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Care Does Not Stop Following ROSC: A Quality Improvement Approach to Postcardiac Arrest Care

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Abstract

Introduction: Pediatric cardiac arrests carry significant morbidity and mortality. With increasing rates of return of spontaneous circulation, it is vital to optimize recovery conditions to decrease morbidity. **Methods:** We evaluated all patients who presented to a large quaternary pediatric intensive care unit with return of spontaneous circulation. We compared patient-specific postcardiac arrest care preimplementation and postimplementation of a standardized postcardiac arrest resuscitation pathway. We implemented evidence-based best practices using the Translating Research into Practice framework and Plan-Do-Study-Act cycles. Our primary aim was to increase the percent of postcardiac arrest care events meeting guideline targets for blood pressure and temperature within the first 12 hours by 50% within 18 months. **Results:** Eighty-one events occurred in the preintervention group (August 1, 2016–April 30, 2018) and 64 in the postintervention group (May 1, 2018–December 1, 2019). The percent of postcardiac arrest events meeting guideline targets for the entirety of their postarrest period improved from 10.9% for goal mean arterial blood pressure to 26.3%, $P = 0.03$, and increased from 23.4% for temperature to 71.9%, $P < 0.0001$. **Conclusions:** Implementing a postcardiac arrest standardized care plan improved adherence to evidence-based postcardiac arrest care metrics, specifically preventing hypotension and hyperthermia. Future multicenter research is needed to link guideline adherence to patient outcomes. *(Pediatr Qual Saf 2021;6:e392; doi: 10.1097/pq9.0000000000000392; Published online March 10, 2021.)*

Each year, 5,000 children will experience an out-of-hospital cardiac arrest,[1] and approximately 7,000 children will experience an in-hospital pulseless cardiac arrest in the United States.[2] Of these 12,000 patients, it is estimated 7,000 will have the return of spontaneous circulation (ROSC) and be at risk of postcardiac arrest syndrome (PCAS).[3] As survival continues to increase due to high-quality cardiopulmonary resuscitation (CPR),[4–8] increased focus on postcardiac arrest care following ROSC is required to optimize outcomes. Mitigating other organ dysfunction and neurological failure during the first 72 hours following cardiac arrest has been demonstrated to decrease morbidity.[3] Furthermore, experts believe the first 12 hours post-ROSC may be the period when early intervention to prevent hyperthermia and hypotension may be most effective.[9] Two crucial focus areas include avoiding hypotension[10,11] and targeted temperature management with controlled normothermia[12,13] to prevent secondary injury.

A standardized, evidence-based treatment plan inclusive of physiologic and process goals is a successful strategy to manage the pediatric postcardiac arrest patient.[3] Standardized pathways for adult postcardiac arrest patients resulted in a nearly 2 times greater likelihood of having a favorable outcome than standard therapy.[14] In pediatrics, adherence to a postcardiac arrest care pathway is associated with increased survival to hospital discharge for children with in-hospital cardiac arrest.[15] At our institution, we noted a lack of standardized postcardiac arrest care in the first 12 hours postcardiac arrest.

Our global aim is to improve survival and reduce morbidity following pediatric cardiac arrest. Lacking

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a standardized approach to postcardiac arrest care and given high rates of hypotension and hyperthermia, the initial goal was to develop and implement a postcardiac arrest care guideline. This work's primary specific aim was to increase the postcardiac arrest care events meeting guideline targets for blood pressure and temperature within the first 12 hours by 50% within 18 months. Our secondary aim was to increase provider knowledge regarding blood pressure and temperature goals from less than 10% to more than 50% within a focused 3-month period.

METHODS

Context

All patients admitted to the pediatric intensive care unit (PICU) who achieved ROSC following in-hospital or out-of-hospital cardiac arrest from August 2016 to December 2019 were included. The 35-bed PICU is a closed, noncardiac, medical/surgical unit with over 2,500 annual admissions. Nurses, respiratory therapists, pharmacists, dieticians, advanced practice practitioners, resident physicians, critical care fellows, and attending physicians comprise the multidisciplinary critical care teams managing postcardiac arrest patients.

Translating Research into Practice

We used the Translating Research into Practice (TRIP-II) framework[16] to assist in the postcardiac arrest care algorithm development and implementation (Table 1). The TRIP-II framework optimizes evidence-based guidelines and their implementation into clinical practice. The framework focuses on using evidence to guide a standardized approach to identifying practices needing change, monitoring performance, and long-term implementation.[16] By applying the TRIP-II framework, we found robust evidence for the management of PCAS; however, our ability to implement the care algorithm effectively was limited. To identify and overcome barriers to postcardiac arrest care, we used Plan-Do-Study-Act (PDSA) cycles to empower the PICU team to improve the delivery of care. We implemented successful processes and adapted or abandoned ones that did not optimize care delivery.

Interventions

Following the TRIP-II framework completion, we used the Model for Improvement[17] to apply critical interventions. Due to high baseline compliance (>75%) with glucose monitoring and the use of video electroencephalogram, these components of the algorithm were not targeted for intervention. The team first developed key drivers for achieving the project aims (Fig. 1), which included: (1) staff knowledge of postcardiac arrest care; (2) optimal room preparation for patient arrival; (3) ensuring clear communication between all disciplines; and (4) ensuring a standardized approach to care. PDSA ramps targeted key drivers and, ultimately, the SMART aim.

Our first intervention, a postcardiac arrest electronic health record (EHR)-based note template and order set (**see Appendix I, Supplemental Digital Content 1,** ***http://links.lww.com/PQ9/A246***), emphasized and standardized postcardiac arrest goals. By using the standardized note template built into the EHR, care providers could

Table 1. Translating Research into Practice Framework for Development of Postcardiac Arrest Care

Step 1	Summarize the evidence	• Hypotension and hyperthermia are associated with worse outcome • Standardized pathway improves outcomes
	Identify interventions	• Education on importance of attaining goals of care • Standardized pathway • Implementation of automated temperature control device
	Prioritize interventions	1 Education 2 Standardization
Step 2	Identify local barriers	• Lack of knowledge regarding post-CA goals • Lack of proper room setup and equipment
	Observe staff performing care tasks	Multidisciplinary team observed rooms being setup before admission of a post-CA patient and observed how patient care was delivered
	Walk the process	Formal modified simple failure mode effect analysis was completed for nursing roles and provider roles (**see Appendix I**, **Supplemental Digital Content 1,** ***http://links.lww.com/PQ9/A246***)
	Solicit feedback	Reviewed each post-CA care case to identify barriers and suggestions for improvement
Step 3	Process and outcome measure	The Number of events and percent of time experiencing hypotension or hyperthermia
	Baseline performance measures	Hypotension within the first 12 h post-CA in 48.3% of patients Hyperthermia within the first 12 h post-CA in 18.3% of patients
Step 4	Ensure that all patients receive intervention	Chart review completed of all post-CA patients with monthly feedback during Morbidity and Mortality conference on performance of metrics, use of the standardized pathway and automated temperature control device

CA, cardiac arrest.

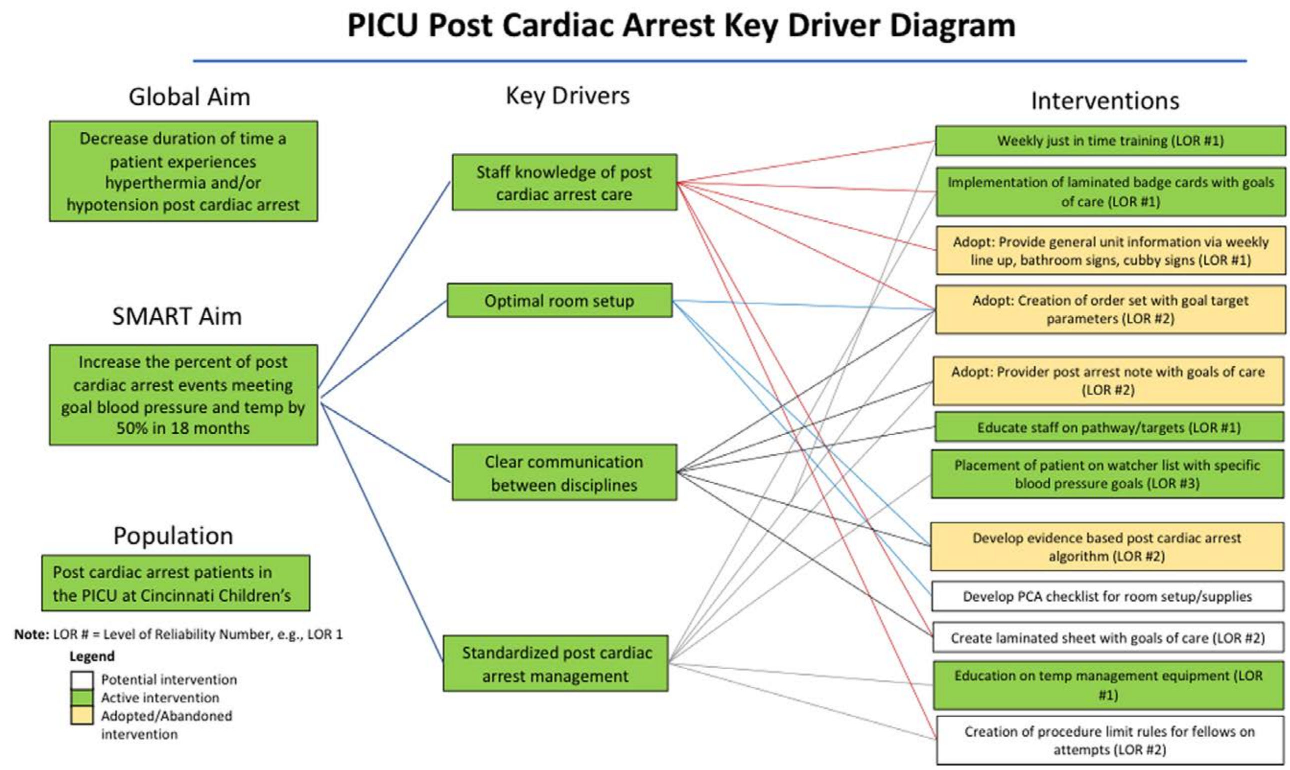

Fig. 1. Key driver diagram for primary outcome metric. LOR, level of reliability; PCA, personal care assistant.

quickly generate a note with details of the cardiac arrest, resuscitation, and age-appropriate goals for postcardiac arrest care, including the targeted mean arterial blood pressure (MAP) and systolic blood pressure (SBP) >5th percentile for age,[18] normal or baseline venous or arterial carbon dioxide level, oxygen saturation of 94%–98%, and temperature of 35–37°C.

To improve the reliability of postcardiac arrest algorithm use and compliance with the above described postcardiac arrest goals, we created an EHR order set emphasizing the use of a temperature control system for targeted temperature management. We used a Blanketrol (Gentherm Medical, Cincinnati, Ohio) early in the study (April 1, 2018–August 31, 2018) or an Arctic Sun (Inova, Falls Church, Va.) later in the study (after September 1, 2018) to achieve the targeted temperature goal. These devices use the flow of cold or warm water to control the patient's temperature.

Second, we focused on education for all care providers. Although education, when used alone, has demonstrated a lower level of reliability for sustaining process improvement, it is often a necessary introduction. During observations and modified simple failure mode effect analysis (**see Appendix II, Supplemental Digital Content 1, *http://links.lww.com/PQ9/A246***), we discovered a knowledge gap among care providers regarding the relationship among postcardiac arrest hypotension, hyperthermia, and increased morbidity. We surveyed providers about common barriers (Fig. 2) they experienced in meeting postcardiac arrest guidelines and tailored the education accordingly. The implementation of an EHR order set, note template, and standardized care algorithm with defined metrics and goals of care facilitated the initial education on postcardiac arrest care goals. Given the rarity of events, we focused on the standardization and availability of educational resources rather than memorization. The team initially utilized posters and informational flyers throughout the unit to call attention to the order set and the note template's higher reliability interventions. In response to provider feedback, we implemented multiple PDSA cycles with different educational tools and venues. Adopted interventions included:

1. weekly rounds by the team through the PICU to address specific questions regarding blood pressure and temperature goals;
2. ID badge cards provided to PICU staff displaying goals for postcardiac arrest care, including age-specific blood pressure, temperature, carbon dioxide, and oxygenation goals; and
3. online resources regarding optimal postcardiac arrest care posted to the nursing online resource guide.
4. provided education at quarterly nursing updates and at pediatric critical care fellow orientation to ensure the information was dispersed regularly for staff turnover.

Additionally, the team created a room setup checklist to help staff with room preparation before the arrival of a postcardiac arrest patient or following the cardiac arrest of an already admitted patient (**see Appendix III,**

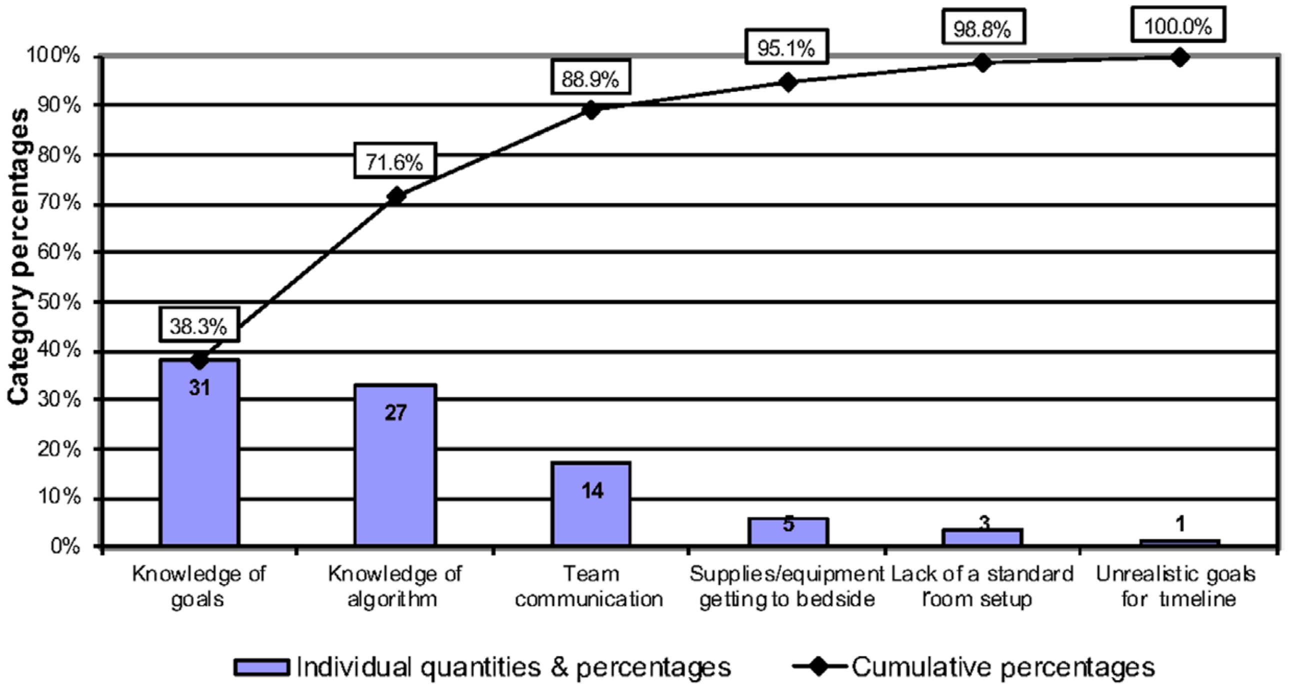

Fig. 2. Common barriers to meeting postcardiac arrest guidelines.

Supplemental Digital Content 1, *http://links.lww.com/PQ9/A246*).

Further PDSA cycles focused on practicing the postcardiac arrest processes with nurses, APPs, residents, fellows, and attending physicians through simulated patient cases. Using Manikin-based simulation, we included postcardiac arrest care in our routine monthly in situ cardiac arrest simulations to reinforce educational concepts and identify gaps in knowledge.

Study of the Interventions

We identified pediatric patients admitted to the PICU who experienced an out-of-hospital or in-hospital cardiac arrest and created a prospective postcardiac arrest database beginning in February of 2017. Cases from August 2016 to February 2017 were added with retrospective chart review. PICU patients were screened daily (Monday–Friday) by clinical research assistants via manual chart review for evidence of a cardiac arrest within the last 24–72 hours and enrolled in the database following identification via diagnosis code, physician documentation, or use of the postcardiac arrest order set or template note. We monitored for changes in process metrics through statistical process control methods, with standard criteria for determining if changes were due to common cause (random chance) or special cause (assignable to the intervention) variation. We used Shewhart control chart rules to determine when special cause occurred.[19] Due to the rarity of pediatric cardiac arrest, we evaluated the data preimplementation and postimplementation to determine if there was statistical significance via the appropriate parametric or nonparametric test.

Measures and Analysis

The global aim of our work is to improve pediatric postcardiac arrest survival and reduce morbidity after cardiac arrest. The primary specific aim was to increase the percentage of postarrest care events meeting guideline targets for blood pressure and temperature in the first 12 hours by 50% within 18 months. Process metrics included percent accurate knowledge of guideline targets by PICU staff for both blood pressure and temperature. Percent accurate knowledge was measured by weekly rounds (S.P., K.B., and L.J.) through the PICU. To assess knowledge, we presented 5 random PICU staff members, including bedside nurses, physicians, and advanced practice providers, with patient vignettes and asked for correct blood pressure and temperature goals. This activity was tracked on a weekly run chart.

We evaluate 2 distinct outcome metrics. First, our primary outcome metric was guideline adherence for blood pressure (by both MAP and SBP) and temperature. Second, as guidelines leave a buffer between blood pressure targets and true hypotension, and between temperature target and fever, we also evaluated episodes of true hypotension and hyperthermia preimplementation and postimplementation. Also, as the burden of hypotension has been shown to impact postcardiac arrest patients' outcomes,[20] we evaluated hypotension and hyperthermia duration within the first 12 hours. Hypotension or hyperthermia duration was defined as the percent of total hourly measurements in which a patient was hypotensive or hyperthermic. Hypotension was defined as a systolic or MAP less than the 5th percentile according to age and sex[21] within the first 12 hours postcardiac arrest. Hyperthermia was defined as a recorded temperature

Table 2. Post-CA Patient Cohorts Preintervention and Postintervention

	Preintervention Patients (N = 67)	Postintervention Patients (N = 63)	*P*
Male, % (N)	62.7% (42)	65.1% (41)	0.96
Medical history % (N)			
Oncology	19.4% (13)	6.3% (4)	0.051
Trauma	13.4% (9)	27.0% (17)	0.054
Sepsis	32.9% (22)	15.9% (10)	0.02
24-h Survival, % (N)	65.7% (44)	77.8% (49)	0.13
Survival to ICU discharge, % (N)	41.8% (28)	46.0% (29)	0.63
Survival to hospital discharge, % (N)	38.8% (26)	42.6% (27)	0.77
Description of cardiac arrests preintervention and postintervention			
	Preintervention Arrests (N = 81)	**Postintervention Arrests (N = 64)**	***P***
Location of cardiac arrest, % (N)			
PICU	66.7% (54)	39.1% (25)	0.001
Ward	7.4% (6)	17.2% (11)	0.07
OR	3.7% (3)	3.1% (2)	0.85
ED	3.7% (3)	1.6% (1)	0.43
Outside	17.3% (14)	39.1% (25)	0.003
Median Age in months at time of arrest, mo (IQR)	27 (10–123)	19 (10–83)	0.44
Age range, mo	1–334	0.4–295	NA
eCPR for in-hospital arrest, % (N)	9.0% (6)	28% (11)	0.07
Median length of chest compressions deliver for in-hospital cardiac arrest, min (IQR)	5.0 (3–21)	7.5 (3.5–35)	0.37
ROSC, % (N)	79.0% (64)	89.1% (57)	0.11

eCPR, cardiopulmonary resuscitation resulting in extracorporeal support; ED, emergency department; IQR, intraquartile range; OR, operating room.

higher than 38 °C within the first 12 hours postcardiac arrest. We used descriptive statistics (number and frequency) to characterize hypotension and hyperthermia events postcardiac arrest and analyzed them with chi-square testing. We collected information regarding patient demographics and arrest characteristics and displayed as descriptive statistics for informational purposes about population characteristics preimplementation and postimplementation.

Cincinnati Children's Hospital Medical Center Institutional Review Board determined this work to be nonhuman subjects research.

RESULTS

Population Characteristics

From August 1, 2016, to April 30, 2018, we collected preintervention data. During this time, 67 patients experienced a cardiac arrest with a 24-hour patient survival of 65.7% (N = 44). Survival to ICU discharge was 41.8% (N = 28), and survival to hospital discharge was 38.8% (N = 26). Eighty-one unique cardiac arrest events occurred, with ROSC achieved in 79% (N = 64), and the majority (66.7%, N = 54) occurred in the PICU. Table 2 describes the precohort and postcohort characteristics of individual patients and cardiac arrest events. From May 1, 2018, to December 1, 2019, we collected postintervention data, during which 63 patients had a cardiac arrest with a 24-hour patient survival of 77.8% (N = 49). Survival to ICU discharge was 46% (N = 29), and survival to hospital discharge was 42.6% (N = 27) (Table 2). Sixty-four unique cardiac arrest events occurred, with ROSC achieved in 89.1% (N = 57), and 39.1% (N = 25) occurred within the PICU. Comparisons between cohort characteristics are provided for further description of the precohort and postcohort characteristics, but statistically significant differences should be interpreted cautiously given the small sample size.

Process and Outcome Metrics

Blood pressure target knowledge improved from <10% to 60%, and temperature target knowledge improved from <10% to 50% (**see Appendix IV, Supplemental Digital Content 1, *http://links.lww.com/PQ9/A246***). We assessed guideline targets for 64 cardiac arrest events preintervention and 57 postintervention (Table 3, p-charts, **see Appendix V, Supplemental Digital Content 1, *http://links.lww.com/PQ9/A246***). Postcardiac arrest events meeting guideline targets for the entirety of their postarrest period improved from 10.9% for goal MAP preintervention to 26.3% postintervention, $P = 0.03$. The targeted temperature management increased from 23.4% preintervention to 71.9% postintervention, $P < 0.0001$. Postcardiac arrest events meeting SBP goal increased from 9.4% preintervention to 15.8% postintervention. However, the improvement was not statistically significant, $P = 0.29$.

Table 3. The Number of Events Meeting Guideline Targets for the Entirety of the Postcardiac Arrest Period PreIntervention and Postintervention

	Preintervention Arrests with ROSC (N = 64)	Postintervention Arrests with ROSC (N = 57)	*P**
Met guideline targets			
12-h MAP goal, % (N)	10.9% (7)	26.3% (15)	.03
12-h SBP goal, %(N)	9.4% (6)	15.8% (9)	.29
12-h temperature goal, % (N)	23.4% (15)	71.9% (41)	<.0001

*Compared via chi square.

Table 4. Hyperthermia and Hypotension in Postcardiac Arrest Patients

	Preintervention Arrests with ROSC	Postintervention Arrests with ROSC	*P**
Hypotension measurement events, N	61	56	
Any hypotension by SBP within first 12 h, % (N)[15]	48.3% (29)	53.6% (30)	0.52
Time duration hypotensive by SBP in first 12 h, %	41.0%	36.9%	0.65
Any hypotension by MAP within first 12 h, % (N)[22]	31.1% (19)	30.4% (17)	0.92
Time duration hypotensive by MAP in first 12 h, %	28.7%	16.1%	0.11
Hyperthermia measurement patients (N)	60	55	
Any hyperthermia within first 12 h, % (N)	18.3% (11)	7.3% (4)	0.08
Time duration hyperthermic in first 12 h, %	38.3%	17.4%	0.01

*Compared via chi square.

The number of postcardiac arrest events preintervention and postintervention with hypotension documentation in the first 12 hours was not statistically different, 48.3% and 53.6%, respectively, $P = 0.52$. Although it did not reach statistical significance, hypotension duration by SBP or MAP within the first 12 hours demonstrated a trend toward a reduction postintervention (by SBP: 41% preintervention and 36.9% postintervention, $P = 0.65$, and by MAP: 28.7% preintervention and 16.1% postintervention, $P = 0.11$) (Table 4). Similarly, postcardiac arrest events with hyperthermia documented in the first 12 hours were not statistically significant in their difference preintervention and postintervention, 18.3% and 7.3%, respectively, $P = 0.08$. However, the hyperthermia duration decreased from 38.3% preintervention to 17.4% postintervention, $P = 0.01$.

DISCUSSION

We leveraged the TRIP-II framework[16] and the Model for Improvement[17] to address our primary aim to increase the percent of postcardiac arrest care events meeting guideline targets for blood pressure and temperature by 50% within 18 months. Using these tools, we demonstrated statistical improvement in adherence to evidence-based postcardiac arrest care standards. We specifically noted a reduction in the time patients spent hypotensive and in patients experiencing hyperthermia episodes in the first 12 hours after arrest with the implementation of a postcardiac arrest note template, order set, and targeted education. Although we were unable to demonstrate a statistical reduction in the number of patients experiencing hypotension, we established that a structured care pathway for postcardiac arrest care in pediatric patients is feasible.

Structured care pathways with evidence-based interventions delivered by an interdisciplinary team may improve functional outcomes in adults with ROSC following cardiac arrest.[14] Specifically, bundles incorporating early hemodynamic optimization and targeted temperature management similar to ours are feasible and effective in adult patients.[22–24] Whether postcardiac care bundles similarly alter pediatric patient outcomes remains a critical knowledge gap.[3] This work is the first step in demonstrating postcardiac arrest care bundle feasibility and effectiveness in improving adherence to guideline targets. Given patients who experience early hypotension postarrest have worse outcomes,[20] we still have work to do to optimize the pediatric postcardiac arrest care at our institution.

Although our postcardiac arrest care pathway led to reductions in the time patients spent hypotensive or hyperthermic within the first 12 hours, we were unable to demonstrate a statistical reduction in the number of patients who experienced an episode of hypotension or hyperthermia. These findings may indicate that our postcardiac arrest pathway increased the recognition of these events by the bedside team and led to improved response time to correct any deviation from our postarrest goals. Specifically, the automation of the response to temperature deviations with the early implementation of temperature control systems likely played a significant role in decreasing the number of hyperthermic events. Unfortunately, no such automated system exists for hypotension. Instead, we rely on the bedside team to escalate therapies as a patient's blood pressure approaches the established thresholds. There may be an unconscious hesitation in pediatrics to escalate more aggressive therapies, including the initiation of vasoactive medications and proactively increasing the infusion to prevent hypotension instead of reacting to the hypotension event. This frameshift represents a key area of focus for future work around contingency and care escalation planning in postcardiac arrest patients. The implementation of an evidence-based algorithm for initiation and titration of vasopressors may be needed to further improve the response to hypotension.

Importantly, with continued iterative enhancements to this pathway, we must assess for associations between improvements in guideline adherence and direct patient outcomes. Due to the rarity of pediatric cardiac arrest events, the next steps must include a multicenter validation to obtain adequate power and generalizability.

LIMITATIONS

Our project has limitations that may impact its generalizability. First, we defined time zero as arrival to the PICU for patients with out-of-hospital arrests as we could not collect or analyze data from transport or other institutions. This limitation may have prevented the exact determination of time hypotensive or hyperthermic. However, given the efforts of this work focused on processes within the PICU, we do not feel this limitation detracts from the learning regarding improvements to care delivery within the PICU setting. Second, our patient cohorts preimplementation and postimplementation of the postcardiac arrest pathway had some significant differences which could have impacted our findings. Specifically, our preimplementation cohort had a significantly larger percentage of patients with sepsis (33% vs. 16%, $P < 0.02$) and code events occurring within the PICU (64% vs. 39%, $P < 0.001$), whereas our postimplementation cohort had a significantly larger percentage of arrests occurring outside the hospital (39% vs. 17.3%, $P < 0.003$). Although these factors could have impacted the degree of intervention required to ensure the attainment of our postarrest goals, our processes need to apply to the spectrum of etiologies and locations of cardiac arrest. It is in that light that we did not include CPR quality and duration metrics as balancing measures. This work focused on improving goal-directed care delivery postarrest. Although the duration of arrest and quality of the resuscitation were important, they were immaterial to the project goals of improving team-level knowledge of, monitoring for, and responding to deviations from postarrest care targets. Third, our small sample size of patients who experienced eCPR remained on ECMO following ROSC, which may have allowed for improved temperature and blood pressure goal adherence. We felt that it was essential to include these cases to further understand and optimize our care for the postarrest patient. Although the interventions may differ to ensure postarrest goals for patients on ECMO, the need for team knowledge of the goals and timely recognition and response to any deviations remained the same. Fourth, our institution changed the device used for temperature control, which may have affected the success. However, understanding the need for a temperature controlling device represents recognition of how vital temperature control is to postcardiac arrest outcomes. The change in the device does not detract from the learning around adherence. Last, this was a single-center study in a large, quaternary, resource-rich PICU, which may not be generalizable to all centers. Although resources at institutions may vary, the fundamental goal of preventing secondary injury to postcardiac arrest patients is consistent. Therefore, the educational strategy around the implementation of a postcardiac arrest pathway should apply to other institutions.

CONCLUSIONS

The management of PCAS in pediatrics remains challenging, with high morbidity and mortality. Implementing a standardized management plan can improve adherence to guideline targets by minimizing variability. We successfully leveraged the TRIP-II framework and the Model for Improvement to increase reliability and improve compliance with blood pressure and temperature targets while decreasing the time postcardiac arrest patients spent hyperthermic. Critical interventions included the development and implementation of a postcardiac arrest note template and order set focused on hemodynamic optimization and targeted temperature management.

DISCLOSURE

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

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