduction

Perioperative hypothermia is defined as a core body temperature of <36°C from 1 hour before to 24 hours after the surgery. It is a common and treatable complication. General anesthesia can impair thermoregulation mechanisms by inhibiting the communication between the central nervous system and the peripheral tissues. Changes in body temperature are mostly stabilized with a standard deviation of about 0.2°C. However, this change can reach 6°C in surgery patients under general anesthesia (1).

Impairments in thermoregulation can lead to severe complications such as hemostatic disorders, late recovery from anesthesia, cardiac function disorders, hepatic dysfunction, coagulation disorders, renal dysfunction, immune dysfunctions or delayed wound healing (2).

As the thermoregulation mechanisms are not fully mature in younger age groups, perioperative hypothermia is more common. The highest-risk groups are newborns and infants. Forced-air warming systems or heater blankets are commonly used for the prevention of pediatric perioperative hypothermia (3).

For adult patients, high-volume blood, blood products, and other fluids are warmed using intravenous fluid and blood warming systems. However, there is no sufficient evidence regarding the effective use of blood- and fluid-warmers for pediatric cases (4).

Researchers concerning pediatric perioperative warming methods mostly compare the efficacy of forced-air warming systems and heater blankets (5). There is no data regarding the application of intravenous blood/fluid warming systems.

For this reason, this study aims to compare intravenous warming systems with forced-air warming systems for pediatric patients aged 6 or younger.

Methods

This prospective, randomized, double-blind study was approved by the Local Ethics Committee of Şişli Etfal Training and Research Hospital (02.08.2016/1238). Written and verbal informed consent was obtained from parents of the patients. The study was conducted in the pediatric surgery clinic in a randomized and prospective manner. The study included 200 electively-operated patients aged 0-6 years and assigned American Society of Anesthesiologists (ASA) physical status class I-II.

Children without parental consent, patients with preoperative hypo/hyperthermia, patients with a risk of malignant hyperthermia, esophagus surgery candidates, low-birth-weight newborns, and prematurely born babies were excluded from the study.

The body temperatures of the patients were measured (from the ear) and recorded maximum 10 minutes before the surgery. Forced-air warming systems were used for patients with a body temperature lower than 36°C. Patients with a body temperature of higher than 36°C were transferred to the operating room.

Demographic data (age, gender, weight, etc.) were recorded for each patient. The operating room temperature was kept at 22-24°C. Randomization of the patients was performed by an independent anesthesiologist who was not in the study team.

Group 1 (n=100): From arrival to the operating room, the patient was actively warmed with a forced-air warming system (3M™ Bair Hugger™ Warming system, 3M, Minnesota, United States) and a special blanket (3M Pediatric Underbody Blanket).

Group 2 (n=100): From arrival to the operating room, the patient was actively warmed with the intravenous fluid/blood warming system (enFlow).

In the operating room, the patients were monitored with electrocardiogram (ECG) (derivation D2), oxygen saturation (SpO_2) and end-tidal carbon dioxide ($EtCO_2$) monitoring. Heart rate (HR), SpO_2 and ear temperature were recorded prior to the induction and these values were accepted as the preoperative starting values. Vascular access was established with a 22-26 Gauge angiocatheter, and hydration started with intravenous isotonic fluid. All patients were anesthetized (general anesthesia) according to their planned operation. It was recorded whether the patient was anesthetized with a laryngeal mask or through intubation. The anesthesia was sustained with the minimum alveolar concentration (MAC) at 1 atmosphere with sevoflurane and a mixture of 50% O_2/50% air. A thermometer was placed in the esophagus to take post-operative measurements. The HR, SpO_2, $EtCO_2$ and esophagus temperatures were recorded at 10-minute intervals starting from the beginning of the operation. In both groups, if the patient's body temperature fell below 36°C, a second forced-air warming system was used. The number of patients who required a rescue warmer, the time when warming was required and the duration of the requirement were recorded. Warming was terminated when the body temperatures rose above 37°C.

The following data were also recorded: the duration of anesthesia (the time between induction and recovery), the duration of the operation (the time between skin incision and final suturing) and the duration of recovery (the time passed until a Modified Aldrete Score of 9 and higher was achieved). The patients were transferred to the post-operative recovery unit after the surgical procedure was completed and the patients recovered from the anesthesia. Body temperature of the patients was measured in the ear. A forced-air warming system (active warming) was used in patients whose body

temperature was below 36°C Unwanted complications, such as bradycardia, desaturation, nausea, vomiting, skin hyperemia and hyperthermia were recorded.

Statistical Analysis

The SPSS 18 package program was used to analyze the data from the Groups 1 and 2, and to determine the differences between the different anesthesia techniques. In the study, the first step was to get to know the groups by studying the demographic variables. Subsequently, the following methods were used for the analysis of the indicated data sets: chi-square test for categorical data, Student's t-test for the continuous/ non-continuous independent variables, and Pearson's correlation coefficient for the determination of any statistically significant correlation between variables and the groups.

Results

The subjects of this study were 200 pediatric ASA I-II patients (aged 0-6 years). The study was prospective and randomized.

There was no statistically significant difference in gender, ASA, age (average) and weight (average) between the two groups (Table 1).

There was no significant difference in airway device application, duration of operation and anesthesia and recovery time between the two groups (Table 2).

There was no significant difference in average operating room temperature, average body temperature (measured at the time of entering the operation room, the beginning of anesthesia, minutes 10, 20, 30, 40, 50, 60, completion of the operation, anesthesia termination, and wake-up) (Table 3) between the two groups.

There was no significant difference in requirement of rescue warmer and the duration of the application of these warmers between the two groups (Table 4).

Table 1. Demographic data of the patients

		Group 1 (n=100)	Group 2 (n=100)	p
Gender	Male	90	81	0.071
	Female	10	19	
ASA Score	1	96	90	0.096
	2	4	10	
Age (year) (Mean)		21.39	24.47	0.292
Weight (kg) (Mean)		12.95	13.92	0.332
Diagnosis	Phimosis	36	30	0.306
	Ingiunal Hernia	25	23	
	Undescended testis	14	10	
	Other	25	37	

ASA: Anesthesiologists physical status

When the correlation between the duration of operation and need for rescue warmers was tested, it was found that increased operative time was associated with the need for rescue warmer (p=0.004) (Tables 5-6).

When the correlation between the duration of recovery from anesthesia and the need for rescue warmers was tested, it was found that the recovery time increased for patients who required rescue warmer (p=0.017) (Tables 7-8).

$EtCO_2$, HR and SpO_2 values that were measured at the beginning of anesthesia, on minutes 10, 20, 30, 40, 50, 60, completion of the operation, and anesthesia termination were compared and it was determined that there were no statistically significant difference.

Table 2. Type of airway and Durations

		Group 1 (n=100)	Group 2 (n=100)	p
Type of airway	Entubation	11	21	0.054
	LMA	89	79	
Duration of operation (minutes) (mean)		42.37	45.16	0.435
Duration of ansthesia (minutes) (mean)		54.92	56.13	0.744
Duration of recovery (minutes) (mean)		5.66	6.11	0.066

LMA: Laryngeal mask airway

Table 3. Body Temperatures at different times of operation

	Group 1 (n=100) (Mean)	Group 2 (n=100) (Mean)	p
Room temperature (C°)	23.86	23.86	0.984
Entrance to operation room (C°)	36.52	36.54	0.657
Beginning of anesthesia (C°)	36.45	36.45	1.000
10^{th} minutes (C°)	36.33	36.31	0.590
20^{th} minutes (C°)	36.21	36.20	0.803
30^{th} minutes (C°)	36.21	36.16	0.331
40^{th} minutes (C°)	36.19	36.16	0.598
50^{th} minutes (C°)	36.26	36.20	0.455
60^{th} minutes (C°)	36.33	36.18	0.241
End of surgery (C°)	36.24	36.19	0.138
End of anesthesia (C°)	36.24	36.19	0.171
Arousal (C°) (mean)	36.33	36.25	0.014

Table 4. Rescue warming requirement and duration

		Group 1	Group 2	p
Rescue warming	Yes	19	21	0.724
	No	81	79	
Duration of rescue warming (minutes) (Mean)		4.00	5.09	0.466

When the changes in the body temperatures were compared in-group, it was observed that the following changes were statistically significant: between minute 40 and minute 50, minute 50 and minute 60 and between the beginning and the termination of the anesthesia.

When the changes in HR were compared in-group, it was observed that the following changes were significant: between the beginning of anesthesia and minute 10, and between minute 30 and minute 40. When the change in $EtCO_2$ monitoring was compared in-group, it was determined that the difference between the beginning and termination of anesthesia was significant. It was observed that this difference was 4 units.

When the changes in SPO_2 values were compared in-group, it was observed that the change between the beginning of anesthesia and minute 10 was significant.

There was a statistically significant correlation with 99% confidence between ambient temperature and duration of rescue warmer requirement. There was also a significant correlation between duration of the operation and duration of need for rescue warmers (99% confidence).

None of the patients had complications such as shivering, nausea-vomiting, or hyperthermia.

Table 5. Rescue warming need- duration of operation

-	Rescue warming need	-	Mean	SD	SE (Mean)
Operation duration	Yes	40	55.83	29.464	4.659
	No	160	40.75	23.112	1.827

SD: Standard deviation, SE: Standard error

Discussion

In this study, we aimed to compare two routinely applied hypothermia prevention methods (forced-air warming and i.v. blood/fluid warming systems): primarily regarding the maintenance of normothermia, the requirement for and the duration of a rescue warmer; and

Table 6. Correlation between rescue warming need and duration of operation

		Levene's test for equality of variances		t-test for equality of means			95% Confidence interval of the difference			
	F	Sig.	T	df	Sig (2-tailed)	Mean difference	SE difference	Lower	Upper	
Operation Duration	Equal variances assumed Equal variances not assumed	10.385	0.001	3.482	198	0.001	15.075	4.330	6.536	23.614
-	-	-	-	3.012	51.621	0.004	15.075	5.004	5.032	25.118

Sig: Significance probability (in some other statistical applications, is called the p value), SE: Standard error, df: Degrees of freedom, T: T value, F: F-statistics

Table 7. Rescue warming need-recovery time

Additional heater needs		n	Mean	SD	SE (Mean)
Recovery time	Yes	40	6.73	2.602	0.411
	No	160	5.68	1.367	0.108

n: Number, SD: Standard deviation, SE: Standard error

Tablo 8. Correlation between rescue warming requirement and recovery time

		Levene's Test for equality of variances		t-test for equality of means				95% Confidence interval of the difference		
	F	Sig.	T	df	Sig (2-tailed)	Mean difference	SE difference	Lower	Upper	
Operation Duration	Equal variances assumed	20.739	0.000	3.528	198	0.001	1.050	0.298	0.463	1.637
	Equal variances not assumed									
-	-	-	-	2.469	44.517	0.017	1.050	0.425	0.193	1.907

Sig: Significance probability (in some other statistical applications, is called the p value), SE: Standard error, df: Degrees of freedom, T: T value, F: F-statistics

secondarily regarding their hemodynamic, respiratory and recovery (from anesthesia) effects. Both methods were successful in preventing hypothermia and there was no superiority for one over the other.

Under normal conditions, the body core temperature is regulated by the hypothalamus. The regular body temperature is 37°C and thermoregulatory mechanisms maintain this temperature with a standard deviation of about 0.2°C. The production and distribution of heat are adjusted to maintain a stable body temperature. Intravenous and inhalation anesthetics have depressant effects on the hypothalamus leading to elevated threshold for heat response as well as diminished threshold for cold response, thus, widening the the normal interthreshold range from 0.2°C to 4°C. In addition, the patient lose body heat as a result of remaining naked and still in the cold operating room conditions, breathing cold gases and losing heat through the body cavities (6,7).

The most important risk groups for perioperative hyperthermia are the acetylsalicylic acid (ASA) III-IV patient group, elderly and pediatric patients (especially newborns). The other predictive factors are the type and duration of the operation, ambient temperature, initial body temperature, the amount of fluid/blood used during the operation and the duration of mechanical ventilation (1,2). For these reasons, we chose our subjects from similar surgery groups. Indeed, the statistical analysis revealed that the groups were similar for age, duration of operation and duration of anesthesia. It was made sure that pre-operative body temperature of the patients was 36°C. In our study, we have found that the need for warming increases with increased duration of the operation.

Beedle et al. (8) have found the incidence of pediatric perioperative hyperthermia to be 16.3% and that this rate can fall to 1.84% with an attentive perioperative care (that is based on the guidelines).

The generally suggested operating room temperature is 20-23.9°C, but it is around 23-24°C for pediatric cases (2,8). This value was maintained for all operations performed in this study. There was no significant difference between the groups regarding changes in ambient temperature. We have determined a correlation between changes in ambient temperature and requirement of a rescue warmer. A decrease in ambient temperature increased the requirement of rescue warming.

The body temperature must be perioperatively monitored in long operations and among patients in the high-risk group. The most valuable measurements are those taken from the lower end of the esophagus (9). In this study, the lower end of the esophagus was the site for core temperature mesurement.

It is also critical to prevent the complications associated with perioperative hypothermia. The cardiovascular complications include tachycardia, increased arterial blood pressure, increased cardiac afterload and increased myocardial oxygen consumption. If the decrease in the body temperature continues, the patient may develop bradycardia, myocardial depression, hypotension and hypovolemia (10). We recorded the HR values in our study. There was no difference in HR measurements between the groups at any time. We believe that the absence of hypothermic cardiovascular complications can be explained by the fact that all patients were normothermic at the beginning of the operation.

Respiratory rate increases through central stimulation in the initial phases of hypothermia. The decreasing body temperature, combined with the decreased respiration and tidal volume, leads to respiratory depression (10). Our study included SPO_2 and $EtCO_2$ measurements. The changes were not found to be significant. However, if there is controlled mechanical ventilation together with general anesthesia, it is not possible to recognize and evaluate some hypothermic complications (such as hypoventilation or apnea).

Hypothermia under general anesthesia extends the duration of action of hypnotic drugs and neuromuscular blockers. This extends the recovery time from the anesthesia (1,9). There was no statistically significant difference in recovery time between the groups in our study. However, the recovery time increased in patients who required rescue warming.

Active warming systems are used for the prevention of perioperative hypothermia. The most preferred ones are resistive and forced-air warming systems. As the resistive systems have a high risk of hyperthermia or burns, forced-air warming methods have become more prominent (4,11).

Forced-air warming systems were also preferred as relief warmers in the cases where normothermia could not be provided despite the chosen warming method.

Previous studies have compared the forced-air warming blankets with other warming blankets peri- or post-operatively among pediatric patients. They have found that forced-air ventilators were more effective and the body temperatures were more stable. There were fewer cases of shivering or feeling cold (3,5,12,13).

Blood/fluid warmers -another active warming technique-, are found to be insufficient in perioperative cases if the infusion amount is less than a liter of fluid per hour (14). The evidence strongly indicates that warming the body fluids with blood/fluid warmers can prevent

perioperative hypothermia and the related complications among adult patients (15).

There is not enough research regarding the use of blood/fluid warmers in pediatric patients. In the last few years, i.v. fluid warming systems with a low volume priming of less than 4 mL and having minimal viscosity have become available. These can raise the body temperature quickly to 40°C (16). These systems have been brought pediatric applications to attention.

In their study including 8 pediatric post-trauma care patients, Bernardo et al. (17) indicated that they did not find a significant difference in the heat-loss prevention results between peripheral forced-air warming systems and fluid warmers. Serour et al. (18) have shown that the warming of the body fluids by placing the i.v. tubing under a warming mattress was effective in preventing hypothermia in abdominal surgery. In his review regarding perioperative heat management, Torossian (19) reported that the combined application of i.v. fluid warmers and forced-air warming systems was the most effective method.

There have been studies comparing forced-air warming systems with fluid warming systems in adult patients and reporting that the incidence of hypothermia decreased when the two methods are combined, as well as those reporting no significant differences between the two methods (20,21).

There was no statistically significant difference in the body temperature measurements between the two groups in our study. The minimal temperature change may be due to the initial normothermia or the warming techniques included in the study. The reason for the changes after minute 40 may be due to the prolonged operative durations. The rate of requirement of a rescue warmer was 21% for the i.v. fluid warmer group and 19% for the forced-air warming system group. The duration of requirement of a rescue warmer was similar for both groups and the duration was short (4-5 minutes)

Study Limitations

The limitations of our study include the wide range of age and the high ASA scores of the subjects and prolonged operative durations.

Conclusion

To conclude, the duration of the operation and the ambient temperature are variables that are correlated with the incidence of hypothermia. Intravenous fluid warming systems are as effective as forced-air warming systems in preventing perioperative hypothermia in pediatric cases.

Acknowledgements

The authors thank all the members of the pediatric surgery team for their support.

Authorship Contributions

Surgical and Medical Practices: H.E., C.T.I., H.Ş.T., G.E. Concept: H.E., C.T.I., H.Ş.T., S.O. Design: H.E., C.T.I., H.Ş.T., G.E., S.O. Data Collection or Processing: H.E., C.T.I., H.Ş.T. Analysis or Interpretation: H.E., C.T.I., H.Ş.T., S.O. Literature Search: H.E., C.T.I., H.Ş.T., S.O. Writing: H.E., C.T.I., H.Ş.T.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

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