Individual QI projects from single institutions

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A Quality Improvement Initiative to Improve Perioperative Hypothermia Rates in the NICU Utilizing Checklists

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ABSTRACT

Background: Premature infants are at high risk for heat loss. Infants undergoing surgical procedures outside of the neonatal intensive care unit have an increased risk of hypothermia. Hypothermia can lead to delayed recovery, hypoglycemia, metabolic acidosis, sepsis, and emotional stress for the parents. We aimed to reduce the incidence of hypothermia for infants undergoing surgical procedures from a baseline of 44.4% to less than 25% over 3 years (2016–2018) with the utilization of a checklist and education. **Methods:** We conducted a retrospective chart review for all infants undergoing surgical procedures from 2014 to 2015 and prospective data for 2016–2018. Next, we created a multidisciplinary team, educated staff members, and instituted a checklist comprising 9 tasks. We conducted Plan-Do-Study-Act cycles quarterly and audited checklist compliance monthly. **Results:** From 2014 to 2015, the total incidence of perioperative hypothermia was 44.4% (n = 54). After the initiation of the checklist, the overall incidence of hypothermia decreased to 23.4% (n = 124, $P = 0.007$). Hypothermia occurred most frequently while the patient was in the operating room. Furthermore, we noticed that hypothermia was significantly associated with neonates requiring emergency procedures. There was an inverse correlation between overall compliance with checklist usage and the incidence of hypothermia. **Conclusion:** A checklist is a useful and simple tool for maintaining an optimal temperature for postsurgical neonates. Frequent re-education and enforcement of the protocol is necessary. Overall, implementation of the checklist, along with regular education, decreased the total incidence of perioperative hypothermia in the neonatal intensive care unit. *(Pediatr Qual Saf 2020;5:e367; doi: 10.1097/pq9.0000000000000367; Published online September 2, 2020.)*

INTRODUCTION

Infants admitted to the neonatal intensive care unit (NICU), particularly low-birthweight infants, have a limited capacity to thermoregulate and are at risk for developing hypothermia.[1] These infants are also prone to rapid heat loss due to internal factors such as high body-surface-area to weight ratio,[2] reduced glycogen and fat stores, higher body water content, immature skin leading to increased evaporative and heat loss, as well as a poor metabolic mechanism for responding to thermal stress (eg, no shivering).[3–6] Infants undergoing surgical procedures outside of the NICU have an augmented risk of hypothermia.[7] This risk is due to suboptimal thermal environments within the operating room (OR) and during transportation to and from the OR.

Hypothermia in the newborn period is associated with increased morbidity and mortality.[8–11] Cold stress in neonates causes increased sympathetic activity and norepinephrine release. This response increases cellular metabolism as the newborn tries to stay warm.[12] The increased metabolism results in increased oxygen and substrate consumption, putting the newborn at risk for hypoxia, cardiorespiratory complications, and metabolic acidosis. These newborns are also at risk for hypoglycemia because of the increased glucose consumption necessary for heat production.[4]

Perioperatively, the consequences of hypothermia include patient discomfort, platelet dysfunction, coagulopathy,[13] and increased peripheral vasoconstriction associated with a higher risk of wound infection.[14–16] One research study investigating the impact of perioperative

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hypothermia in NICU infants noted that the hypothermic group had significantly more respiratory adverse events ($P = 0.025$), were 6 times more likely to require thermoregulatory interventions ($P < 0.001$), 5 times more likely to require cardiac support interventions ($P < 0.006$), and 3 times more likely to require respiratory interventions ($P = 0.02$) than normothermic infants.[7]

Checklists are common and powerful tools used in many industries to standardize work and create independent checks for critical processes. They have been adopted nationally in a wide variety of hospital settings to reduce medical errors and have significantly reduced morbidity and mortality in multicenter studies.[17,18] One study by Berenholtz et al[19] at John Hopkins Hospital demonstrated that the checklist successfully decreased the incidence of central line-associated infections as well as improved patient care and communication in the ICU. In addition to reducing medical error and near misses, checklists ensure adherence to updated clinical practice guidelines.

Previously, our institution investigated and published a quality improvement (QI) research study aimed at reducing hypothermia in the delivery room using a checklist.[20] The success of the research project in the delivery room brought motivation as well as stimulated interest in applying the checklist to other NICU settings. At the time, we noted that NICU patients at our institution were also having a relatively higher incidence of perioperative hypothermia at 44% as compared to the average national rate reported by the Children's Hospital Neonatal Consortium of approximately 20.3%.[21]

This QI effort at NYU-Winthrop Hospital (NYU-WH) devised a checklist to improve thermoregulation for all infants leaving the NICU for surgical procedures. The global aim of this project was to eliminate the incidence of hypothermia [defined as core temperature less than 97°F (36.1°C)] for infants undergoing surgical procedures. Our specific aim was to decrease the incidence of perioperative hypothermia from a baseline of 44% to less than 25% over 3 years (2016–2018) with the utilization of a checklist and education.

METHODS

Context

NYU-WH is a suburban tertiary care academic hospital in Mineola, N.Y., with an accredited residency training program in general pediatrics. NYU-WH is also a Children's Medical Center and designated regional perinatal center with over 4,800 newborn deliveries per year. A level 4, 36-bed NICU receives approximately 700 admissions per year, with approximately 100 infants born at younger than 32 weeks of gestation. On average, there are 40 surgical procedures performed on NICU patients every year. About one-third of these surgeries are considered emergency cases, which we defined as procedures necessitating surgical intervention within 24 hours of identified abnormality.

We formed a multidisciplinary team consisting of various stakeholders, including neonatologists, pediatric residents and nurses, neonatal nurse practitioners, anesthesiologists, as well as OR nurses, surgical personnel, and transport services. The partnership between the Pediatrics, Surgical, and Anesthesiology departments facilitated the implementation of this QI project.

Measures

We defined hypothermia as a core temperature of less than 97°F (36.1°C). Our primary outcome measure was the incidence of perioperative hypothermia at any point during the process. From 2016-2018, we looked at the incidence of hyperthermia, defined as a temperature higher than 100.4°F (38°C), as our balancing measure. The team also audited each checklist to monitor checklist compliance, which we used as our process measure.

Establishment of Baseline Data

A retrospective chart review for all NICU infants undergoing surgical procedures from January 2014 to December 2015 established a baseline perioperative hypothermia incidence rate of 44.4% (24 out of a total of 54 subjects). Further analysis of the data suggests that 75% of patients with hypothermia developed it in the OR.

Interventions

At the start of 2016, the multidisciplinary team mapped the transport process from the NICU to the OR, and back, to identify opportunities for preventing perioperative hypothermia. Three temperature checkpoints were identified: (1) in the NICU before transport; (2) within the OR following completion of the procedure; and (3) upon return back to the NICU. These checkpoints formulated the basis of our key drivers diagram (Fig. 1). Subsequently, the team formulated specific interventions around these 3 checkpoints to maintain and (if necessary) correct the infants' core body temperature. The result was a 9-item surgical procedure checklist (Fig. 2) aimed to standardize the process of preventing perioperative hypothermia.

Implementation of the Checklist (January 2016)

The first significant task focused on building provider knowledge and fostering a teamwork effort. The team educated NICU staff, OR nurses, and house officers on the complications of perioperative hypothermia as well as on the proper use of the checklist. NICU and OR nurses recorded the infants' temperatures as well as performed the other items on the checklist. It was encouraged that all team members participating in the care of the infant, actively contribute to the checklist tasks.

To reinforce knowledge and encourage checklist compliance, we sent frequent email reminders and conducted hands-on coaching with NICU and OR staff immediately following the checklist rollout. Debriefing sessions addressed gaps in knowledge and opportunities to improve

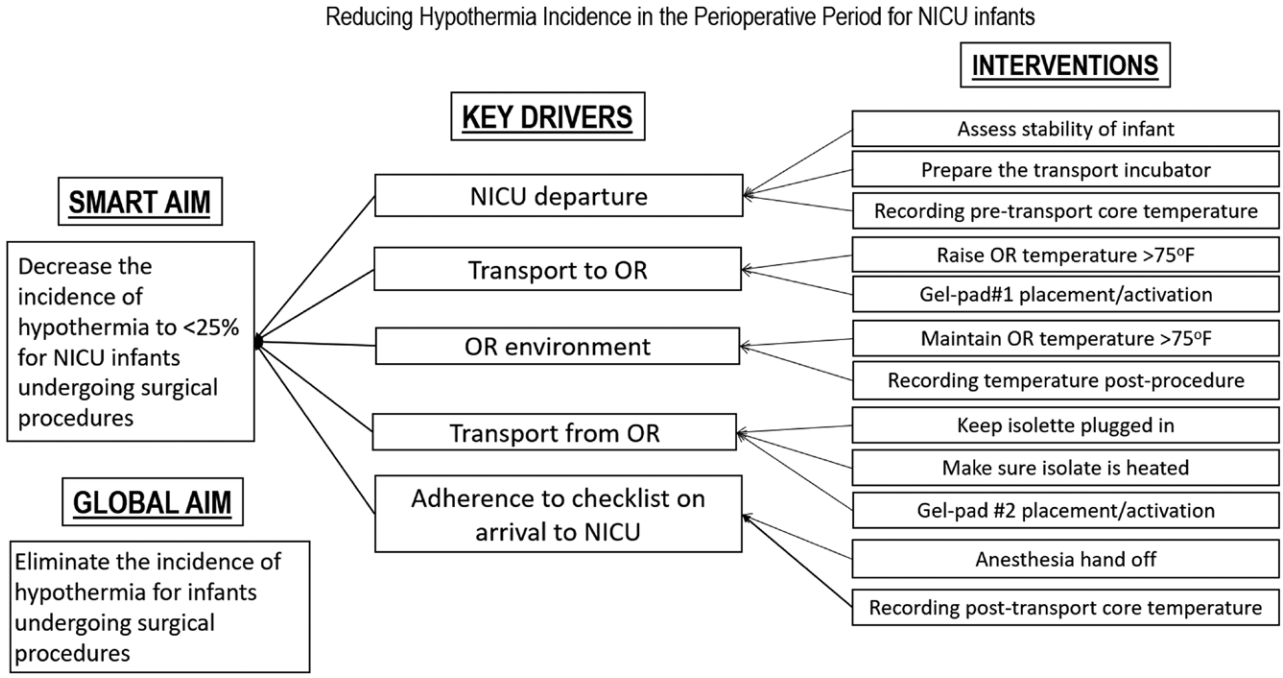

Fig. 1. Key driver diagram depicting essential checkpoints as well as the interventions aimed at reducing the incidence of perioperative hypothermia in NICU patients. Reducing hypothermia incidence in the perioperative period for NICU infants.

compliance. We conducted Plan-Do-Study-Act cycles every quarter to evaluate our hypothermia rate, after initiating the checklist in January of 2016. The first quarter had no postoperative hypothermia. We attributed this to the fact that the staff members had received education, and the checklist had just been implemented. In the second quarter, we saw an increased rate of hypothermia. We initiated in situ simulations for all staff members, which consisted of following the checklist and completing each of the entailing steps. Timely feedback was given to all the staff regarding the hypothermia rates in the NICU. It was noticed that some of the responsibilities were not clearly stated in the checklist; hence, in 2017, we revised the checklist and delineated responsibilities to the various interdisciplinary teams at different time points. This change helped to reduce the hypothermia rate. In the third quarter of 2018, we noted a surge in hypothermia. Re-education was provided to all staff members, and the improvement showed in the next quarter. This showed us that timely re-education and just in time intervention are needed for improving hypothermia rates in the NICU. The team also audited and analyzed compliance with checklist tasks and used it to evaluate the corresponding incidences of hypothermia.

In Situ Simulation

The use of simulation as an educational tool has become increasingly more prevalent in healthcare practice. Simulation is the process of recreating characteristics of

	NICU Transport Temperature Checklist		
Patient Name: MRN:		Procedure Diagnosis:	Date:
	Before Transport		
1	Pre-Transport temperature (rectal)	Temperature:	
2	Activated Gel pad #1 placed under infant for transport	□ YES	□ NO
3	Procedure room Temp measured at 75F prior to calling for transport	□ YES	□ NO
4	Transport Incubator plugged in during entire length of procedure	□ YES	□ NO
	After Procedure		
5	Post-pocedure temperature (prior to transport)	Temperature:	
6	NICU Charge Nurse and Respiratory Therapy aware of Pending Arrival	□ YES	□ NO
7	Warm Blankets available	□ YES	□ NO
8	Activated gel pad #2 placed under infant for transport	□ YES	□ NO
	In NICU		
9	Infant's Temperature within 30 minutes of arrival to NICU (rectal)	Temperature:	

Fig. 2. A 9-item perioperative NICU transport temperature checklist centered around obtaining core rectal temperatures (unless contraindicated) before transport to the OR (item 1), following completion of the procedure within the OR (item 5), and upon return back to the NICU (item 9).

the real world,[22] allowing the trainer to carefully control the learning environment and optimize conditions for the skill being taught. We provided simulation training to nursing staff, both from the NICU and the OR. Training included education on correct activation and placement of the gel pads, turning on the incubator within the OR, as well as improving interdisciplinary communication. We conducted simulation sessions every quarter to reinforce compliance and ensure the correct usage of the checklist.

Data Feedback

Investigators presented data from the first 12 months of checklist implementation to the NICU staff and team members. We used data reports from national studies on the incidence of perioperative hypothermia as a comparison. Graphs depicting the decreased incidence of hypothermia in 2016 were posted in the NICU to boost checklist compliance.

Addressing Practice Drift

The team noted an increased incidence rate of hypothermia during the fourth quarter of 2017. At every opportunity, we emphasized education and compliance with the checklist. Additionally, staff huddles at each change of shift in the NICU included a reminder to use the surgical checklist in daily safety discussion. Furthermore, interdisciplinary team review helped to address gaps in practice and brainstorm how the process can become streamlined.

Checklist Revision

Frontline staff initially attributed poor compliance with some of the checklist components to excessive wordiness or vague interpretations. Specifically, activation of the second gel pad during transport back to the NICU was the least performed item on the checklist. This failure was partly due to the combination of 2 tasks (activating gel pad #1 and #2) into 1 checklist item, inexperience from the OR nurses on how to activate the gel pads, as well as confusion on whether reusing the first gel pad was sufficient if it still felt warm to touch. As a result, we modified the checklist to include a separate checklist item for activating a second gel pad while returning to the NICU.

Assessing Completeness and Accuracy of Data

Checklist data was cross-referenced with the surgical and anesthesiologists' procedure notes.

Data Analysis

We assessed continuous variables for normality using the Kolmogorov–Smirnov test, histograms, and probability plot. We computed and compared descriptive statistics such as median (interquartile range), frequency (percentage) between pre and postchecklist groups. For bivariate comparisons, we used the Wilcoxon rank-sum test to compare continuous variables and the Chi-Square test for categorical variables. We assessed the trend of hypothermia over time using the Cochran–Armitage test for trend. We developed a multivariable Poisson regression model with robust error variance and log link for binary data[23] to assess risk factors associated with developing hypothermia. We utilized the Quasilikelihood under the Independence model criterion statistic to appraise the model fit. A result was considered statistically significant at the $P < 0.05$ level of significance. The team used Minitab 18 software to produce statistical process control charts of ongoing data points. All other analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, N.C.).

Ethical Considerations

There were no ethical considerations or conflicts of interests within our quality initiative as it was not human subjects research. As such, the NYU-Winthrop Institution Review Board approval was not required as this initiative did not affect human subjects.

RESULTS

From 2014 to 2015, there were a total of 54 surgical cases from the NICU evaluated as baseline data. The total incidence of hypothermia during this time was 44.4% (n = 24 of 54). Of the 24 subjects who developed hypothermia, one was hypothermic in the NICU before transport, 18 subjects developed hypothermia while in the OR, and the remaining 5 subjects were normothermic after surgery but developed hypothermia during the transport back to the NICU.

Following the implementation of the checklist, the total incidence of hypothermia decreased to 23% in 2016 (eight out of 35 cases). In 2017, hypothermia rates increased to 33% (13 out of 40 cases). After new interventions, including modification of the checklist, an emphasis on compliance with checklist usage, and frequent education, the incidence of hypothermia in 2018 decreased to 16% (eight out of 49 cases).

In total, there were 124 neonatal surgical cases from 2016 to 2018, with an overall perioperative hypothermia incidence rate of 23.4% (29 out of 124). This fact represented a significant overall decrease in the incidence of hypothermia ($P = 0.007$). Of those who developed hypothermia in the postchecklist group, only one subject was hypothermic in the NICU before transport, 22 subjects developed hypothermia in the operating room, and the remaining 6 subjects had onset of hypothermia during transportation back to the NICU.

We used statistical process control p-charts for tracking outcomes and analyzing the impact of improvement. We tracked the process measures monthly and outcomes data quarterly. The outcomes data from 2016 to 2018 showed significant improvement (Fig. 3) with a centerline shift in the postchecklist years to a mean proportion of hypothermia in the OR of 17.74%. Similarly, a control p-chart of the temperature upon return to the NICU from 2014 to 2018 again showed a centerline shift in the postchecklist years, indicating a decline in the mean proportion of

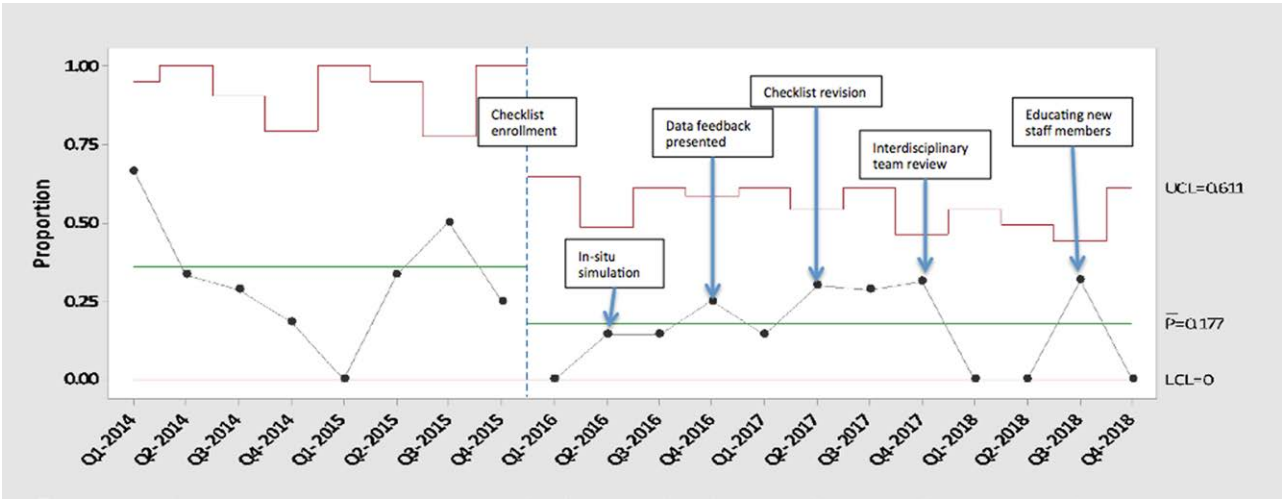

Fig. 3. P-chart illustrating quarterly data for the before-and-after incidence rate of hypothermia measured in the OR. Hypothermia was considered as a defect and was measured each month against the number of neonates undergoing a procedure. There is centerline shift and tighter control limits after interventions.

hypothermia upon arrival to the NICU to 18.55%. Both figures were statistically significant, with a *P* value of <0.05.

Table 1 summarizes demographic characteristics comparing pre and postchecklist subjects for gender, procedure classification (emergency versus elective), average gestational age at birth, corrected gestational age, birth weight, and age (in days) at the time of the procedure. Although the postchecklist subjects were relatively older chronologically at the time of the procedure compared to the prechecklist group (42 versus 14 d), we noted that the postchecklist subjects were born at a significantly younger gestational age (29 versus 36 wks of gestation). Thus, when corrected for gestational age, both groups were, on average, 38 weeks of gestation at the time of their procedure. All other characteristics were similar between groups.

We developed a Multivariable Poisson regression model to estimate the adjusted relative risks of hypothermia (Table 2). Adjusted for gender, gestational age at birth, gestational age at the time of procedure, weight, procedure type (elective versus emergency), and chronological age (day of life), the postchecklist group had a 49% decreased risk of hypothermia compared to the prechecklist group.

Emergency Procedures

In the prechecklist years of 2014-2015, we considered 26 out of the total 54 procedures as emergent. Of those 26 emergency cases, 54% (n = 14) of subjects developed hypothermia. In the postchecklist years, there were 42 of 124 cases labeled as emergency procedures. Of these 42 cases, only 38% (n = 16) of subjects developed hypothermia. Compared to elective procedures, patients who had an emergency procedure had 1.95 times greater risks of developing hypothermia adjusted for all other covariates (Table 2).

Checklist Compliance

In the postintervention years of 2016–2018, compliance with the checklist items was used as our process measure. The mean number of tasks (out of 9 total items) completed in 2016 and 2018 was 8 out of 9; the mean number of tasks completed in 2017 was 7 out of 9. We hypothesized that the decrease in compliance with checklist usage in 2017 contributed to the increase of hypothermia rates from 2016 to 2017. Following the interventions to increase checklist compliance in 2018, we successfully decreased the total incidence of hypothermia to its lowest rate of 16%. The tasks which were

Table 1. Patient Demographics Comparing Prechecklist and Postchecklist Subjects

Variable	Prechecklist (N = 54)	Postchecklist (N = 124)	*P**
Sex			0.924
Male	34 (63.0)	79 (63.7)	
Female	20 (37.0)	45 (36.3)	
Procedure			0.072
Emergency	26 (48.2)	42 (33.9)	
Elective	28 (51.8)	82 (66.1)	
Gestational age at birth	36 (30–38)	29 (26–34)	<0.0001
Gestational age at procedure	38 (36–41)	38 (34–40)	0.191
Weight (g)	2,515 (1,930–3,500)	2,388 (1,777–2,956)	0.145
Days of life	14 (4–52)	42 (7–84)	0.044

**P* values are from the Chi-Square test for categorical variables and Wilcoxon rank-sum test for continuous variables

Table 2. A Multivariable Poisson Regression Model Used to Estimate the RR with 95% CI for Potential Factors Associated with Hypothermia

Factors	RR (95% CI)*	*P*
Post vs. Prechecklist	0.51 (0.32–0.81)	0.005
Sex (female vs. male)	1.02 (0.66–1.58)	0.940
Gestational age	0.97 (0.92–1.02)	0.258
Gestational age of procedure	0.99 (0.91–1.07)	0.790
Weight (g)	0.9999 (0.9996–1.0003)	0.738
Procedure (emergency vs. elective)	1.95 (1.23–3.10)	0.005
Days of life	0.999 (0.99–1.01)	0.873

*RR was estimated via Poisson regression model with robust error variance estimates.
CI, confidence interval; RR, relative risk.

most often missed were activating and utilizing the second gel pad (2016 and 2017) and notifying the NICU charge nurse and Respiratory Therapist of pending arrival (2018). Figure 4 depicts the quarterly percent compliance with all checklist items. The median compliance percentage with all checklist items from 2016 to 2018 was 50%.

Hyperthermia

As our balancing measure, we looked at the number of babies who developed hyperthermia, defined as core temperature greater than 100.4°F. In both the pre and post-checklist groups, there was only 1 case every year from 2014 to 2018.

DISCUSSION

The checklist and subsequent interventions successfully decreased the overall incidence of perioperative hypothermia for NICU patients from 44.4% to 23.4%. This change was a 47% decrease from our baseline hypothermia rate. The data further support the benefits and effectiveness of incorporating checklists to achieve the desired outcome measures and reduce potential complications of perioperative hypothermia.

The initial intervention of education on perioperative hypothermia and its complications on NICU patients increased awareness as well as motivated staff members to comply with this quality initiative goal. Staff education supported by monthly email reminders and coaching sessions achieved an initial decrease in the rate of hypothermia from baseline. In December 2017, in response to increased cases of hypothermia, the checklist was incorporated into NICU nurses shift safety huddles. We further revised the checklist and posted "Days Since Last Hypothermic Event" sign in the NICU for full transparency with parents and families. New staff members were asked to champion the quality initiative effort within their respective units and brought a renewed enthusiasm to the project. These interventions contributed to the overall decrease in the incidence rate of perioperative hypothermia in 2018 to 16%.

Interestingly, we noted that all hypothermic cases in 2018 occurred in the 3rd quarter, which correlated with July–September. This finding correlated with a decrease in compliance with the checklist in 6 out of the 8 hypothermic cases in 2018. We postulated that this was a result of the hiring of new staff members, both medical residents and nurses, who were not as familiar with the process. As a result, we incorporated education on this quality initiative and checklist usage into orientation to the NICU. Email reminders, coaching sessions, and hands-on simulations were emphasized before the winter months. This effort was successful in increasing checklist compliance and eliminating hypothermia during the fourth quarter of 2018.

Several actions on the checklist remained underutilized despite education and frequent reminders. In 2016 and

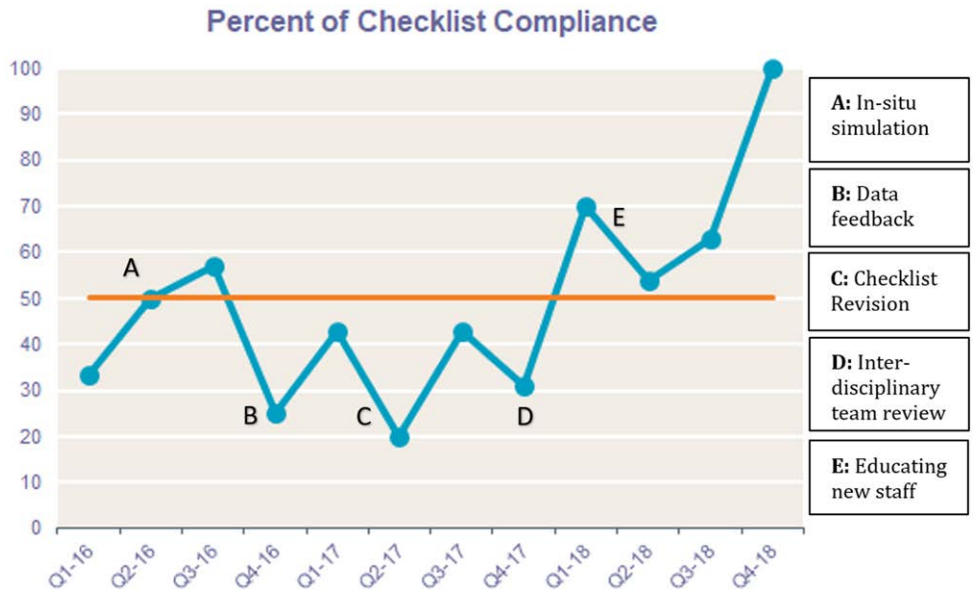

Fig. 4. A run-chart of quarterly compliance percentage with all checklist items. Checklists that were deficient in any item were regarded as incomplete.

2017, activating and utilizing the second gel pad was the item most frequently missed, which negatively affected checklist compliance rates. Other frequently undocumented items included recording the baby's postoperative temperature from the OR onto the checklist sheet.

Although we did not distribute a formal anonymous survey to elicit the staff's perception of the checklist, several staff members openly voiced their concern that utilizing the checklist created an additional layer of work. This was found to be a common complaint with quality initiatives at other institutions.[24] Frontline staff specifically pointed out that both NICU nurses and anesthesiologists already chart the infant's temperatures on our electronic medical record, thus questioning the necessity of having to document the temperature on the checklist as well. As a result, multiple revisions to the checklist were made in an attempt to make it more user-friendly and without ambiguity. We deliberately decided to include recording temperatures onto the checklist to bring to attention and remind house staff of the importance of maintaining normothermia in these high-risk infants.

Limitations

We conducted this project at a single institution, and the results may not be generalized to other pediatric hospitals. Furthermore, temperature checks were not done upon arrival to the OR to assess the risk of developing hypothermia while en-route to the OR from the NICU. This oversight was later addressed in 2019 and is currently part of the most updated version of the checklist. Finally, the type and duration of the surgical procedure were not accounted for when analyzing data.

CONCLUDING SUMMARY AND NEXT STEPS

In conclusion, a checklist is a useful and simple tool for maintaining the optimal temperature for postsurgical neonates. Frequent education and re-enforcement of the checklist are necessary to sustain compliance. Overall, the total incidence of perioperative hypothermia decreased as a result of education and the checklist. After implementation, our hospital's NICU has expanded this QI initiative to every neonate leaving the NICU for any reason—including imaging and feeding studies. This initiative has the potential to help decrease the overall incidence of hypothermia in all NICU patients as well as decrease their associated morbidity and mortality.

DISCLOSURE

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

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