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Reducing Intraoperative Hypothermia in Infants from the Neonatal Intensive Care Unit

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Abstract

Introduction: Infants from the neonatal intensive care unit (NICU) undergoing surgery in the operating room (OR) are at greater risk for hypothermia during surgery than afterward due to environmental heat loss, anesthesia, and inconsistent temperature monitoring. A multidisciplinary team aimed to reduce hypothermia (<36.1 °C) for infants at a level IV NICU at the beginning of the operation (first OR temperature) or at any time during the operation (lowest OR temperature) by 25%. **Methods:** The team followed preoperative, intraoperative (first, lowest, and last OR), and postoperative temperatures. It sought to reduce intraoperative hypothermia using the "Model for Improvement" by standardizing temperature monitoring, transport, and OR warming, including raising ambient OR temperatures to 74°F. Temperature monitoring was continuous, secure, and automated. The balancing metric was postoperative hyperthermia (>38 °C). **Results:** Over 4 years, there were 1235 operations: 455 in the baseline and 780 in the intervention period. The percentage of infants experiencing hypothermia upon OR arrival and at any point during the operation decreased from 48.7% to 6.4% and 67.5% to 37.4%, respectively. Upon return to the NICU, the percentage of infants experiencing postoperative hypothermia decreased from 5.8% to 2.1%, while postoperative hyperthermia increased from 0.8% to 2.6%. **Conclusions:** Intraoperative hypothermia is more prevalent than postoperative hypothermia. Standardizing temperature monitoring, transport, and OR warming reduces both; however, further reduction requires a better understanding of how and when risk factors contribute to hypothermia to avoid further increasing hyperthermia. Continuous, secure, and automated data collection improved temperature management by enhancing situational awareness and facilitating data analysis. *(Pediatr Qual Saf 2023;8:e665; doi: 10.1097/pq9.0000000000000665; Published online July 10, 2023.)*

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INTRODUCTION

Available Knowledge

About one-third of infants admitted to children's hospitals' neonatal intensive care units (NICUs) require surgery and are thus at increased risk for hypothermia during the perioperative period.[1] Infants are already at greater risk for hypothermia than children or adults because of their high body surface area to volume ratio, increased evaporative heat loss, and the absence of brown adipose tissue in preterm infants.[2,3] The environmental heat loss compounds this risk from an open body cavity to a cold operating room (OR) and anesthesia exposure that induces vasoplegia.[4,5] Hypothermic infants are at risk for infection,[6] coagulopathy,[4] mortality,[7–9] increased oxygen consumption, and the need for cardiorespiratory support.[10,11]

Problem Description

Several improvement initiatives have addressed postoperative hypothermia; however, few have addressed intraoperative hypothermia.[12] The NICU of the Ann & Robert H. Lurie Children's Hospital of Chicago participated in the Children's Hospital Neonatal Consortium's (CHNC) quality improvement project, Safe Transitions and Euthermia in the Perioperative Period in Infants and

Newborns (STEPP IN), to decrease postoperative hypothermia, defined as a temperature <36.1 °C upon return to the NICU.[13] Preoperative, intraoperative (first, lowest, and last OR temperature), and postoperative temperatures were manually abstracted and reviewed. While the NICU achieved low rates of postoperative hypothermia, high rates of intraoperative hypothermia persisted, consistent with a prior observational study.[14] Furthermore, distinguishing between the rapid onset of hypothermia and probe detachment complicated intraoperative temperature monitoring.

Rationale

A multidisciplinary team convened to improve infant intraoperative temperature management. Using the "Model for Improvement,"[15] the team standardized temperature monitoring and thermal support during the infant's transport and operation. Monitoring using a preoperatively placed continuous temperature probe (CTP) enhanced providers' situational awareness of infant temperature and guided support. The specific, measurable, attainable, relevant, and time-bound aim was to implement interventions to reduce hypothermia (<36.1 °C) at the beginning of the operation (first OR temperature) and at any time (lowest OR temperature) for NICU infants by 25% by December 2020. The purpose of this article is to describe the implementation tools used and lessons learned from this multidisciplinary quality improvement project following the SQUIRE 2.0 guidelines.[16]

METHODS

Ethics

The Lurie Children's Hospital institutional review board determined that the project was exempt because it did not meet the definition of human subjects research (IRB 2017-1381). Team members reviewed protected health information and kept it on the hospital's secure network drive only when necessary.

Context

The Lurie Children's Hospital is a free-standing children's hospital affiliated with Northwestern University. This regional-referral NICU has 64 beds and is a member of the CHNC, a quality collaborative of 41 United States and Canadian children's hospital NICUs.[1,17] The NICU has approximately 550 admissions annually, with an average census of 57 infants per day. The American College of Surgeons has recognized the hospital as a Level 1 Children's Surgery Center since 2016.[18]

Intervention

The Lurie Children's Hospital Center for Quality and Safety formed a multidisciplinary team of members from anesthesiology, NICU and OR nursing, surgery, neonatology, and Data Analytics and Reporting. The project's scope included operations in the OR and excluded bedside operations in the NICU and imaging procedures. The team initially met twice per month and performed a gap analysis with the development of a fishbone (**see Figure, Supplemental Digital Content 1, *http://links.lww.com/PQ9/A497***) and key driver diagrams (Fig.1). The analysis revealed several barriers, including variations in timing and source of the infant temperature, variations with the transport process and equipment, knowledge deficits in the use of warming equipment for transport and in the OR, and a lack of recognition that intraoperative hypothermia was a problem. An anesthesia provider usually places a CTP in the OR, delivering a temperature measurement to the electronic health record (EHR) every minute. Probe placement varied regarding performance, location (usually axillary and occasionally nasopharyngeal or esophageal), and timing (upon OR arrival or following anesthesia induction). Superficial probe detachment occurred and made distinguishing between hypothermia and a falsely depressed reading challenging. In addition, it contributed to a lack of faith in measurements.

Using the "Model for Improvement," the team implemented several interventions through 2 Plan-Do-Study-Act (PDSA) cycles. (**See Figure 2, Supplemental Digital Content, *http://links.lww.com/PQ9/A498*.**) The first PDSA cycle implemented in January 2020 ensured documentation of OR ambient temperatures and temperatures of at least 74°F (23.33 °C, OR thermostats are in Fahrenheit, not Celsius), a recommendation from the CHNC based on the association with decreased postoperative hypothermia.[13] The second PDSA cycle implemented in December 2020 standardized: (1) temperature monitoring with a preoperatively placed CTP, (2) the transport process whereby infants are transferred by an anesthesia provider and NICU nurse in a thermal bed (in servo mode) with the shuttle and a thermoreflective cap, and (3) warming equipment used in the OR including a forced air warmer underneath the patient, a portable heat lamp during infant exposure, and warmed betadine, fluid, and irrigation solutions.

The bedside NICU nurse preoperatively placed a CTP rectally (axillary if contraindicated) before departure. This placement ensured monitoring during transport to and from the OR, facilitated consistent timing of the first OR temperature, and provided a core temperature measurement less susceptible to detachment or the environment.[19] Previously, the NICU nurse transferred non-ventilated infants to a preoperative waiting room, while an anesthesia provider transferred ventilated infants directly from NICU to the OR. With the revised transport process, the anesthesia provider and nurse transferred infants using the thermal bed and shuttle (open crib and chemical mattress for larger infants) directly to the OR, bypassing the preoperative waiting room. The shuttle is a transportable power source for thermal beds providing up to 45 minutes of auxiliary power to maintain thermal support during intrahospital transport. In addition, the NICU nurse was available to troubleshoot issues with the bed and/or shuttle.

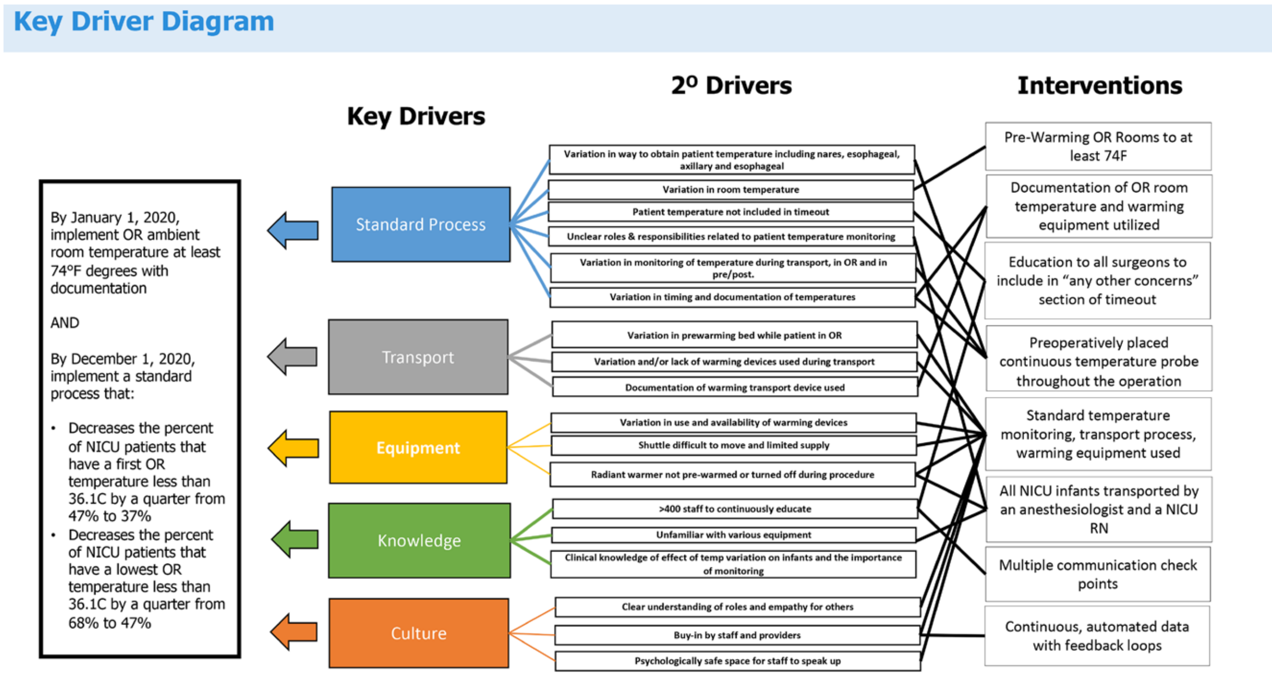

Fig. 1. Key driver diagram.

Study of the Interventions

The multidisciplinary team automated data collection and reporting to facilitate review. It edited discrete fields within the EHR to accurately capture thermal and transport processes. Using internal Microsoft Forms (Redmond, Wash., nurse data abstractors sent surveys postoperatively to all anesthesia providers, neonatologists, and NICU nurses involved in the operation for feedback and to reinforce existing PDSA cycles. (**See Table, Supplemental Digital Content 1, *http://links.lww.com/PQ9/A502*.**) Also, the team reviewed metrics and surveys regularly to evaluate barriers to adhering to the revised processes and ensure the continuing education of new providers.

Automatically reporting temperatures required a set of rules to define each temperature and determine whether an acute deviation in the infant's temperature represented a real clinical change or probe detachment (still a concern, albeit less, with rectal probes). Previously, nurse data abstractors manually reviewed operative records to determine preoperative, intraoperative, and postoperative temperatures using infant location times entered in the EHR by nursing (eg, "NICU out," "OR in"). Then, they used clinical judgment to determine which temperatures to disregard. Through iterative case review, the multidisciplinary team developed the following automated rules to determine each temperature:

1. exclude any infant undergoing therapeutic hypothermia,
2. exclude any temperature <31 °C,
3. define preoperative temperature as the last measurement before "NICU out" time,
4. define intraoperative temperatures as measurements after "OR in" and before "OR out" times,
5. include 3 or more consecutive intraoperative measurements where each temperature was <0.3 °C per minute different than the preceding temperature to determine the first, lowest, and last temperatures (stability rule), and
6. define postoperative temperature as the first measurement after "NICU in" time.

An example of the stability rule is provided in **Figure 3, Supplemental Digital Content, *http://links.lww.com/PQ9/A499*** and allows for a maximum deviation of ±1 °C every 5 minutes. The team retrospectively compared baseline automated and manually abstracted temperatures using boxplots and 2-sided paired *t* tests.

Measures

All metrics used automated data. Outcome metrics comprised the percentage of infants with first and lowest OR temperatures below 36.1 °C (ie, first and any OR hypothermia). A secondary outcome metric was the percentage of infants with postoperative hypothermia upon return to the NICU. Process metrics included: (1) OR ambient temperature ≥74°F and documentation of OR ambient temperature, (2) shuttle utilization with use of a thermally regulated bed for infant transport, (3) forced-air warmer use in the OR, and (4) use of a preoperatively placed CTP throughout the operation. The balancing metric was the percentage of infants with postoperative hyperthermia upon return to the NICU (>38 °C).

Analysis

Infant demographic data described the cohort. Operative characteristic data and the frequency of temperature documentation described operations in the baseline period to the intervention period using a Wilcoxon Rank Sum or χ^2 test when appropriate—2-tailed tests with an α of 0.05 defined statistical significance.

P-charts and run charts tracked outcomes, processes, and balancing metrics. Data Analytics and Reporting updated the charts monthly for review through the hospital's secure portal using SAS Enterprise Guide version 7.1 (Cary, N.C.). The team considered a run of 8 points above or below the centerline special cause variation and recalculated centerlines for prospective tests.[20]

RESULTS

The project began as anticipated on January 1, 2020, with the first PDSA cycle. The COVID-19 pandemic delayed the second PDSA cycle until December 1, 2020. Therefore, the intervention period was extended through April 30, 2022. There were 455 operations in the baseline period and 780 in the intervention period. The entire cohort's median gestational age and birth weight were 34 weeks (interquartile range, 27–37) and 2090 g (870–3020), respectively, and the cohort was 38.8% female. The median number of surgeries per infant was 1 (1–2), with 19 infants having surgery during baseline and intervention periods. Operative characteristics are provided in Table 1 and did not differ significantly between periods except for weight at the time of surgery. Ambient OR temperatures were frequently higher than 74F. Temperature documentation increased intraoperatively compared to the baseline period.

Figure 2 demonstrates pairs of manually abstracted and automated temperatures from the baseline period. They were generally similar; however, automated last OR temperatures were 0.1 °C higher (P = 0.02) than manual temperatures. Nevertheless, automated data demonstrated similar findings—most infants experienced hypothermia during the operation, with the largest drop in temperature occurring between the preoperative NICU and the first OR temperatures. It was unclear, however, whether this drop occurred during transfer or after arrival to the OR because of inconsistency in the timing of CTP placement during the baseline period.

The percentage of infants experiencing first OR hypothermia decreased with centerline shifts from 48.7% to 35.7% just before the first PDSA cycle .in December 2019 following the announcement of the project and again from 35.7% to 6.4% before the second PDSA cycle in September 2020 (Fig. 3). Likewise, the percentage of infants experiencing hypothermia decreased with a centerline shift from 67.5% to 37.4% before the second PDSA cycle in September 2020 (Fig. 4). In addition, the percentage of postoperative hypothermia upon return to the NICU decreased from 5.8% to 2.1% just before the first PDSA cycle. (**See Figure 4, Supplemental Digital Content, *http://links.lww.com/PQ9/A500*.**)

Table 1. Operative Case Characteristics and Temperature Documentation

Characteristic and Temperature Documentation	Baseline	Intervention	*P*
Number of procedures	455	780	—
Case characteristics			
Age at surgery in days	61 (14–139)	61 (15–141)	0.743
Weight at surgery (g)	3,600 (2,800–4,880)	3,853 (2,998–5,193)	0.006
OR time* (h)	2.4 (1.6–3.3)	2.3 (1.5–3.4)	0.405
Ambient OR temperature (°F)			
Beginning of case	NA	75.5 (74–77)	NA
End of case	NA	75.5 (74.5–77)	NA
Surgical type (primary procedure)			
Abdominal and gastro-intestinal system	160 (35.2)	287 (36.8)	0.458
Access	4 (0.9)	13 (1.7)	
Airway	27 (5.9)	30 (3.9)	
Central nervous system	52 (11.4)	86 (11.0)	
Cardiovascular system†	6 (1.3)	11 (1.4)	
Genitourinary system	50 (11.0)	73 (9.4)	
Head and neck	39 (8.6)	59 (7.6)	
Musculoskeletal system	3 (0.7)	1 (0.1)	
Skin and soft tissue	4 (0.9)	10 (1.3)	
Thoracic noncardiac†	107 (23.5)	207 (26.5)	
Other‡	3 (0.7)	3 (0.4)	
Temperature documentation			
Preoperative NICU	452 (99.3)	777 (99.6)	0.515
First OR	366 (80.4)	722 (92.6)	<0.001
Lowest OR	366 (80.4)	722 (92.6)	<0.001
Last OR	366 (80.4)	722 (92.6)	<0.001
Postoperative NICU	453 (99.6)	778 (99.7)	0.585

Reported as median with interquartile range, or number and percent.
*OR time determined by "NICU departure" and "NICU return" times in EHR.
†Patent ductal arteriosus ligations were documented as "thoracic noncardiac."
‡Unspecified primary procedure type.
NICU, neonatal intensive care unit; NA, not applicable; OR, operating room.

The percentage of infants transferred from the NICU to the OR with the shuttle and monitored with a preoperatively placed CTP increased from May to November 2020 (**See Figure 5, Supplemental Digital Content, *http://links.lww.com/PQ9/A501***); special cause variation coincided with the second PDSA cycle in December 2020. The percentage of operations with an ambient OR temperature documented and at least 74°F and use of a forced air warmer remained stable at 91.3%, 88.3%, and 89.0%, respectively. The percentage of postoperative hyperthermia upon return to the NICU increased from 0.8% to 2.6% with the second PDSA cycle (Fig. 5).

Survey response rates were 59%, 55%, and 64% for anesthesia providers, neonatology, and NICU nursing, respectively. The multidisciplinary team targeted cultural barriers ("Hate the shuttle…hard to maneuver in tiny operating room. Everyone hates them") and process gaps ("Bed was not plugged in to charge after OR drop off") revealed by surveys.

Post Hoc Analysis

Infant weights were significantly higher in the intervention period; therefore, we performed ordinary least

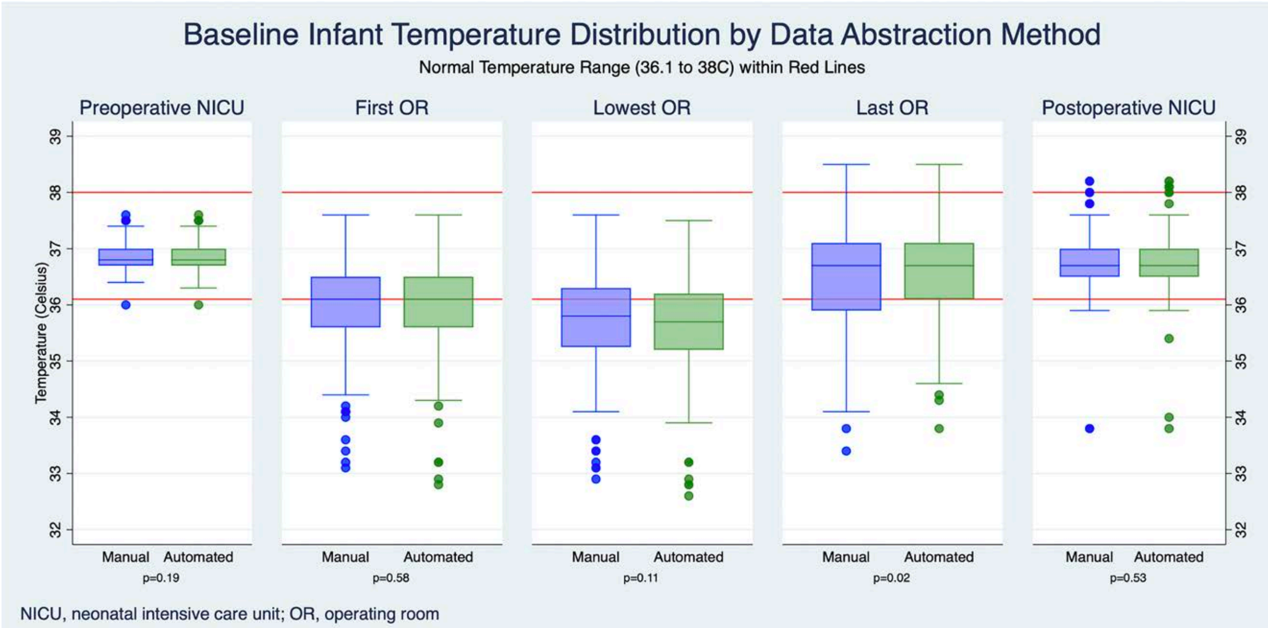

Fig. 2. Baseline infant temperature distribution by the data abstraction method.

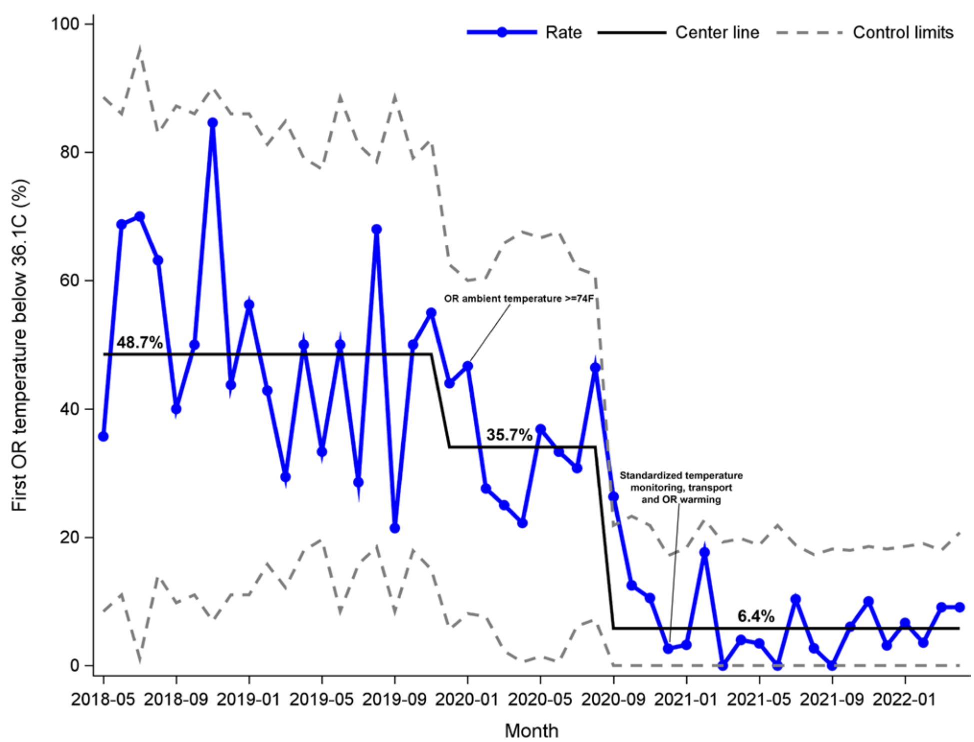

Fig. 3. First OR hypothermia P-chart.

squares regressions to determine the association between weight and perioperative temperatures. For every 1000 g increase in weight at the time of the operation, there was an increase in the first OR temperature by 0.04 °C (95% confidence intervals, 0.01–0.06; $P = 0.003$), an increase in the lowest OR temperature by 0.07 °C (0.04–0.1; $P < 0.001$), and a decrease in the postoperative temperature by −0.03 °C (−0.05 to −0.02; $P < 0.001$).

DISCUSSION

Summary

Intraoperative hypothermia is more prevalent than postoperative hypothermia for infants from the NICU undergoing surgery in an OR. A multidisciplinary team reduced rates of intraoperative hypothermia by standardizing temperature monitoring, the transport process to the OR, and

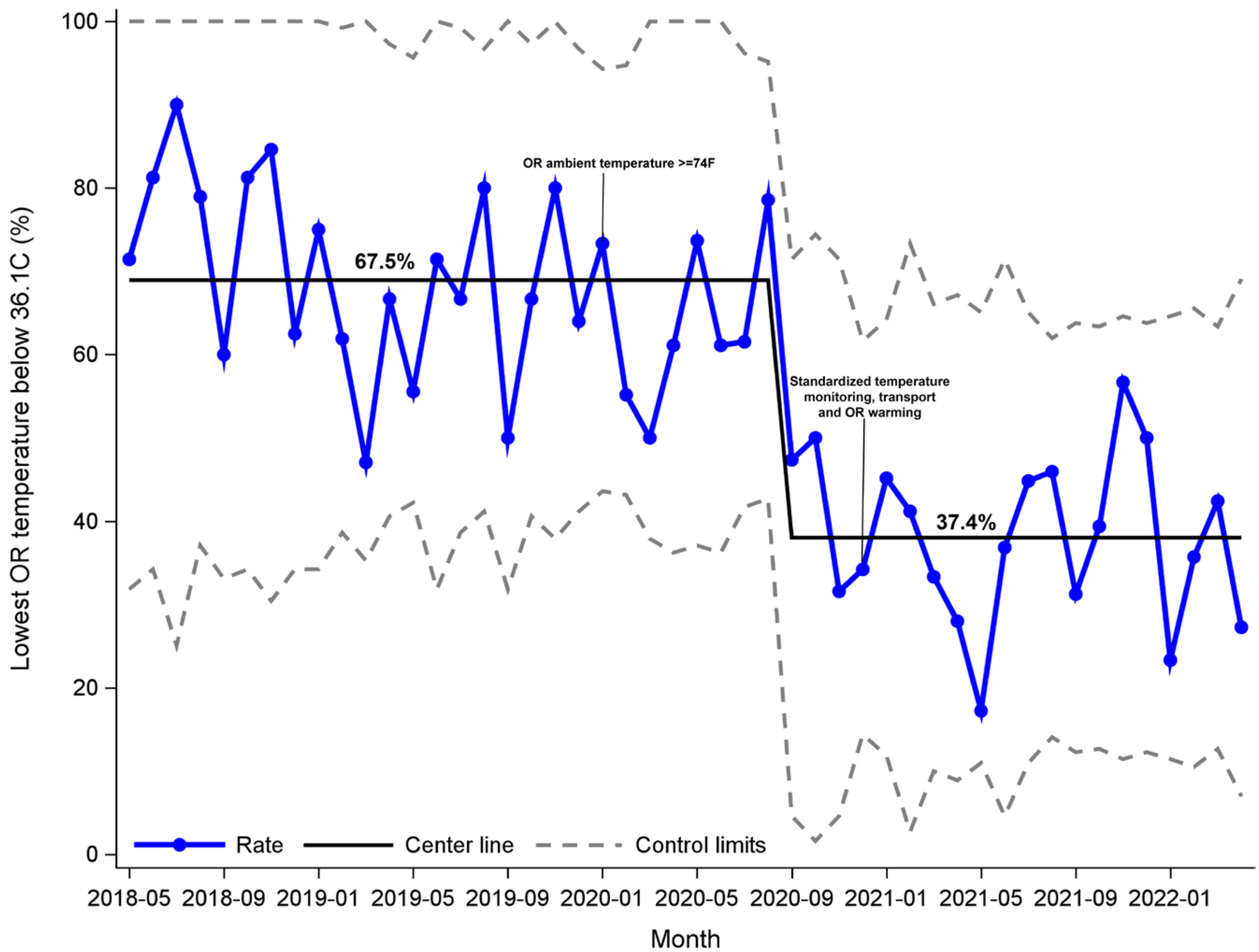

Fig. 4. Any OR hypothermia P-chart.

intraoperative warming. Postoperative hypothermia rates decreased slightly while hyperthermia rates increased slightly, but rates remained similar to another large, single-center improvement project with hypothermia and hyperthermia rates of 2.5% and 3.6%, respectively.[21]

The strengths of this project were the large cohort of infants and the use of continuous, secure, and automated data to ensure euthermia for infants before, during, and after an operation despite a pandemic that affected staffing and supplies. Most projects have addressed postoperative hypothermia in surgical infants[13,19,21]; one study addressed intraoperative hypothermia with a cohort 90% smaller than this project.[12]

Interpretation

The high rates of intraoperative hypothermia surprised many; however, probe detachment reduced confidence in measurements. Some episodes, identified by an abrupt change or extreme outlier (eg, 25 °C), were obvious to anesthesia providers in the OR and data abstractors manually reviewing cases. Other episodes were not. Improvement required standardization of CTP type and a method for distinguishing between probe detachment and hypothermia. The team developed the rules for including and excluding data through iterative case reviews. Although they may have excluded accurate values, the similarity between automated and manually abstracted data performed by a nurse is reassuring (Fig. 2). Simply keeping all temperature values was not reasonable. Objective criteria, consistent throughout the entire project, were ideal.

The team also standardized CTP timing. The bedside NICU nurse placed the CTP before departure from the NICU. This enhanced awareness during transport and ensured consistent timing of first OR temperatures. First OR hypothermia may have improved with routine capture of temperatures upon arrival to the OR when the patient was most likely to be the warmest; however, the rate of first OR hypothermia also improved with the first PDSA cycle and likely benefited from improved thermal support during transport. Standardization of CTP timing would have been unlikely to impact rates of any OR hypothermia because most infants already had a continuous probe in place.

Improvement preceded each PDSA cycle. Providers "[did] not make the decision to adopt changes at the same

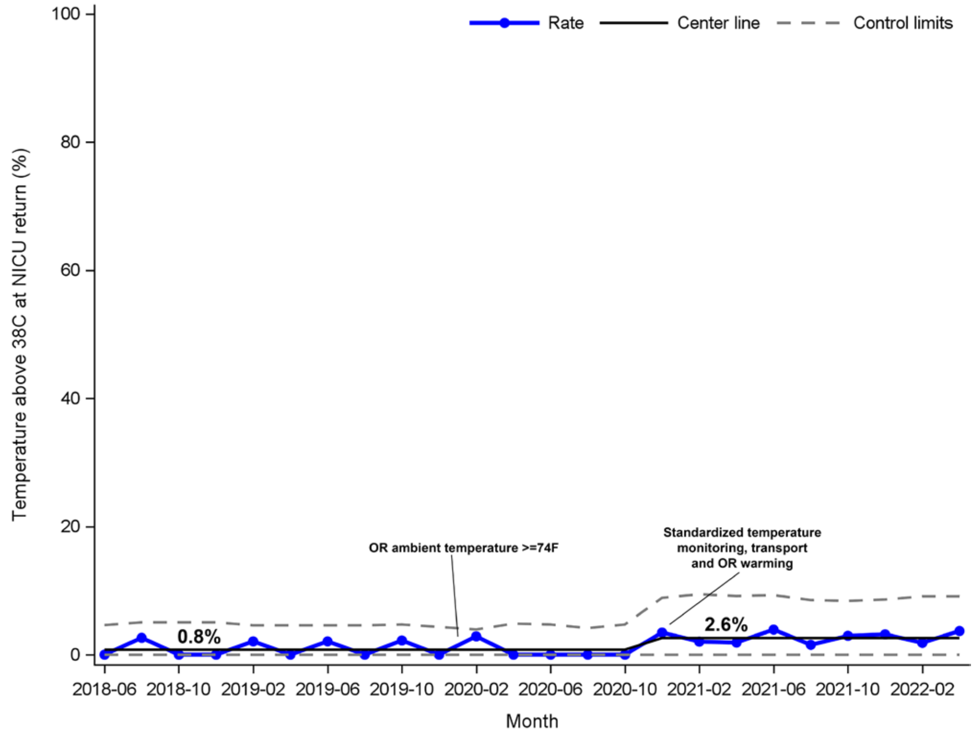

Fig. 5. Postoperative hyperthermia in the NICU P-chart.

time."[22] Early adopters were eager to participate following multidisciplinary conversations. A reduction in the rate of first OR hypothermia began in December 2019, before the first PDSA cycle (January 2020), following several preparatory meetings. Further reduction in the first and a reduction in any OR hypothermia began in September 2020, before the pandemic-delayed introduction of the second PDSA cycle in December 2020. Shuttle and preoperatively placed CTP usage were negligible before May 2020. Usage slowly increased and contributed to early reductions in intraoperative hypothermia before the second PDSA cycle.

The CHNC collaboration and support of hospital leaders played important roles in the improvement effort. The collaborative's focus on perioperative care highlighted significant deficiencies compared to other NICUs in the collaborative.[13] The hospital's Center for Quality & Safety coordinated care and resources between multiple departments. It achieved consensus and buy-in from providers despite competing factors such as perspiring surgeons, busy anesthesia providers transporting all infants to the OR, and delays associated with the difficulty of shuttle and thermal bed use. It identified key participants vested in revising this process and facilitated adoption with their colleagues, following up on missed opportunities and process gaps identified through observation and surveys. It provided data analysts who worked iteratively with providers to generate valid, actionable, and real-time data. The success of the automated data reporting depended on providers who understood the data capture and storage process and data analysts who understood the significance and limitations of clinical data. Medicine prizes specialization; however, this success relied upon individuals with various talents "importing" skills from one domain to another.[23]

Using the current approach, further decreasing intraoperative and postoperative hypothermia may not be possible without further increasing postoperative hyperthermia. Therefore, a targeted approach is required. The ad hoc analysis demonstrated that smaller infants have lower intraoperative and warmer postoperative temperatures, though the magnitude appears small. For the same heat exchange, smaller infants with less mass will experience a greater change in temperature than larger infants.[24] A previous study determined that infants undergoing neurosurgery are at increased risk for hypothermia.[21] Regardless, further studies are needed to understand how and when infant (weight and comorbid conditions), anesthetic (preparation and medications), and surgical (incision timing, type, and length of operation) factors interact to affect temperature. Technological improvements are also needed. Surveys revealed a significant barrier to maintaining a normal temperature was the inconsistent or improper use of a thermal bed with the shuttle, which can be difficult to maneuver and use without training.

Limitations

There are limitations. First, this was a single-center project. Each hospital NICU and OR are different; therefore, each may require different interventions to improve intraoperative hypothermia. Second, the multidisciplinary team defined hypothermia as <36.1 °C following the CHNC multicenter STEPP IN project. As a result, it likely missed episodes of mild hypothermia, defined as 36.0 °C–36.4 °C by the World Health Organization's "Thermal Protection of the Newborn."[25] This guideline, however, does not pertain to infants undergoing surgery. Finally, the team did not measure the impact on anesthesia provider workflow, including OR delays associated with transporting all infants, though anesthesia providers previously transported two-thirds of infants.

Conclusions

Infants undergoing surgery are at risk for intraoperative hypothermia. Maintaining normal temperatures requires the input of key personnel and institutional support to effect cultural change. It also requires actionable, real-time data that track a holistic range of metrics and mitigates measurement errors.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

REFERENCES

1. Murthy K, Dykes FD, Padula MA, et al. The Children's Hospitals Neonatal Database: an overview of patient complexity, outcomes and variation in care. *J Perinatol*. 2014;34:582–586.
2. Rutter N, Hull D. Water loss from the skin of term and preterm babies. *Arch Dis Child*. 1979;54:858–868.
3. Houstěk J, Vízek K, Pavelka S, et al. Type II iodothyronine 5'-deiodinase and uncoupling protein in brown adipose tissue of human newborns. *J Clin Endocrinol Metab*. 1993;77:382–387.
4. Sessler DI. Temperature monitoring and perioperative thermoregulation. *Anesthesiology*. 2008;109:318–338.
5. Nemeth M, Miller C, Bräuer A. Perioperative hypothermia in children. *Int J Environ Res Public Health*. 2021;18:7541.
6. Barie PS. Surgical site infections: epidemiology and prevention. *Surg Infect (Larchmt)*. 2002;3(suppl 1):S9–21.
7. Miller SS, Lee HC, Gould JB. Hypothermia in very low birth weight infants: distribution, risk factors and outcomes. *J Perinatol*. 2011;31(suppl 1):S49–S56.
8. Silverman W, Fertig JW, Berger A. The influence of the thermal newly environment premature upon infants. *Pediatrics*. 1958;22:876–886.
9. Day RL, Caliguiri L, Kamenski C, et al. Body temperature and survival of premature infants. *Pediatrics*. 1964;34:171–181.
10. Malin SW, Baumgart S. Optimal thermal management for low birth weight infants nursed under high-powered radiant warmers. *Pediatrics*. 1987;79:47–54.
11. Morehouse D, Williams L, Lloyd C, et al. Perioperative hypothermia in NICU infants: its occurrence and impact on infant outcomes. *Adv Neonatal Care*. 2014;14:154–164.
12. Hanna M, Htun Z, Islam S, et al. A quality improvement initiative to improve perioperative hypothermia rates in the NICU utilizing checklists. *Pediatr Qual Saf*. 2020;5:e367.
13. Brozanski BS, Piazza AJ, Chuo J, et al. STEPP IN: working together to keep infants warm in the perioperative period. *Pediatrics*. 2020;145:e20191121.
14. Qing M, Peng Z, Ying D, et al. Intraoperative hypothermia in the neonate population: risk factors, outcomes, and typical patterns American Society of Anaesthesiologists. *J Clin Monit Comput*. 2023;37:93–102.
15. Institute for Healthcare Improvement. Science of Improvement. Available at http://www.ihi.org/about/Pages/ScienceofImprovement.aspx. Published 2022. Accessed February 11, 2022.
16. Ogrinc G, Davies L, Goodman D, et al. SQUIRE 2.0 (Standards for QUality Improvement Reporting Excellence): revised publication guidelines from a detailed consensus process. *BMJ Qual Saf*. 2016;25:986–992. 10.1136/bmjqs-2015-004411
17. American Academy of Pediatrics Committee on Fetus and Newborn. Levels of neonatal care. *Pediatrics*. 2012;130:587–597. 10.1542/peds.2012-1999
18. American College of Surgeons. Children's surgery verification. Available at https://www.facs.org/quality-programs/childrens-surgery/childrens-surgery-verification. Published 2022. Accessed February 11, 2022.
19. Engorn BM, Kahntroff SL, Frank KM, et al. Perioperative hypothermia in neonatal intensive care unit patients: effectiveness of a thermoregulation intervention and associated risk factors. *Paediatr Anaesth*. 2017;27:196–204.
20. Benneyan JC. Use and interpretation of statistical quality control charts. *Int J Qual Heal Care*. 1998;10:69–73.
21. Cronin JA, Soghier L, Ryan K, et al. A quality initiative for reducing postoperative hypothermia for neonatal intensive care unit surgical patients. *Pediatr Qual Saf*. 2020;5:e318.
22. Langley GJ, Moen RD, Nolan KM, et al. Spreading improvements: phase for executing and refining the spread plan. *The Improvement Guide*. 2nd ed. Jossey-Bass; 2009:210–213.
23. Epstein D. Deliberate amateurs. *Range: Why Generalists Triumph in a Specialized World*. Riverhead Books; 2019:268–286.
24. Fishbane PM, Gasiorowicz S, Thornton ST. Thermal energy and heat flow. *Physics for Scientists and Engineers*. 2nd ed. Prentice Hall; 1996:485–490.
25. World Health Organization (WHO) Staff, Division of Reproductive Health. *Thermal Protection of the Newborn: A Practical Guide*. World Health Organization; 1997:1–67. Available at https://apps.who.int/iris/handle/10665/63986.