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ABSTRACT

Objective: To determine the incidence and risk factors for intra-operative hypothermia in paediatric patients undergoing general anaesthesia at the Kenyatta National Hospital.

Design: A prospective observational study.

Setting: The Kenyatta National Hospital main operating theatres and affiliated satellite operating theatres.

Subjects: A total of 100 paediatric patients (range; three days to 12 years, mean; 4.1 ± 3.3 years) were enrolled in the study.

Results: Thirty out of 100 patients developed hypothermia defined as a core temperature $<36^{\circ}\text{C}$ recorded at least once during provision of general anaesthesia. Ninety percent of those developing hypothermia were male compared to 63% who remained normothermic ($p = 0.006$). Proportionally, more than twice as many hypothermic patients had a caudal block (43% versus 20%, $p = 0.016$) and received 121ml more of fluid ($p = 0.002$) compared to the normothermic group. The patients who became hypothermic tended to be colder at induction of anaesthesia ($36.6 \pm 0.5^{\circ}\text{C}$ versus $37.0 \pm 0.5^{\circ}\text{C}$, $p = <0.0001$) but there was no significant difference in the waiting time, time of induction, environmental temperatures or theatre temperatures compared to those not developing hypothermia. There was no significant difference in the BMI between the two groups ($14.0 \pm 2.9 \text{ kg/m}^2$ versus $15.2 \pm 3.5 \text{ kg/m}^2$, $p = 0.101$).

Conclusion: The incidence of intra-operative core hypothermia in paediatric patients undergoing general anaesthesia at the Kenyatta National Hospital is 30%. Gender (male), lower body temperature at induction, use of caudal block and the volume of intravenous fluids infused were significant independent predictors of core hypothermia. The most significant predictor was body temperature at the time of induction of general anaesthesia.

INTRODUCTION

Inadvertent hypothermia during anaesthesia occurs in a significant proportion of patients undergoing major surgery (1). The incidence of core hypothermia (defined as core temperature $<36^{\circ}\text{C}$) has variously been reported to be 52% among North American children (2), 57.1% in a cohort of general surgical patients in Thailand (3), 48% in an Australian cohort (4) and 57.8% in a Portuguese study (5).

Intra-operative hypothermia is associated with increased post-operative wound infections (6) increased perioperative blood loss, the need for blood and blood product transfusions and has been associated with thrombocytopenia during cardiac by-pass (7). Mild intra-operative hypothermia has been found to triple the incidence of post-operative myocardial events (8) and increases the risk of

re-bleeding from vascular injury. It impairs drug metabolism prolonging recovery from anaesthesia (10) and may also cause a diuresis and subsequent electrolyte abnormalities (11).

The normal thermoregulatory system is impaired by pharmacological agents that induce regional and general anaesthesia, and in patients exposed to the cold temperatures of the operating theatre this results in a redistribution of heat from the core of the body to the periphery and a net heat loss to the environment (12).

In children, this thermo-dysregulation is compounded by a larger surface area to body-weight ratio compared to adults, a reduced insulating capacity from subcutaneous tissue, a poorly developed shivering mechanism and a thinner epidermal keratine layer which increases evaporative heat loss (13).

There is little baseline data for Africa in general and East Africa in particular. This study was, therefore, designed to determine the incidence of hypothermia in paediatric patients undergoing general anaesthesia at the Kenyatta National Hospital and to identify any risk factors for developing hypothermia. It is hoped that an understanding of the associated risk factors will serve as a basis for future interventional studies aimed at reducing the incidence of hypothermia.

MATERIALS AND METHODS

The study was designed as a prospective observational study of consecutive paediatric patients presenting for emergency or elective surgery under general anaesthesia or combined general/regional anaesthesia at the Kenyatta National Hospital with informed consent from the parents/guardian. Institutional board approval was sought and obtained from the Kenyatta National Hospital/University of Nairobi – Ethics and Research Committee.

The exclusion criteria included patients undergoing open heart surgery, general anaesthesia lasting less than 30 minutes and any pathology or surgery precluding access to the tympanic membrane for instance; bilateral auditory meatal obstruction, perforation or infection, bilateral peri-auricular or head and neck surgery.

Paediatric was defined as an age <12 completed years. Intra-operative hypothermia was defined as a core temperature <36°C recorded at least once during the intra-operative period.

Temperature measurements of the tympanic membrane were obtained by a handheld infrared thermometer (Braun Thermoscan IRT 3020, Braun GmbH, Kronberg, Germany) at induction of general anaesthesia and after every 15 minutes as representative of core temperature and categorised as hypothermic (<36°C) or normothermic (\geq 36°C).

Environmental temperatures were obtained from data collected by the Dagoretti meteorological station and posted in the Global Observing Systems Information Center (GOSIC) (<http://gotic.org>). Theatre temperatures were recorded using a Brannan wall thermometer (Brannan Thermometers & Instrumentation, Cleator Moor, England).

All patients had a new Heat and Moisture Exchanger placed appropriately in the breathing circuit. General anaesthesia was induced by inhalation of Halothane in a Nitrous Oxide and Oxygen mixture and maintained by Isoflurane in a Nitrous Oxide and Oxygen mixture. Caudal blocks were administered using 0.25% Bupivacaine at 1ml/kg. Where indicated, intravenous opioids were administered using Fentanyl at 1 μ g/kg or Morphine at 0.1mg/kg.

The two groups (hypothermic and normothermic) were compared to assess the statistical relationship between clinical variables and core hypothermia

using the Student's t-test for parametric data and the Mann-Whitney U test for non-parametric data.

A binary logistic regression analysis was performed to determine the clinical variables that were independently predictive of intra-operative hypothermia. Logistic regression analyses are tabulated with their odds ratio (OR) and 95% confidence interval (CI). P-values <0.05 were considered statistically significant. Data is presented as number (%) or mean \pm SD.

All analyses were performed using SPSS Statistics (version 17.0, Chicago, IL).

RESULTS

One hundred consecutive patients meeting the inclusion criteria were enrolled in the study between June and August 2012. The mean age of the patients was 4.1 ± 3.3 years (range; three days to 12 years), three patients were neonatal (<28 days old). Seventy one percent were male and 29% female. The mean body mass index (BMI) was 14.9 ± 3.4 kg/m². At the preanaesthetic visit, 83% were classified as American Society of Anesthesiologists physical status (ASA) I, 14% as ASA II, 2% as ASA III and 1% as ASA IV. Thirty four percent were scheduled for inguinal/perineal surgery, 22% for laparotomy (major abdominal surgery), 20% for Ear/Nose/Throat procedures, 8% for orthopaedic procedures, 7% for minor abdominal procedures (umbilicoplasty), 3% for thoracotomy, 1% for skin grafting, 1% for craniotomy and 4% for other procedures. Ninety seven percent of the patients had elective surgery while 3% were surgical emergencies. The average time spent waiting in the theatre receiving area was 1 hour 46 minutes (range, 5min – 5hr 30min). The average starting time for induction of general anaesthesia was 11:37am (range; 8.50am – 9.00pm). Eighty four percent had general anaesthesia induced in the main theatres while 16% were induced in satellite theatres. The majority of cases were done in the designated paediatric surgery theatre (theatre 12).

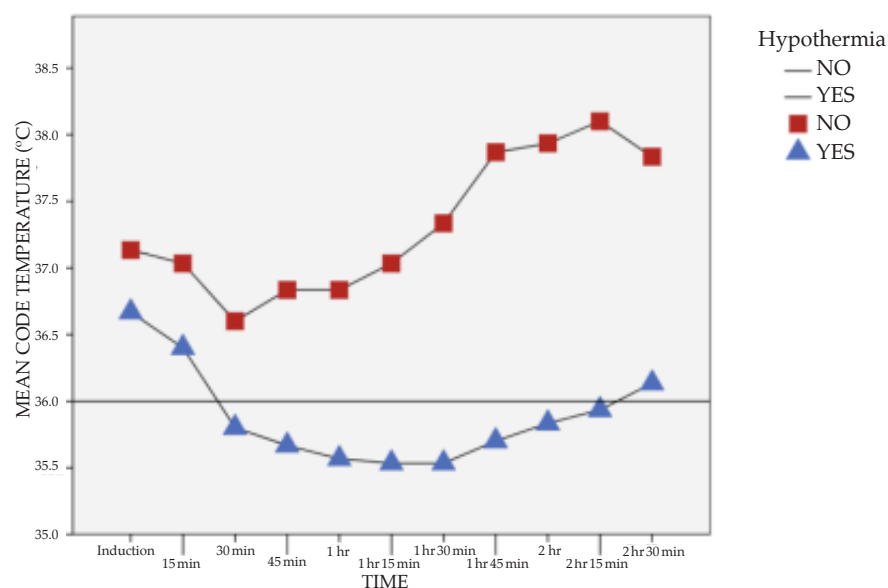
The mean environmental temperature on the days during which the study was carried out was $17.2 \pm 1.5^\circ\text{C}$ (range; 14.6 – 20.5°C). The mean theatre temperatures were $21.9 \pm 0.7^\circ\text{C}$. The coldest theatre was theatre 11 with an average temperature of $19.6 \pm 0.4^\circ\text{C}$. It was the only theatre with regular air-conditioning. The mean body temperature of the patients at induction of anaesthesia was $36.9 \pm 0.6^\circ\text{C}$.

The overall incidence of core hypothermia was found to be 30%. The onset of hypothermia was found to be between 15 and 30 minutes post induction of general anaesthesia and lasted for an average of two hours. The average decrease in core body temperature 30 minutes after induction of general anaesthesia was $-0.4 \pm 0.5^\circ\text{C}$. The core body temperatures then remained steady for about 45 minutes before slowly returning to pre-induction values at two hours post

induction. Although this study was not designed to evaluate hyperthermia, a number of patients were noted to have temperatures $>37.5^{\circ}\text{C}$ especially for

procedures lasting longer than 1 hour 30 minutes which may reflect excessive heat transfer from heating devices as well as other factors.

Figure 1
Mean core temperatures while under general anaesthesia



The mean length of general anaesthesia was 1hour 19 minutes \pm 42minutes (range; 30 minutes to three hours) and the patients received a mean of $245 \pm 179\text{ml}$ of intravenous (IV) fluids ($17.3 \pm 10.5\text{ml/kg}$) during surgery, 88% of which were warmed. No patient received a blood transfusion. The mean estimated blood loss was $33 \pm 37\text{ml}$ ($2.8 \pm 3.4\text{ml/kg}$ body weight).

Four different intra-operative warming techniques were recorded. Eighty eight percent of the patients had intravenous fluids warmed, 65% had a warming mattress, 13% were wrapped in cotton wool and 99% were covered with surgical drapes or hospital linen. Thirty three percent of the patients had two warming techniques used, while 48% had three techniques and only 12% had all four warming techniques used.

Seventy three patients received general anaesthesia while 26 received a combination of regional (caudal block) and general anaesthesia. Ninety nine percent of the patients received an inhalational anaesthetic and no patient received total intra-venous anaesthesia. Sixty seven percent received intravenous opioids at induction or during the maintenance of anaesthesia. All patients were connected to the breathing circuit via a heat and moisture exchanger.

Risk factors for hypothermia: Univariate analysis (Table 1) showed that the normothermic and hypothermic groups differed significantly in four preoperative variables (gender, age, height, body temperature at induction) and two intra-operative variables (use of caudal block and volume of IV fluids infused).

Table 1
Peri-operative risk factors for hypothermia

	Normothermia (n=70)	Hypothermia (n=30)	Average (n=100)	p-value
Gender Male/Female (No.)	44/26	27/3	71/29	0.006
Age (yrs)	3.6 ± 3.1	5.4 ± 3.4	4.1 ± 3.3	0.010
Height (cm)	95 ± 26	108 ± 29	99 ± 27	0.036
Use of caudal block	14 (20%)	13 (43%)	27 (27%)	0.016
IV Fluids infused (ml)	208 ± 136	329 ± 234	245 ± 179	0.002
Body Temperature at Induction ($^{\circ}\text{C}$)	37.0 ± 0.5	36.6 ± 0.5	36.9 ± 0.6	<0.001

Of the normothermic patients, 63% were male while of the hypothermic patients 90% were male ($p = 0.006$). The hypothermic patients tended to be older compared to the normothermic patients (5.4 ± 3.4 years versus 3.6 ± 3.1 years, $p = 0.01$) and as a consequence were taller (108 ± 29 cm versus 95 ± 26 cm, $p = 0.036$) but there was no significant difference in the BMI (14.0 ± 2.9 kg/m² versus 15.2 ± 3.5 kg/m², $p = 0.101$).

Proportionally, more than twice as many hypothermic patients had a caudal block compared to normothermic patients (43% versus 20%, $p = 0.016$). The majority of the perineal/inguinal surgeries performed were for hypospadias reconstruction and orchidopexies and as a consequence, caudal blocks were administered in 21% of the males and only 6% of the females but the proportion of those developing hypothermia following a caudal block was similar for both the gender groups (50% for females and 48% for males) and caudal block association with hypothermia was not a consequence of gender bias.

On average the hypothermic patients received 121ml of fluid more than the normothermic group (329 ± 234 ml versus 208 ± 136 ml, $p = 0.002$). There

was a slight difference between the two groups for the IV fluids infused per body weight (16.1 ± 9.9 ml/kg in the normothermic group versus 20.0 ± 11.4 ml/kg in the hypothermic group) but this difference did not reach statistical significance ($p = 0.09$). The volume of IV fluids infused was positively correlated to the age, weight, length of GA and estimated blood loss ($p = <0.001$, $p = <0.001$, $p = 0.006$ and $p = 0.004$ respectively). Ninety percent of the patients who remained normothermic received warmed fluids compared to 83% of those who developed hypothermia but the difference was not significant ($p = 0.352$).

The patients who became hypothermic were significantly colder at induction ($36.6 \pm 0.5^\circ\text{C}$ versus $37.0 \pm 0.5^\circ\text{C}$, $p = <0.0001$) and had a higher temperature change at 30 minutes from induction of GA compared to those who remained normothermic ($-0.8 \pm 0.4^\circ\text{C}$ versus $-0.2 \pm 0.4^\circ\text{C}$, $p = <0.00001$). However, there was no difference in the waiting time, time of induction, environmental temperatures or theatre temperatures between the two groups which could have contributed to this ($p = 0.086$, $p = 0.406$, $p = 0.887$ and $p = 0.91$ respectively – Table 2).

Table 2
Time and temperature variables for normothermic vs. hypothermic groups

	Normothermia (n = 70)	Hypothermia (n = 30)	Average (n=100)	p-value
Time waiting for surgery (hrs:min)	1:53 ± 1:04	1:30 ± 0:57	1:46 ± 1:02	0.086
Time at Induction (am ± hrs)	11:44 ± 2:00	11:21 ± 2:21	11:37 ± 2:06	0.406
Environmental Temperature (°C)	17.2 ± 1.6	17.2 ± 1.2	17.2 ± 1.5	0.887
Theatre Temperature (°C)	21.9 ± 0.7	21.9 ± 0.6	21.9 ± 0.7	0.910

There was no significant difference between the two groups as to the ASA status ($p = 0.968$), theatre ($p = 0.906$) or type of surgery ($p = 0.951$). There was also no significant difference in the intra-operative use of warmed fluids, opioids, warming mattress, cotton wrapping, drapes, use of more than one warming technique or anaesthetic agent, length of general anaesthesia or estimated blood loss.

Only four patients were pre-medicated with oral Midazolam and Paracetamol. None received Atropine. Premedication with Paracetamol was not associated with core hypothermia ($p = 0.825$) or body temperature at induction ($p = 0.96$).

There was no significant difference between the main theatre temperatures and the satellite theatre temperatures ($21.9 \pm 0.7^\circ\text{C}$ versus $21.8 \pm 0.4^\circ\text{C}$,

$p = 0.181$) which could have contributed to the pattern of hypothermia.

Predictive model for hypothermia: The six significant variables identified on univariate analysis (Table 1) were entered stepwise in a binary logistic regression model using hypothermia as the dependent variable. Age and height were not found to be significant in the model ($p = 0.142$ and $p = 0.249$ respectively) and the two variables were dropped from subsequent regression analyses. The Hosmer and Lemeshow test verified the validity of the model ($p = 0.689$) and the four independent predictors of intra-operative core hypothermia found to be significant in the model (Table 3).

Table 3
Independent predictors of core hypothermia

	Odds Ratio	95% CI	p-value
Body temperature at induction	0.099	0.027 - 0.368	0.001
Volume of IV fluids infused	1.005	1.00 - 1.01	0.004
Gender (male vs. female)	4.768	1.13 - 20.07	0.033
Caudal block (yes vs. no)	3.477	1.09 - 11.14	0.036

A 1°C positive difference in body temperature at induction had an odds ratio of 0.099. The inverse is that a 1°C negative difference in body temperature at induction (for example, 36°C as opposed to 37°C) was predictive of a ten fold increase in the risk of developing hypothermia (odds ratio 10.093, 95% CI, 2.72 – 37.44). Males were 4.8 times as likely as females to develop hypothermia and the administration of a caudal block increased the risk of hypothermia 3.5 times. Though the volume of IV fluids infused had a small odds ratio (1.005, 95% CI 1.00 - 1.01), the odds ratio is calculated on a single unit (ml) and the risk of hypothermia proportionally increased with the volume of IV fluids infused.

DISCUSSION

Incidence: This study found that intra-operative core hypothermia developed in thirty out of a hundred paediatric patients undergoing general anaesthesia at the Kenyatta National Hospital giving an incidence of 30%. This incidence is less than the average incidence of 50% reported in western literature (2,5) which may corroborate the general hypothesis that warmer temperatures in a tropical setting are a protective factor. However, this study differed in the ASA status of the patients compared to Pearce *et al.* (2) who reported an ASA I & II of 81% and ASA III & IV of 19% and Abelha *et al.* (5) who reported an ASA I & II of 42% and ASA III & IV of 58% while in this study the proportion of patients with ASA I & II was 97% and ASA III & IV was 3%. The duration of general anaesthesia reported by Pearce *et al.* (2) was 99.9 ± 83.9min, that reported by Abelha *et al.* (5) was 218 ± 108min while the patients in this study had an average length of general anaesthesia of 79 ± 42min. Unfortunately the studies quoted did not report their ambient theatre temperatures and comparisons cannot be drawn.

The incidence of 30% is slightly higher than that reported by El Gamal *et al.* (14) in Egypt who recorded an incidence of 10%. The theatre temperatures in their study were significantly higher (25.8 ± 0.2°C) compared to those recorded in this study (21.9 ± 0.7°C). Of note is that this study was carried out during the coldest months for the region (June to August) and the real incidence of hypothermia may be actually lower taking this into account.

Risk factors: Four peri-operative independent predictors of core hypothermia were identified; body temperature at induction, the volume of IV fluids infused, male gender as opposed to female and the use of a caudal block. This is in keeping with risk factors reported in literature which have included neuraxial anaesthesia, infusion of large volumes of intravenous fluids and a low temperature of the patient before induction (2,3, 15). However, this study identified males as being at a higher risk of developing core hypothermia as opposed to females. No other studies have been found reporting this. The age, BMI, volume of IV fluids infused, use of a caudal block and body temperature at induction did not differ significantly between the gender groups (p = 0.480, p=0.494, p=0.255, p=0.366 and p=0.170 respectively) and therefore do not explain the difference. A possible explanation is that males tend to be more hyperactive than females and physical resistance to induction of anaesthesia may contribute to increased sweating and heat loss through evaporation and vasodilatation. Secondly, the fact of being male could contribute to less effort by the guardians and theatre staff at covering exposed areas of the body leading to an increased loss of heat through radiation.

The most significant predictor of core hypothermia was found to be the body temperature at induction (p = 0.001). Linear logistic regression failed to identify environmental temperature, waiting time, starting time or theatre temperature as factors contributing to body temperature at induction (p = 0.979, p = 0.612, p=0.621 and p=0.677 respectively). The study was not designed to exhaustively explore factors contributing to body temperature at induction but possible factors would include ward room temperature, proximity to an open window and/or draft during the night preceding operation, the level of activity of the patient prior to transfer to theatre, the route and time taken between the ward and theatre and the amount of clothing on the patient during the waiting period.

The total volume of IV fluids infused was a predictor of core hypothermia but the fact of being warmed or not did not alter the significance. Of note is that in this study, no in-line fluid warmers were used and warmed IV fluids were considered to be those obtained from immersing the IV fluid bottle in a container with hot water. The slow rate of fluid

infusion for paediatric patients would allow heat dissipation via radiation negating the theoretical advantage conferred by warming fluids. The patients developing hypothermia had a slightly higher volume of IV fluids infused per kilogram body weight compared to those who remained normothermic but this difference was not able to statistically predict core hypothermia whereas the total volume of IV fluids infused was an independent predictor. A possible explanation is that the total volume of IV fluids administered was based more on the age, length of GA and estimated blood loss rather than simply the body weight of the patients as shown by the positive correlations between these factors and the total IV fluids administered (age, $p = <0.001$; length of GA, $p = 0.006$ and estimated blood loss, $p = 0.004$ respectively). This constellation of factors taken together with the total volume of IV fluids infused may therefore be more predictive of hypothermia as opposed to simply the volume of IV fluids infused per kilogram body weight.

The use of a caudal block was also a predictor for core hypothermia. Generally, regional anaesthesia induces hypothermia due to sympatholytic vasodilatation and subsequent radiant heat loss. However, a further factor observed in the study was that during the time spent in positioning, confirming landmarks and administering the caudal block, many patients were inadequately covered contributing to further radiant heat loss.

Study limitations: This study was confined to Kenyatta National Hospital and as such is reflective of a large tertiary level public hospital and the results may not be generalisable to other private institutions. Due to logistical constraints, the study was carried out during a three month period which coincided with the coldest months of the region. This may have increased the incidence of hypothermia recorded. The study sample included only one skin grafting, three neonates, three emergency surgeries and seven patients with ASA status III and IV. These high risk sub-groups may have been under-represented in the study. The intra-operative blood loss was only an estimate as Kenyatta National Hospital lacks a dry weight machine for an accurate measure of blood volume in blood-soaked gauzes. The study was not designed to evaluate plasma drug concentrations of anaesthetic agents and opioids which may also be predictors of hypothermia.

In conclusion, this study was able to demonstrate that monitoring of core temperature during general anaesthesia is feasible and as a result was able to show that intra-operative core hypothermia develops in 30% of paediatric patients undergoing general anaesthesia at the Kenyatta National Hospital. Gender, age, height, body temperature at induction

(pre-operative variables), use of caudal block and volume of IV fluids infused (intra-operative variables) were found to be significantly different between those who developed core hypothermia and those who remained normothermic. Of the six variables, only gender (male), lower body temperature at induction, use of caudal block and the volume of IV fluids infused were significant independent predictors of core hypothermia. The most important predictor was body temperature at the time of induction of general anaesthesia.

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