A standardized protocol to reduce preoperative hypothermia in pediatric spinal fusion surgery: a quality improvement initiative

Katrina Ducis, MD, R. Dianne Seibold, RN, Tylyn Bremer, RN, and Andrew Jea, MD, MHA

Department of Neurological Surgery, Indiana University School of Medicine, Indianapolis, Indiana

OBJECTIVE Hypothermia in adult surgical patients has been correlated with an increase in the occurrence of surgical site wound infections, increased bleeding, slower recovery from anesthetics, prolonged hospitalization, and increased healthcare costs. Pediatric surgical patients are at potentially increased risk for hypothermia because of their smaller body size, limited stores of subcutaneous fat, and less effective regulatory capacity. This risk is exacerbated during pediatric spinal surgery by lower preoperative temperature, increased surface exposure to cold during induction and positioning, and prolonged surgical procedure times. The purpose of this quality improvement initiative was to reduce the duration of hypothermia for pediatric patients undergoing spine surgery.

METHODS Demographic and clinical data were collected on 162 patients who underwent spinal deformity surgery between October 1, 2017, and July 31, 2019. Data points included patient age, gender, diagnosis, surgical procedure, and temperature readings throughout different phases of perioperative care. Temperatures were obtained upon arrival to the day of surgery, upon presentation to the operating room, during prone positioning, at incision, and at the end of the procedure. Twelve patients were analyzed prior to implementation of a protocol, while 150 patients composed the post-protocol group.

RESULTS Using descriptive statistics, the authors found that the average body temperature at the time of incision was 34.0°C prior to the adoption of a preoperative warming protocol, and 35.3°C following a preoperative warming protocol ($p = 0.001$). There were no complications, such as burns, hyperthermia, or arrhythmias, related to preoperative warming of patients.

CONCLUSIONS The placement of a warming blanket on the bed prior to patient arrival and actively targeting normothermia reduced the incidence and duration of hypothermia in pediatric patients undergoing spine surgery with no adverse events.

<https://thejns.org/doi/abs/10.3171/2020.8.PEDS20297>

KEYWORDS perioperative hypothermia; spinal deformity; quality improvement; preoperative hypothermia; spine

BODY temperature homeostasis is a tightly regulated process, with daily core body temperature variation of 1°C.¹ Pediatric patient homeostasis is disrupted by agents used for general anesthesia,^{1–4} leading to diminished capacity to regulate temperature. This disruption, compounded by an increased body surface area-to-mass ratio, less subcutaneous fat, and decreased intrinsic regulatory ability,⁵ all further lead to a greater risk of hypothermia in children undergoing surgery. The complications of hypothermia in surgical patients are well documented, including coagulopathy, impaired immune function, suboptimal wound healing capacity,⁶ decreased clearance of anesthetic agents,⁷ and prolonged hospitalization,⁸ thereby increasing healthcare costs.

Patients undergoing spine surgery were observed by an operating room nurse to have marked decreased core body temperatures prior to surgery onset. This led to the institution of a nurse-driven quality improvement initiative with the goal of reducing the severity and duration of hypothermia, as defined by a temperature less than 36.0°C prior to the start of the operation.

Methods

Data were collected on patients undergoing elective spine surgery necessitating fusion by the pediatric neurosurgery or pediatric orthopedic surgical groups. Data collection began October 1, 2017, through July 31, 2019, for

SUBMITTED April 16, 2020. **ACCEPTED** August 21, 2020.

INCLUDE WHEN CITING Published online January 29, 2021; DOI: 10.3171/2020.8.PEDS20297.

TABLE 1. Patient demographics and temperature measurements

Variable	Pre-Protocol (n = 12)	Post-Protocol (n = 150)	p Value
Age (yrs)	12.58	13.32	0.31
Weight (kg)	49.0	50.5	0.88
Height (cm)	153.6	152.4	0.88
BMI (kg/m ²)	22.1	21.8	0.90
Preop temp (°C)	36.4	36.7	0.08
Time to first OR temp measurement (mins)	66.75	5.27	<0.0001
First OR temp (°C)	34.1	36.7	0.001
Time in OR to procedure start (mins)	81.5	88.9	0.176
Temp at procedure start (°C)	34	35.3	0.001

Temp = temperature.

Data are given as means unless otherwise indicated.

the study (post-protocol) cohort. A population of 12 consecutive patients who were cared for with standard room temperature and exposure-limiting methods had data collected in a retrospective manner. This represents the control (pre-protocol) cohort. Prospective data were then collected on the subsequent 150 patients who were then cared for using the operating room warming protocol that included an underbody forced-air warming blanket (Bair Hugger System, 3M) set at 43°C, placed and turned on in the preoperative area directly under the patient and gown. The warming blanket remained in place, but not powered on, during transport from the preoperative area to the operating room. The forced-air warming blanket was reconnected and powered on as the patient entered the room. The warming blanket remained in place until preparation for prone positioning. The operating room was also intentionally warmed, but without a specific temperature goal.

In the control group, the first temperature upon room entry and the temperature at incision were recorded. In the warming intervention group, patient temperature was measured at preoperative surgical area arrival, operating

room arrival, secured prone positioning, and incision. This was recorded by the preoperative nurse and operating room circulating nurse onto designated study forms. Two authors then transferred this information to a de-identified spreadsheet for analysis. The method of temperature measurement was also recorded. The patients' demographic data collected included age, gender, weight, height, diagnosis, surgeon, and specific surgical procedure.

Statistical Analysis

The aforementioned variables were analyzed by univariate analysis using the Student t-test to compare means between the two cohorts. Statistical significance was set at $p < 0.05$ prior to data analysis.

Results

Patients demonstrated no statistical difference in age, height, weight, BMI, and temperature in the preoperative area (Table 1). The average body temperature at incision prior to warming protocol implementation was 34.0°C, a decrease from the operating room entry temperature by 0.1°C. Following the use of underbody forced-air warming blanket application in the preoperative area and active attention to operating room ambient temperature, this average temperature increased to 35.3°C ($p = 0.001$). When analyzing all patients, intervention patients in the preoperative area and at room entry were the warmest at 36.7°C. Observational patients at skin incision were the coolest at 34.0°C. The largest observed decrease in temperature occurred in the observational cohort between the preoperative area and first operating room temperature measurement, which was 2.3°C (Fig. 1). This was improved to a change of 0°C following protocol implementation. The time from temperature measurement decreased from 67 minutes in the observational cohort to 5 minutes in the intervention group. No complications were observed from use of the underbody forced-air warming blankets.

Discussion

Patient warming has not always been recognized as beneficial to outcomes. In fact, purposeful cooling of pedi-

FIG. 1. Temperature (°C) trends between the preoperative area and procedure commencement. Figure is available in color online only.

atric patients undergoing cardiac and noncardiac surgery to 29°C was a component of anesthesia and included ice bath submersion and anesthetic agents to control shivering. Patients were then hyperventilated to compensate for the metabolic acidosis. These patients experienced a 13% death rate, which was ascribed to the underlying cardiac disease, but bleeding and thrombosis complications were also culprits.⁹ As recently as 2009, mild hypothermia in pediatric patients undergoing scoliosis surgery was found to be protective from surgical site infections.¹⁰ Fortunately, marked changes in pre- and perioperative patient management over several decades have occurred. The use of forced-air warming blankets in pediatric patients undergoing scoliosis was found to be more effective in warming patients than standard methods, but all other outcome metrics, including blood loss and time to extubation, were unchanged.¹¹

Hypothermia in surgical patients has several deleterious effects. The clot formation is altered as there is reduced thromboxane A3 that leads to initial platelet plug formation.¹² The coagulation cascade is also altered at temperatures below 37°C,¹³ further worsening coagulopathy. A meta-analysis of adult patients with mild (34°C–36°C) hypothermia revealed both increased blood loss and increased risk for blood transfusion. Specifically, for a change in 1°C, patients experienced a 16% decrease in estimated blood loss. In addition, the relative risk of need for a blood transfusion was increased by 22% in the group that was 1° cooler.¹⁴ Wound healing is also of concern as hypothermia leads to vasoconstriction, decreased tissue oxygen partial pressure, and therefore decreased oxidative killing of bacteria by neutrophils. Macrophages are less able to mobilize, and there is also decreased tissue healing from hypothermia.⁶

The greatest decrease in temperature occurred between operating room entry and incision in the observation cohort. On average, more than 1 hour passed from operating room entry until temperature recording in the first patient. In the intervention cohort, this was decreased to just over 5 minutes. This was a statistically significant finding and an unexpected outcome. While the primary intervention was the addition of an underbody forced-air warming blanket, increased attentiveness to patient temperature was likely a second, unintended intervention. The observation cohort's greatest decrease in temperature was from room entry to first temperature measurement. This likely correlates to the greatest drop in patient temperature from first operating room temperature to prone positioning in the intervention group. During this time is when increased patient skin exposure takes place for line, neuromonitoring, and catheter placement. In addition, induction of anesthesia included a paralytic agent, reducing the patient's ability to shiver and intrinsically generate heat. The temperature drop is not as great in the intervention group due to the presence of the underbody heating blanket, and one could argue, the Hawthorne effect, or simply paying closer attention to the issue at hand.

The initial solution to managing preoperative hypothermia in pediatric patients undergoing spinal fusion surgery was not initially straightforward. Patient skin exposure upon entering the operating room was inevitable as prepa-

ration for surgery was concurrent among the anesthesia, nursing, and neuromonitoring teams. Even then, the time from room entry was on average between 80 and 90 minutes for both cohorts. In addition, the solution had to allow continued patient accessibility and portability. The underbody forced-air heating blanket proved an excellent solution. Forced-air warming blankets are commonplace in the operating room, but application in the preoperative area and continued use during times of increased patient exposure while preparing for surgery proved a useful intervention. The operating room was already equipped with the heating units, and the cost per disposable blanket was nominal and included in an operating room charge bundle, whether or not it was applied to the patient. No unexpected complications were identified from the use of the underbody forced-air heating blankets.

Limitations of the Study

A very specific patient population was observed, limiting the generalizability of our findings. Also, as previously mentioned, the decrease in severity of hypothermia may have resulted from increased situational awareness, as patient temperature was checked more rigorously in the interventional cohort. Lastly, improvement of hypothermia was not correlated with outcomes, including but not limited to estimated blood loss, wound healing/infection, and length of stay.

Conclusions

Perioperative hypothermia has been associated with increased surgical site infection, increased operative bleeding, slower anesthetic recovery, and prolonged hospitalizations. The use of an underbody forced-air heating blanket preoperatively led to a decrease in severity of hypothermia in pediatric patients undergoing elective spine fusion surgery compared with a cohort without additional warming adjuncts, thereby reducing overall surgical risks.

References

1. Sessler DI, Lee KA, McGuire J. Isoflurane anesthesia and circadian temperature cycles in humans. *Anesthesiology*. 1991;75(6):985–989.
2. Matsukawa T, Kurz A, Sessler DI, et al. Propofol linearly reduces the vasoconstriction and shivering thresholds. *Anesthesiology*. 1995;82(5):1169–1180.
3. Ozaki M, Sessler DI, Suzuki H, et al. Nitrous oxide decreases the threshold for vasoconstriction less than sevoflurane or isoflurane. *Anesth Analg*. 1995;80(6):1212–1216.
4. Kurz A, Go JC, Sessler DI, et al. Alfentanil slightly increases the sweating threshold and markedly reduces the vasoconstriction and shivering thresholds. *Anesthesiology*. 1995; 83(2):293–299.
5. Tander B, Baris S, Karakaya D, et al. Risk factors influencing inadvertent hypothermia in infants and neonates during anesthesia. *Paediatr Anaesth*. 2005;15(7):574–579.
6. Sessler DI. Perioperative thermoregulation and heat balance. *Lancet*. 2016;387(10038):2655–2664.
7. Leslie K, Sessler DI, Bjorksten AR, Moayeri A. Mild hypothermia alters propofol pharmacokinetics and increases the duration of action of atracurium. *Anesth Analg*. 1995;80(5): 1007–1014.
8. Kurz A, Sessler DI, Lenhardt R. Perioperative normother-

- mia to reduce the incidence of surgical-wound infection and shorten hospitalization. *N Engl J Med*. 1996;334(19):1209–1215.
9. Lewis GB Jr, Leigh MD, Belton MK. Hypothermia in 363 pediatric surgical procedures. *Anesth Analg*. 1958;37(1):20–28.
 10. Linam WM, Margolis PA, Staat MA, et al. Risk factors associated with surgical site infection after pediatric posterior spinal fusion procedure. *Infect Control Hosp Epidemiol*. 2009;30(2):109–116.
 11. Murat I, Bernière J, Constant I. Evaluation of the efficacy of a forced-air warmer (Bair Hugger) during spinal surgery in children. *J Clin Anesth*. 1994;6(5):425–429.
 12. Valeri CR, Khabbaz K, Khuri SF, et al. Effect of skin temperature on platelet function in patients undergoing extracorporeal bypass. *J Thorac Cardiovasc Surg*. 1992;104(1):108–116.
 13. Reed RL II, Johnson TD, Hudson JD, Fischer RP. The disparity between hypothermic coagulopathy and clotting studies. *J Trauma*. 1992;33(3):465–470.
 14. Rajagopalan S, Mascha E, Na J, Sessler DI. The effects of mild perioperative hypothermia on blood loss and transfusion requirement. *Anesthesiology*. 2008;108(1):71–77.

Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Ducis, Jea. Acquisition of data: all authors. Analysis and interpretation of data: Ducis, Seibold, Jea. Drafting the article: all authors. Critically revising the article: Ducis, Jea. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Ducis. Administrative/technical/material support: all authors. Study supervision: all authors.

Supplemental Information

Previous Presentations

Data from this study were previously presented orally at the Annual Meeting of the AANS/CNS Section on Pediatric Neurological Surgery, December 6, 2019, in Scottsdale, Arizona.

Current Affiliations

Dr. Jea: Department of Neurological Surgery, The University of Oklahoma College of Medicine, Oklahoma City, Oklahoma.
Ms. Bremer: Seattle Children's Hospital, Seattle, Washington.

Correspondence

Katrina Ducis: University of Vermont College of Medicine, Burlington, VT. katrina.ducis@uvmhealth.org.