HeartWatch: Implementing a Pediatric Heart Center Program to Prevent Cardiac Arrests Outside the ICU

Alexandra Birely, MSN, APRN, ACCNS-P*; Sravani Avula, MD†; Ryan J. Butts, MD†; Joshua S. Wolovits, MD‡; Matthew S. Lemler, MD†; Olivia L. Hoffman, MD‡

ABSTRACT

Introduction: Pediatric patients with cardiovascular disease are at increased risk of cardiopulmonary arrest. Despite utilization of Cardiac Pediatric Early Warning Scores to identify patients at risk of decompensation, our institution had a twofold increase in cardiac arrests (CAs) in the acute care cardiology unit (ACCU) over 2 years. Through a quality improvement initiative, we developed a watcher program, HeartWatch, to reduce the CA arrest rate in the ACCU by 50% over the first year of implementation. Methods: HeartWatch aims to identify patients not adequately captured by Cardiac Pediatric Early Warning Scores who are at high risk for sudden decompensation. Inclusion criteria were developed and evaluated during pilot and implemented phases (April 2020–April 2021) and then monitored in a sustained phase through June 2022. Our primary outcome was the reduction in the out-of-ICU CA rate. Results: During the 13 months, we enrolled 169 patients, and the CA rate decreased from 0.7 to 0.33 per 1,000 patient days, a 53% reduction. The CA rate further decreased to 0.28 events per 1,000 patient days, a 60% reduction, by June 2022. The most common indications for HeartWatch inclusion were high-risk single-ventricle patients (31%) and patients with diminished ventricular function (20%). Conclusions: Implementation of HeartWatch was associated with a meaningful reduction in CA in the ACCU. Creating shared mental models for high-risk patients is essential for patient safety. Future work will optimize local processes that focus on the sustainability of our gains. We will also evaluate opportunities to adapt and implement a similar framework in other institutions to assess reproducibility. (Pediatr Qual Saf 2022;7:e617; doi: 10.1097/pq9.0000000000000617; Published online December 7, 2022.)

INTRODUCTION

Cardiac arrest (CA) events occurring in hospitalized pediatric patients are associated with poor outcomes and pose significant patient safety concerns, with an estimated 15,200 events per year.¹ Pediatric patients with congenital or acquired heart disease experience CA at a rate nearly 10 times that of other hospitalized children, with approximately 7 arrests per 1,000 hospitalizations.²,³ Evidence suggests that CA events in higher resource environments, such as an intensive care unit (ICU), correlate with better outcomes than arrest events in noncritical care inpatient units.⁴ Efforts aimed to reduce CA outside an ICU focus on the importance of early recognition of patient deterioration through early warning scoring tools.⁴

Many pediatric hospitals utilize an early warning score, such as the Pediatric Early Warning Score, to help identify patients at risk for a cardiopulmonary arrest outside of the ICU.⁵ However, implementation and utilization of these scores are inconsistent.⁴ Some institutions utilize a cardiac-specific warning score, such as the Cardiac Children’s Hospital Early Warning Score, given the increased incidence of CA in patients with heart disease.⁶,⁷ Our Heart Center utilizes a cardiac-specific pediatric early warning scoring tool, Cardiac Pediatric Early Warning Scores (CPEWS), and an escalation algorithm to detect patients at risk for deterioration and prompt, timely intervention. Though helpful in identifying clinical change, individual early warning tools have weaknesses and may fail to detect patients inherently at high risk of
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sudden clinical deterioration. This suggests that lack of situational awareness continues to contribute to adverse events despite using warning tools.

Our acute care cardiology unit (ACCU) had a two-fold increase in CA events over 2 years (January 2018–December 2019), resulting in a rate of 0.7 CA per 1,000 patient days. We developed and implemented HeartWatch with the global aim to decrease the incidence of CA in the ACCU through improved identification of high-risk patients and creating shared mental models among multidisciplinary team members. Our SMART (specific, measurable, attainable, realistic, time-based) aim was to decrease the CA rate in the ACCU by 50%, from 0.7 to 0.35 per 1,000 patient days by December 31, 2020.

METHODS

Setting
The ACCU is 22-bed, cardiac-specific inpatient service within a 490-bed pediatric, quaternary, academic medical center with approximately 1,000 annual ACCU admissions. Like most large centers, the population includes congenital and acquired heart disease, including patients following ventricular assist device (VAD) placement and transplant. A patient admitted to the ACCU can be cared for by 1 or 2 teams. The general cardiology service focuses on managing pre- and post-operative congenital heart disease. The pediatric advanced cardiac care (PACC) service focuses on patients with heart failure, including those with a VAD or transplant. Both services include multidisciplinary teams, including registered nurses (RNs), advanced practice providers (APPs), and physicians. Medical student, resident, and fellow trainees rotate approximately monthly, and attending physicians rotate weekly.

Intervention Planning
The University of Texas Southwestern institutional review board reviewed this QI project and deemed it nonregulated research. A multidisciplinary stakeholder group, including APP, RN, clinical manager, medical trainee, and physician representatives, first convened in January 2020. That group developed our SMART aim and identified key drivers, including shared mental model, early patient identification, standardized care, and competent and empowered staff (Fig. 1). These key drivers informed the development of change ideas and related interventions. The framework for interventions incorporated principles of situational awareness and risk mitigation through the identification of high-risk patients as “watchers,” inspiring the program name of HeartWatch.

Watcher Criteria
We conducted detailed event reviews of prior CA events (defined as any pulseless event requiring chest compressions for any duration) on the ACCU to identify high-risk patient characteristics and risk factors. Risk factors identified from those reviews and stakeholder group consensus led to developing patient inclusion criteria for HeartWatch, including timeframes for enrollment (Table 1). As an example, patients with a heart failure diagnosis may meet HeartWatch inclusion for the duration of ACCU admission. However, patients with more acute clinical conditions, such as signs of necrotizing enterocolitis, may only meet HeartWatch inclusion for several days.

Standardized Bundle
We developed a bundle of patient care interventions for those meeting HeartWatch inclusion criteria. Bundle elements include posting a HeartWatch sign outside patient rooms and twice-daily safety huddles. The huddle involves all pertinent ACCU team members, including the attending cardiologist, fellow, primary APP or resident, charge, and bedside RNs. The huddle aims to develop a shared mental model while completing a bedside communication tool. This tool outlines key safety items, prompts discussion of the team’s perception of the patient’s most likely causes of decompensation, and facilitates creating a plan for interventions to prevent a CA. Patient code status, mechanical circulatory support eligibility, and vascular access are reviewed. During the huddle, the team also considers appropriate vital sign frequency and nurse-to-patient ratio. Once complete, the communication tool is posted in the patient’s room for the duration of HeartWatch enrollment to facilitate review during morning and evening rounds and if decompensation occurs.

Plan-Do-Study-Act (PDSA) Cycle 1
The pilot phase of HeartWatch occurred from April to September 2020. During this time, the team outlined processes, tested the feasibility, and refined patient selection criteria and bundle elements. A nurse champion attended medical rounds during the pilot phase to facilitate patient identification and huddles. The initial bundle included HeartWatch team huddles three times daily, which proved challenging and disrupted workflow, thus was scaled back to twice daily. A recent version of the huddle sheet, shown in Figure 2, is used to facilitate team discussion during the huddle. During the pilot, nurses reported enhanced awareness of high-risk patients. The medical team did not believe that the addition of the HeartWatch huddle substantially increased the duration of medical rounds.

Based on informal medical team feedback, we revised patient inclusion criteria to include specifications for high-risk single ventricle patients and unpalpated neonates. Specifically, the team identified the importance of distinguishing patients requiring enhanced surveillance versus applying the bundle universally to all patients with those
diagnoses. We, therefore, modified HeartWatch inclusion criteria to include such patients for 7 days following ICU transfer instead of 48 hours as piloted.

Providers also identified challenges locating patient vessel patency and occlusion in the electronic medical record (EMR) during the review of mechanical circulatory support eligibility. To address this, the HeartWatch leadership team helped create a modification within the EMR, facilitating easier documentation and review.

**PDSA Cycle 2**

We formally implemented HeartWatch in September 2020. The HeartWatch leadership team manually collected and reviewed HeartWatch outcome and process data through April 2021. During this phase, the implementation of HeartWatch supported several changes to the ACCU care model, which helped bolster the program’s reliability. For instance, cardiology fellow presence in the ACCU increased with a transition to 24-hour in-house call. As a result, formal night rounds commenced and incorporated the second daily HeartWatch huddle, including review of current HeartWatch patients and their respective posted communication tool.

**PDSA Cycle 3**

HeartWatch shifted to the sustained phase in April 2021 and remains active. HeartWatch inclusion criteria and the intervention bundle remain unchanged except for minor workflow modifications to maintain current processes while reducing manual maintenance tasks. For example, we created an EMR-based list of patients enrolled on HeartWatch. This universally available list enhances transparency throughout the Heart Center of current high-risk patients. ACCU charge nurses maintain the list, adding or removing patients as appropriate. Recently, we added documentation of the HeartWatch huddle safety information in the attending physician’s daily progress note, allowing for greater visibility of huddle information beyond the bedside. This remains an expected documentation

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**Table 1. HeartWatch Patient Inclusion Criteria**

| General patient criteria (place on bundle for 24h unless otherwise specified and reevaluate daily) |
| Direct admissions from outside hospitals |
| Concern for NEC |
| Initiation/discontinuation/titration of milrinone |
| Rapid increase in respiratory support or oxygen requirement OR any patient receiving maximum support on high-flow nasal cannula (maximum = 6LPM, 50% FiO2) |
| Emergency event or rapid response within 24h without transfer to ICU |
| Medication error requiring additional monitoring or treatment |
| Status postcardiac catheterization with pulmonary capillary wedge pressure >18 |
| Team member concern |
| Interstage single ventricle transferred from ICU (remain on bundle for 7d from transfer) |
| Unpalliated neonate with potential for unbalanced circulation |
| Heart failure/transplant patient criteria (remain on bundle duration of admission unless otherwise specified) |
| Severe ventricular dysfunction as defined by ejection fraction <35% or shortening fraction <17% |
| Hypertrophic cardiomyopathy |
| Restrictive cardiomyopathy |
| Transplant patient with active rejection |
| History of TCAD or cardiac allograft vasculopathy |
| Patient with VAD or heart failure and known history of arrhythmia |
| Heart failure or transplant patient transferred from ICU (remain on bundle for 48h from transfer) |

TCAD, transplant-related coronary artery disease; VAD, ventricular assist device.
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Evaluation and Analysis
HeartWatch enrollment was tracked manually and kept in a database managed by key stakeholders. Data collected included basic patient demographics, hospitalization characteristics (eg, defining a surgical patient as one with any surgical procedure during admission), and reasons for enrollment. Key stakeholders met monthly through the implementation period and ad hoc after that, reviewing the primary outcome metric of CA events and refining processes as needed. The CA rate for the pilot, implemented, and sustained phases was defined by 12-month rolling rate per 1,000 patient days. We used QI Macros (KnowWare International, Inc., version 2021) software to create run and g charts and used standard definitions for special cause variation.10

RESULTS
During the pilot phase, 70 patients were enrolled in HeartWatch, of which 10 had more than one HeartWatch encounter. There were 102 patients enrolled during the implemented phase, of which 8 had more than one encounter. Basic patient demographics and details pertaining to HeartWatch enrollment are described in Table 2. The median HeartWatch encounter length was 2 days (range, 1–153) during the pilot and 2 days (range, 1–35) during the implemented phase. Patients enrolled in HeartWatch during the pilot were more commonly admitted to the PACC service (61%) than general cardiology service (39%). Refinement of HeartWatch enrollment criteria through serial PDSA cycles resulted in a more even distribution of patients between the 2 services during the implementation phase (general cardiology 53% versus PACC 47%).

During the pilot, the most frequent indication for HeartWatch enrollment was a heart failure or transplant patient transferring from the ICU to the ACCU (23%), followed by patients placed on the bundle for diminished ventricular function (19%). During the implemented phase, the most frequent indications for HeartWatch inclusion were high-risk single ventricle patients (31%), and patients with diminished ventricular function (20%).

During our baseline phase (January 2018–March 2020), there were 10 CA events resulting in an average CA rate of 0.7 per 1,000 patient days. For the pilot phase (April 2020–September 2020), there were 0 arrests with a 12-month rolling rate of 0.45 per 1,000 patient days. The implemented phase (October 2020–April 2021) had 2 CA events with a 12-month rolling rate of 0.33 events per 1,000 patient days. One patient who arrested was actively on HeartWatch for diminished ventricular function at the time of CA, and the other had previously been on HeartWatch but was not at the time of CA (Table 2). The sustained phase (May 2021–June 2022) had 2 CA events with a 12-month rolling rate of 0.28 per 1,000 patient days. The CA events are displayed in run and g charts (Figs. 3, 4). The end of the implemented and sustained phases demonstrated a 53% and 60% reduction, respectively, from the 2-year baseline rate of 0.7 arrests per 1,000 patient days. Since the pilot, there have been multiple periods of greater than 100 days between CA events, including 349 days between CA events (February 2021–January 2022), demonstrating special cause variation (Fig. 4).

DISCUSSION
Institution of the HeartWatch program resulted in a 53% reduction in the CA rate over the first 13 months of implementation and a 60% reduction at 25 months, exceeding our initial aim. Multidisciplinary review of
the 2 arrest events during the implemented phase led to process changes maintained during the sustained phase, including standardization of the huddle sheet and updating the criteria for high-risk single ventricle patients to be included on HeartWatch for 7 days instead of 48 hours. Additionally, as reflected in Figure 4, there was a significant period of time (349 days—February 5, 2021 to January 20, 2022) between CA events demonstrating special cause variation, indicating a significant change in our system.

Most patients enrolled in HeartWatch were those managed by our PACC team with diagnoses of heart failure,
transplant, and VAD implantation, followed by high-risk single ventricle patients admitted to the general cardiology team. Our enrollment observation correlates with a 2013 study by Lowry et al., which described patients with heart failure, history of heart transplant, or single ventricle physiology having some of the highest incidences of in-hospital cardiopulmonary resuscitation at 2%, 1.1%, and 1.6%, respectively. This suggests that creating HeartWatch inclusion criteria targeting these patient groups may effectively reduce CA events.

HeartWatch is similar to CA prevention bundles described in the ICU setting, including the Pediatric Cardiac Critical Care Consortium CA prevention bundle trial aimed at reducing CA in high-risk pediatric CICU patients. Although their bundle elements are ICU-specific, they offer a model by which multidisciplinary huddles demonstrate improved outcomes, specifically decreased CA rate, for high-risk patients. Dewan et al. described the implementation of a bundle to increase situational awareness of patients at risk for CA within the pediatric ICU. Their bundle included daily safety huddles and was associated with a significant reduction in CA events following implementation, similar to our findings with HeartWatch. Dewan et al. described their institution’s arrest prevention bundle in a pediatric cardiac ICU. Implementation of that bundle was associated with a 68% reduction in CA, similar to our experience with HeartWatch.

Diagnoses that place a patient at high risk of sudden decompensation may be nonmodifiable and often not captured by a dynamic early warning system such as CPEWS. For example, patients with chronic heart failure and a diagnosis of hypertrophic cardiomyopathy will remain on HeartWatch for the duration of their ACCU admission. However, the risk of CA for those patients may remain significant regardless of their care setting (eg, ICU, ACCU, and home). Teams need to develop a comfort with these patients’ chronic illness to help promote quality of life and eventual transition home. Yet, the team also needs to maintain a shared mental model and situational awareness to be prepared for potential decompensation, something the HeartWatch program promotes. Discussing these patients in HeartWatch may improve the team’s comfort level in caring for them outside of the ICU.

HeartWatch focuses on identification, preparation, communication, and teamwork but does not standardize medical management of these high-risk patients, which we believe was a key component to achieving buy-in and adoption. The HeartWatch huddle promotes situational awareness, shared mental models, and contingency planning, which are previously described key elements for watcher programs’ success. Furthermore, a scoping review reports that interdisciplinary huddles are associated with improved teamwork, communication, and clinical outcomes.

Some versions of early warning systems, like Pediatric Early Warning Scores and Cardiac Children’s Hospital Early Warning Score, include subjective components that score a point for “team concern,” but do not require actions until the total score meets a preset threshold. One goal of HeartWatch was to translate subjective concerns into meaningful intervention. Our delineation of “team concern” as an explicit inclusion criterion for HeartWatch allowed any team member, at any time, to request a patient’s enrollment. We believe that this is important since there may be patients at risk for sudden decompensation that do not fit a priori clinical HeartWatch criteria. HeartWatch enrollment requires a team huddle to discuss the most likely cause of decompensation and contingency plans, allowing early identification of high-risk patients. Increased awareness about their risk of decompensation likely leads to more timely transfer.
to the ICU before an acute event and before reaching a CPEWS threshold. Additionally, patients with CPEWS scores triggering an ICU evaluation, but remaining on the ACCU after assessment, are placed on HeartWatch. This allows HeartWatch and CPEWS to work in synergy for high-risk patients rather than solely relying on CPEWS to detect patients beginning to exhibit signs of clinical deterioration.

Exploration of the team’s concern may help reduce barriers to the escalation of care. Several studies have described challenges associated with the escalation of care, including interpersonal factors (e.g., existing hierarchies), difficulty recognizing deteriorating patients, and expectations of specific outcomes (e.g., only calling when the patient truly needs ICU care). A system like HeartWatch may decrease barriers to escalation because it prompts those with concerns to have a team discussion. This is especially important in an academic medical center, where turnover in an ACCU can be high due to medical trainee scheduled rotations and general staff (e.g., nursing) turnover. Those new to a team may have less knowledge and feel less empowered to speak up with a question or concern. Having a system to discuss high-risk patients may serve as learning opportunities for junior team members and provide openings to ask further questions.

It is important to recognize the limitations of a single-center QI project, and our results may not be generalizable to other medical systems. Though reports of safety huddle effectiveness exist, there is not yet a standard for reporting such outcomes. There may be important process, balancing, and outcome metrics we have not considered nor were able to track during this initial work. The pilot and implemented phases of HeartWatch coincided with the initial months of the COVID-19 pandemic. There may have been changes to the hospital census, patient care, workflow, and education processes that may have contributed to the decreased CA rate. Though HeartWatch has specified inclusion criteria, there is also a large subjective component, allowing for team members to enroll or unenroll a patient at any time. This subjectivity may lead to overenrollment or underenrollment of patients into HeartWatch. Based on our current criteria, some patients with nonmodifiable risk factors (e.g., heart failure) result in HeartWatch enrollment for their entire admission. This can create a perception of “overenrollment” of some patients and subsequent team complacency with the huddles. Finally, our manual processes to identify, enroll, document, and review HeartWatch may have inadvertently missed data, and we may not have considered all important QI metrics. For example, we may have missed opportunities to enroll patients who would have qualified for enrollment, an important process metric to consider in the future. Additionally, though patient transfers from ACCU to ICU are tracked in our Heart Center, they were not formally monitored as a balancing measure for HeartWatch. Assessing appropriate process and balancing metrics will be key next steps in sustaining this work.

CONCLUSIONS

At our institution, the development and implementation of the HeartWatch program were associated with a decreased CA rate in the ACCU. Though a goal of zero CAs outside of the ICU is aspirational, it is unlikely achievable, especially in pediatric patients with heart disease. A framework to create shared mental models for high-risk patients is essential for patient safety. It may improve early identification and intervention for patients at risk of sudden decompensation beyond existing score-based systems. Future work includes local optimization and automatization of processes to enhance HeartWatch enrollment, compliance, effectiveness, and outcomes. Additionally, we will focus on adapting and implementing HeartWatch in other pediatric ACCU environments.

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DISCLOSURE

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

REFERENCES

1. Holmberg MJ, Ross CE, Fitzmaurice GM, et al. Annual incidence of adult and pediatric in-hospital cardiac arrest in the United States. Circ Cardiovasc Qual Outcomes. 2019;12:e005580.
2. Lowry AW, Knudson JD, Cabrera AG, et al. Cardiopulmonary resuscitation in hospitalized children with cardiovascular disease: estimated prevalence and outcomes from the kids’ inpatient database. Pediatr Crit Care Med. 2013;14:248–255.
3. Marino BS, Tabbutt S, MacLaren G, et al. Cardiopulmonary resuscitation in infants and children with cardiac disease: a scientific statement from the American Heart Association. Circulation. 2018;137:e691–e782.
4. Sandquist M, Tegtmeyer K. No more pediatric code blues on the floor: evolution of pediatric rapid response teams and situational awareness plans. Transl Pediatr. 2018;7:291–298.
5. Parshuram CS, Duncan HP, Joffe AR, et al. Multicentre validation of the bedside paediatric early warning system score: a severity of illness score to detect evolving critical illness in hospitalized children. Crit Care. 2011;15:R184.
6. McLellan MC, Connor JA. The cardiac children’s hospital early warning scores (C-CHEWS). J Pediatr Nurs. 2013;28:171–178.
7. McLellan MC, Gauvreau K, Connor JA. Validation of the cardiac children’s hospital early warning score (C-CHEWS). J Pediatr Nurs. 2013;28:171–178.
8. Brady PW, Muething S, Kotagal U, et al. Improving situational awareness to reduce unrecognized clinical deterioration and serious safety events. Pediatrics. 2013;131:e298–e308.
9. Provost LP, Murray SK. The Health Care Data Guide: Learning From Data for Improvement. Jossey-Bass; 2011.
11. Alten J, Klugman D, Cooper DS, et al. Cardiac arrest prevention quality improvement project from the pediatric cardiac critical care consortium. *Circulation*. 2019;140(suppl_1):A11798.
12. Alten J, Cooper DS, Klugman D, et al; PC4 CAP Collaborators. Preventing cardiac arrest in the pediatric cardiac intensive care unit through multicenter collaboration. *JAMA Pediatr*. 2022;176:1027–1036.
13. Dewan M, Soberano B, Sosa T, et al. Assessment of a situation awareness quality improvement intervention to reduce cardiac arrests in the PICU. *Pediatr Crit Care Med*. 2022;23:4–12.
14. Riley CM, Diddle JW, Harlow A, et al. Shifting the paradigm: a quality improvement approach to proactive cardiac arrest reduction in the pediatric cardiac intensive care unit. *Pediatr Qual Saf*. 2022;21:e525.
15. Stapley E, Sharples E, Lachman P, et al. Factors to consider in the introduction of huddles on clinical wards: perceptions of staff on the SAFE programme. *Int J Qual Health Care*. 2018;30:44–49.
16. Deighton J, Edbrooke-Childs J, Stapley E, et al. Realistic evaluation of Situation Awareness for Everyone (SAFE) on paediatric wards: study protocol. *BMJ Open*. 2016;6:e014014.e014014.
17. Edbrooke-Childs J, Hayes J, Sharples E, et al. Development of the Huddle Observation Tool for structured case management discussions to improve situation awareness on inpatient clinical wards. *BMJ Qual Saf*. 2018;27:363–372.
18. Pimentel CB, Snow AL, Carnes SL, et al. Huddles and their effectiveness at the frontlines of clinical care: a scoping review. *J Gen Intern Med*. 2021;36:2772–2783.
19. Chapman SM, Maconochie IK. Early warning scores in paediatrics: an overview. *Arch Dis Child*. 2019;104:395–399.
20. Roberts KE, Bonaﬁde CP, Paine CW, et al. Barriers to calling for urgent assistance despite a comprehensive pediatric rapid response system. *Am J Crit Care*. 2014;23:223–229.
21. Thrasher J, McNeely H, Adrian B. When nursing assertion stops: a qualitative study to examine the cultural barriers involved in escalation of care in a pediatric hospital. *Crit Care Nurs Clin North Am*. 2017;29:167–176.
22. Reese J, Simmons R, Barnard J. Assertion practices and beliefs among nurses and physicians on an inpatient pediatric medical unit. *Hosp Pediatr*. 2016;6:275–281.
23. Cotter JM, Ziniel S, Lockwood J, et al. Care escalation: teaching residents how to effectively communicate patient care concerns. *MedEdPORTAL*. 2019;15:10833.
24. Franklin BJ, Gandhi TK, Bates DW, et al. Impact of multidisciplinary team huddles on patient safety: a systematic review and proposed taxonomy. *BMJ Qual Saf*. 2020;29:1–2.