Incidence of Unintentional Intraoperative Hypothermia in Pediatric Scoliosis Surgery and Associated Preoperative Risk Factors

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Abstract:

Introduction: Intraoperative hypothermia is associated with perioperative complications such as blood loss and wound infection. Thus, perioperative heat retention methods to prevent perioperative hypothermia such as providing a warmed blanket and active patients' warming are important. Although major surgery and pediatric patient age are noted as risk factors, only a few studies focus on hypothermia as an intraoperative complication in pediatric scoliosis surgery. The aim of this study is to investigate the incidence of intraoperative hypothermia in pediatric scoliosis surgery and the associated preoperative risk factors.

Methods: We retrospectively reviewed the records of pediatric patients who underwent posterior spinal fusion at a single institution between 2015 and 2019. We recorded the background data, perioperative data, lowest recorded core temperature, and perioperative complications. Patients were divided into those whose temperature decreased below 36°C (Group H) and those who maintained a temperature of 36°C or greater (Group N) during surgery. We compared the two groups and performed multivariate analysis to identify preoperative risk factors for intraoperative hypothermia.

Results: A total of 103 patients underwent posterior spinal fusion; 56 for adolescent idiopathic scoliosis and 47 for neuromuscular scoliosis. Hypothermia was observed in 40 patients (38.8%). Group H had more non-adolescent idiopathic scoliosis (AIS) patients, lower mean body mass index, greater mean blood loss, greater number of fused vertebrae, larger preoperative Cobb angle, and lower initial core body temperature (immediately after induction of anesthesia). On multivariate analysis, a diagnosis of neuromuscular scoliosis, a lower body mass index, and a lower initial core body temperature were identified as independent risk factors for intraoperative hypothermia.

Conclusions: The incidence of hypothermia in pediatric posterior scoliosis surgery is 38.8%. Diagnosis of non-AIS, lower body mass index, and lower core body temperature at the time of anesthesia induction are preoperative risk factors for intraoperative hypothermia.

Keywords:

hypothermia, pediatric, scoliosis surgery, complication, risk factor

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Introduction

Core body temperature is normally tightly regulated by balancing the body's heat loss and gains. Unintentional intraoperative hypothermia occurs mainly because of the combination of anesthetic-induced impairment of thermoregulatory control and exposure to a cool environment[1,2]. Perioperative hypothermia is observed in 2.7% to 74% of all patients who underwent elective surgery[3-8]. It has been reported that hypothermia is associated with perioperative complications such as blood loss, wound infection, shivering, and mortality[1,9-13]. Therefore, perioperative heat retention methods to prevent perioperative hypothermia such as providing a warmed blanket and active patients warming are

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Table 1. Demographic Data.

Sex, n	M: 28 F: 75
Age, mean (SD), yr	14.4 (1.9)
Diagnosis, n	AIS: 56 non-AIS: 47
Height, mean (SD), cm	150.8 (12.1)
Weight, mean (SD), kg	41.2 (11.4)
Body mass index, mean (SD), kg/m^2	17.9 (3.6)
Cobb angle, mean (SD), degrees	69.9 (25.6)
Fixed vertebrae, mean (SD), n	11.8 (3.3)
Operative time, mean (SD), min	311.7 (98.2)
Estimated blood loss, mean (SD), mL	1009.8 (726.9)
Hospital stay, mean (SD), days	22.8 (16.2)

Abbreviations: AIS, adolescent idiopathic scoliosis; SD, standard deviation
Table 1 shows demographic data of the patients included in this study. Almost half of this cohort included non-ais patients. The averaged preoperative cobb angle, operative time, and estimated blood loss was 69.9°, 311.7 minutes, and 1009.8 ml, respectively.

important[3,9,10,13]. Risk factors associated with hypothermia have been surveyed[3,4,9,13]. Although major surgery, requiring a long operative time, and young (pediatric) patient age are noted as risk factors[3,9], only a few studies focus on hypothermia as an intraoperative complication in pediatric scoliosis surgery[5]. The purpose of this study is to investigate the incidence of unintentional hypothermia during pediatric scoliosis surgery and to determine the associated preoperative risk factors.

Materials and Methods

Patient selection and data collection

The institutional review board of our hospital approved this retrospective review of medical records. The procedures employed adhere to the tenets of the Declaration of Helsinki. A total of 105 pediatric patients underwent posterior spinal fusion at our institution between January 2015 and December 2019. To be included in analysis, patients had to be between 10 to 19 years of age at the time of surgery and to have at least 6 months of documented follow-up after surgery. Two patients were excluded because important intraoperative data were missing. Therefore, a total of 103 patients were included; their general characteristics are summarized in Table 1. We recorded the age at the time of surgery, diagnosis (adolescent idiopathic scoliosis [AIS] vs non-AIS), sex, height, weight, body mass index (BMI), preoperative Cobb angle, operative time, estimated blood loss (EBL), number of fused vertebrae, core body temperature measurements, and perioperative complications, including superficial and deep surgical site infection. The bladder temperature was used as a proxy for core body temperature, measured through an indwelling urethral catheter placed immediately after induction of anesthesia. The temperature was recorded every minute. Hypothermia was defined as a core body temperature below 36°C; the duration of hypothermia was calculated as the total time recorded with a temperature below 36°C. We assessed the time from the end of surgery to the time of extubation as an index of recovery from anesthesia. The patients were divided into two groups: Group H (hypothermia), comprised of patients whose temperature decreased below 36°C at some point during surgery; and Group N (normothermia), comprised of patients who maintained a core temperature of 36°C or greater throughout surgery.

Perioperative warming methods

After induction of anesthesia, the patient's surgical gown was removed, and they were placed on the surgical bed in a prone position. The posterior skin surface of the buttocks and legs was warmed using a blanket connected to a forced air system (Bair Hugger™ Temperature Management Unit, Model 750; 3M Co., United States). A warmed intravenous solution was routinely provided through an intravenous catheter. The temperature of the operating room was set at approximately 27°C before the start of surgery and decreased to 21°C to 25°C after the patient was covered by surgical drapes.

Anesthetic technique

Anesthesia was induced using propofol (1.0-2.0 mg/kg), and fentanyl (2.0 μg/kg) was used for analgesia. Neuromuscular blockade was accomplished using rocuronium (0.6 mg/kg). After tracheal intubation, anesthesia was maintained with continuous intravenous infusion of propofol (5-10 mg/kg/h), and analgesia was maintained with remifentanil (0.05-0.3 μg/kg/min). Intravenous fentanyl was also administered during surgery to manage pain immediately after extubation. Extubation was performed on the day of surgery in all stable patients.

Surgical procedure

A midline incision was made from the upper to the lower instrumented vertebral levels, widely exposing the posterior elements of the spine. Whenever possible, pedicle screws were placed using the assistance of a navigation system (StealthStation™ S7 Surgical Navigation System; Medtronic Sofamor Danek, United States) using data from preoperative computed tomography. Spinal correction was performed by inserting rods, rod rotation, and using appropriate distraction and compression techniques. Hooks and sublaminar tape were used to help correct the spinal deformity and to maintain the correction. Autogenous local bone grafts were harvested from the spinous processes, inferior facets, and transverse processes. Artificial bone grafts were also applied. Spinal cord function was monitored using motor-evoked potentials throughout the procedure. Intraoperative autotransfusion was performed in patients who were able to undergo preoperative blood donation. We also used the C.A.T.S® Continuous AutoTransfusion System (Fresenius SE & Co., Bad Homburg vor der Höhe, Germany) for intraoperative blood collection and return.

Statistical analysis

Variables were compared between Groups H and N using the chi-squared or independent-samples *t*-test. Differences were considered significant at a *P*-value less than 0.05. A multivariate logistic regression model was used to determine the preoperative risk factors for intraoperative hypothermia. Variables were considered for multivariate analysis only if they showed significant difference on univariate analysis and were considered clinically useful. Stepwise model selection procedures were implemented. Statistical Package for Social Sciences software, version 19.0 (IBM Japan Business Services Co., Tokyo, Japan) was used for all statistical analyses.

Results

Of the 103 included patients, 56 had AIS and 47 had non-AIS (congenital muscular dystrophy, n=26; spinal muscular dystrophy, n=9; cerebral palsy, n=7; Prader Willi syndrome, n=1; Angelman syndrome, n=1; Marfan syndrome, n=1; congenital scoliosis, n=1; Noonan syndrome, n=1). Hypothermia was observed in a total of 40 patients (38.8%). Of these, 36 patients (35%) experienced mild hypothermia (35-35.9°C) and 4 (3.9%) experienced severe hypothermia (<35°C). The mean duration of hypothermia was 45.6 minutes (Table 2). Perioperative complications were observed in 25 patients, although some patients experienced more than one complication; complications rates were calculated from the total number of patients (103). Respiratory complications were most frequently observed, mainly in patients with non-AIS. Two patients with non-AIS required reintubation in the operating room, and 1 required reintubation in the intensive care unit because of insufficient recovery of lung function. Surgical site infection was noted in 12 patients as follows: 10 patients had superficial infection treated with intravenous antibiotics and 2 had deep infection requiring surgical debridement (Table 3).

On univariate analysis, Group H was more likely to have a diagnosis of non-AIS, lower BMI, larger EBL, greater number of fused vertebrae, larger preoperative Cobb angle, lower core body temperature at the time of anesthesia induction, and higher rate of postponed extubation (Table 4). We could not find a statistically significant difference in the rate of perioperative complications and surgical site infection between the two groups. The following preoperative factors were used for multivariate analysis: preoperative diagnosis, BMI, preoperative Cobb angle, and initial core body temperature. Multivariate analysis determined that a diagnosis of non-AIS, lower BMI, and lower initial core body temperature were independent risk factors associated with intraoperative hypothermia (non-AIS: odds ratio [OR], 2.9; 95% confidence interval [CI], 1.020-8.151; *P*=0.046; BMI: OR, 0.824; 95% CI, 0.702-0.968; *P*=0.019; initial core body temperature: OR, 0.044; 95% CI, 0.009-0.206; *P*<0.001; Table 5).

Table 2. Intraoperative Hypothermia.

Hypothermia, n (%)	Total	40 (38.8%)
	Mild: 35°C–36°C	36 (35%)
	Severe:<35°C	4 (3.9%)
Duration of hypothermia, mean (SD)	45.6 (101.1) min	

Abbreviations: SD, standard deviation
Hypothermia was observed in a total of 40 patients (38.8%). Of these, 36 patients (35%) experienced mild hypothermia and 4 (3.9%) experienced severe hypothermia. The mean duration of hypothermia was 45.6 minutes.

Discussion

Incidence of hypothermia

The incidence of unintentional intraoperative hypothermia in pediatric patients undergoing surgery for scoliosis was 38.8% in our cohort, even with the use of standard intraoperative warming techniques. The reported incidence of in-

Table 3. Perioperative Complications.

Total [cases] (rate [%])		25	(24.3)
Respiratory complication	Atelectasis [cases] (rate [%])	5	(4.9)
	Pneumonia [cases] (rate [%])	3	(2.9)
	Bronchitis [cases] (rate [%])	2	(1.9)
	Hemothorax [cases] (rate [%])	1	(1)
Surgical site infection	Superficial [cases] (rate [%])	AIS: 5 non-AIS: 5	(9.7)
	Deep [cases] (rate [%])	non-AIS: 2	(1.9)
Delayed awaking from anesthesia [cases] (rate [%])		3	(2.9)
Urinary tract infection [cases] (rate [%])		3	(2.9)
Ileus [cases] (rate [%])		1	(1)

Abbreviations: AIS, adolescent idiopathic scoliosis
Twenty-five patients experienced perioperative complications. The most frequent complications were respiratory complications. We experienced 10 patients with superficial infection (five AIS patients, including 2 with atopic dermatitis, and 5 non-AIS patients), and 2 patients with deep infection (1 with Duchenne Muscular Dystrophy and 1 with Noonan syndrome).

Table 4. Comparison Between Hypothermia and Normothermia Groups.

		Hypothermia	Normothermia	*P*-value
n		40	63	
Age, yr		14.3	14.6	0.438
Sex, n		M: 12	M: 16	0.609
		F: 28	F: 47	
Diagnosis, n		AIS: 16	AIS: 40	0.02*
		non-AIS: 24	non-AIS: 23	
Height, cm		147.9	152.7	0.053
Weight, kg		36.1	44.5	<0.001*
Body mass index, kg/m^2		16.3	18.9	<0.001*
Operative time, min		335.5	296.6	0.05
Estimated blood loss, mL		1218.6	877.3	0.019*
Number of fused vertebrae, n		12.9	11.1	0.008*
Preoperative Cobb angle, degrees		79.6	63.7	0.002*
Core body temperature	Initial, °C #	36	36.6	<0.001*
	Beginning of surgery, °C	35.9	36.4	<0.001*
	End of surgery, °C	36.3	37.1	<0.001*
Time from end of surgery to extubation, min		36.3	40.5	0.217
Hospital stay, days		24.6	21.7	0.377
Postponed extubation, %		25	9.5	0.035*
Complications, %		35	19	0.069
Surgical site infection, %		12.5	11.1	0.83

Abbreviations: AIS, adolescent idiopathic scoliosis

Measured immediately after induction of anesthesia

*P<0.05

Patients in the Hypothermia group were more likely to have a diagnosis of non-AIS, lower BMI, larger EBL, greater number of fused vertebrae, larger preoperative Cobb angle, lower core body temperature at the time of anesthesia induction, and higher rate of postponed extubation. We could not find a statistically significant difference in the rate of perioperative complications and surgical site infection between the two groups.

Table 5. Multivariate Analysis.

Variable	Coefficient (β)	Standard error	Wald χ^2	*P*-value	OR	95% CI
Intercept	116.7	29				
Diagnosis of non-AIS	1.059	0.53	3.987	0.046*	2.9	1.020–8.151
Body mass index	−0.193	0.082	5.527	0.019*	0.824	0.702–0.968
Initial CBT#	−3.013	0.791	15.635	<0.001*	0.044	0.009–0.206

Abbreviations: CBT, core body temperature; AIS, adolescent idiopathic scoliosis; OR, odds ratio; 95% CI, 95% confidence interval

#Measured immediately after induction of anesthesia

*P<0.05

The preoperative factors that showed significant difference on univariate analysis were used for multivariate analysis. Multivariate analysis determined that a diagnosis of non-AIS, lower BMI, and lower initial core body temperature were independent risk factors associated with intraoperative hypothermia.

traoperative hypothermia ranges from 2.7% to 74%[3-8]. Lai et al assessed 502 pediatric patients undergoing general surgery, including neonates and older children, and found intraoperative hypothermia in 53.2%[3]. Mehta et al report that 74% of patients undergoing major colorectal surgery experience mild perioperative hypothermia[6]. In studies of orthopedic surgery, Parodi et al assessed intraoperative hypothermia in 73 patients (mean age, 33 years) who underwent hip arthroscopy, noting that only 2.7% of the patients experience a decrease in core temperature to less than 35°C[4]. Scholten et al and Leijtens et al studied the incidence of hypothermia after total knee and total hip arthroplasty[7,8], reporting that 11.7% to 26.7% of patients, respectively, experience mild hypothermia (<36°C). This wide range may be explained by differences in patient population, surgical procedures, definitions of hypothermia, measuring methods, warming methods, and operating room temperatures.

Pediatric patients are particularly susceptible to developing intraoperative hypothermia because of their lesser capacity for temperature regulation compared with adults[14]. Schur et al surveyed 510 pediatric scoliosis patients with both idiopathic and nonidiopathic scoliosis, a very similar cohort to that used in our study. They reported that 45% of patients experience hypothermia below 35°C during scoliosis surgery[5]. We found that 38.8% experience hypothermia below 36°C. This difference may be explained by a difference in measuring methods (urethral catheter vs Schur's esophageal probe) and in the definition of hypothermia (<36°C vs < 35°C). The timing of application of the warming device may also influence the difference in incidence. We routinely use warmed intravenous fluids and a forced air device, applied immediately after draping the patient but before starting surgery. In contrast, Schur et al started warming methods after hypothermia was recognized.

Risk factors

Many risk factors for intraoperative hypothermia have previously been identified[15]. Billeter et al surveyed adult patients undergoing elective general and orthopedic surgery and found that the severity of illness at admission, the presence of neurologic disorders, male sex, older age, weight loss, anemia, renal failure, and diabetes mellitus are risk factors for perioperative hypothermia[9]. Parodi et al report that the operative time, temperature of the saline solution, BMI, and diastolic blood pressure are risk factors for hypothermia in patients undergoing hip arthroscopy[4]. Lai et al studied surgery in 502 children and reported that major surgery, a longer duration of surgery, the type of surgery, the type of anesthesia, and the age of the child are risk factors for inadvertent hypothermia[3]. We found that a diagnosis of non-AIS, lower BMI, and lower initial core body temperature are risk factors for intraoperative hypothermia. Patients with neuromuscular disease are reportedly predisposed to hypothermia because of reduced heat production in atrophic or dystrophic muscles[16]. Several studies show the relation between BMI or body weight and intraoperative core body temperature; our results are consistent with those of these previous reports[3,17-20]. Kurz et al studied 40 adult patients undergoing colon surgery and found that the risk of intraoperative hypothermia is inversely proportional to the percentage of body fat[19]. Groene et al observed 206 patients who underwent lower limb and abdominal surgery and found that the body temperature decreases to a greater degree at an early stage in patients with a lower BMI than in those with a normal or high BMI[17]. Lai et al noted that body weight is among the risk factors for hypothermia; they suggest that patients with a smaller body surface area lose body heat faster than those with a larger body surface area[3].

Prevention of hypothermia

To prevent intraoperative hypothermia, a guideline developed by the German Society of Anaesthesiology and Intensive Care Medicine recommends pre- and intraoperative active warming, ambient operating room temperature of at least 21°C for adult patients and at least 24°C for children, the use of warmed infusions and blood transfusions, and insulation of the body surface[15]. Although we used intraoperative warming techniques, such as warmed intravenous solution and a forced-air warming blanket, we noted a relatively high rate of unintentional intraoperative hypothermia.

The core body temperature drops immediately after induction of anesthesia, mainly because of an internal redistribution of body heat from the core to the periphery[21]. Prewarming using forced-air warming devices is reportedly an effective method to prevent intraoperative hypothermia[22-24]. Horn et al performed a randomized controlled trial in patients (mostly adults) undergoing elective surgery under general anesthesia, including orthopedic surgery[24]. They show significant differences in the change in core temperature between the patients who did and did not undergo prewarming. Our results show that the initial core body temperature, measured in the operating room after induction of anesthesia and before surgery, is significantly lower in patients who go on to develop intraoperative hypothermia than in those with normothermia. Therefore, one of the reasons for the hypothermia noted in our cohort may be the omission of prewarming before surgery. The use of a warmed blanket and active warming in the preoperative period should be considered, especially in patients with a diagnosis of non-AIS or with a lower BMI.

Limitations

There are some limitations to this study. First, this retrospective study was performed at a single center with a relatively small sample size. Therefore, our statistical power is not strong. Second, we included a variety of diagnoses for patients with non-AIS—most of these are relatively rare diseases, such as congenital muscular dystrophy. These population characteristics may affect the incidence of hypothermia and perioperative complications. Finally, although the room temperature may influence the intraoperative hypothermia, we could not obtain accurate data of room temperature around the surgical bed during surgery. However, we believe that the results of this study have clinical meaning; we were able to determine the incidence of intraoperative hypothermia in pediatric scoliosis surgery with the use of standard prevention methods.

Conclusion

Unintentional intraoperative hypothermia occurs in 38.8% of patients undergoing pediatric scoliosis surgery, even with the use of several standard warming methods. Patients with non-AIS, lower BMI, and lower core body temperature at the time of anesthesia induction are at risk for intraoperative hypothermia.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

Ethical Approval: The study was approved by the Institutional Review Board of the Kitasato University, School of Medicine (B16-236).

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Author Contributions: MO and WS were responsible for the organization and coordination of the study. MO was the chief investigator and also responsible for data analysis. MM, ES, TI, TN, KU, TA, MT, and GI developed the study design. All authors contributed to the writing of the final manuscript. All authors approved the manuscript for publication and agreed to be accountable for all aspects of the work and to ensure that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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