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Reducing Chest Compression Pauses During Pediatric ECPR

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Abstract

Objective: To quantify chest compression (CC) pauses during pediatric ECPR (CPR incorporating ECMO) and implement sustainable quality improvement (QI) initiatives to reduce CC pauses during ECMO cannulation. **Methods:** We retrospectively identified baseline CC pause characteristics during pediatric ECPR events (pre-intervention), deployed QI interventions to reduce CC pause length, and then prospectively quantified CC pause metrics post-QI interventions (post-intervention). Data were gathered from a single center review of CC-pause characteristics in children less than 18 years old with a PICU ECPR arrest. QI Interventions included: (1) sharing baseline CC data with ECPR stakeholders, (2) establishing consensus among providers regarding areas for improvement, and (3) creating a communication aid to encourage counting CC pauses out loud. Multidisciplinary ECPR simulations allowed for practice of these skills. Using telemetry data, CC pause metrics were analyzed in the medical (CPR before cannulation) and surgical (CPR during ECMO cannulation, demarcated by the sterile draping of the patient) phases of ECPR, pre- and post-intervention. **Results:** Pre-intervention, 11 ECPR events (5 central cannulation, 6 peripheral cannulation) met inclusion criteria compared with 14 ECPR events (2 central, 12 peripheral) post-intervention. Pre-intervention analysis identified longer CC pauses and lower chest compression fraction (CCF) during the surgical versus medical phase of ECPR. Compared to pre-intervention data, CCF during the surgical phase of ECPR improved from 66% to 81% (73-85%) post-intervention ($P = .02$). Median CC pause length was significantly reduced from 20 s pre-intervention to 10.5 (9-13) seconds post-intervention ($P = .01$). There was no change in the surgical phase of ECPR duration (44 min pre- vs 41 min post-intervention, $P = .8$) or survival to hospital discharge (45% vs 21%, $P = .4$). **Conclusion:** Simple and feasible communication interventions during ECPR can minimize CC pauses, increase CCF and improve CPR quality without prolonging the time needed for ECMO cannulation.

Keywords

cardiopulmonary resuscitation, pediatrics, extracorporeal circulation, chest compression pauses

Background

Each year in the United States, approximately 15 000 children require cardiopulmonary resuscitation for in-hospital cardiac arrest (IHCA).[1,2] Survival ranges from 19%-54%[1,3–5] and is thought to be affected by multiple factors, including arrest etiology, CPR duration, and CPR quality.[6–8] International guidelines defining high quality CPR include minimizing chest compression (CC) pauses and expert consensus has recommended a chest compression fraction (CCF) greater than 80%.[9,10] Both adult and pediatric studies have associated longer CC pauses with worse survival.[11–16] Guidelines recommend that no pauses should be longer than 10 s.

Extracorporeal membrane oxygenation (ECMO) has been integrated into cardiac resuscitation algorithms as a surgical adjunct to improve outcomes for refractory cardiac arrest.[6,10,17,18] An international registry recently reported a 41% survival to discharge for pediatric CPR incorporating ECMO (ECPR),[19] with significant variability in ECPR outcomes reported elsewhere.[2,20,21] ECPR requires precise placement of cannulae into major blood vessels or the heart, and therefore may necessitate long CC pauses during delicate surgical portions of the procedure. Longer CC pauses have been measured during segments of ECPR when compared to conventional CPR.[15,22] A simulation study using video review demonstrated concern for extended CC pauses during ECMO cannulation.[23] Similarly, a recent pediatric study found that longer interruptions in chest compressions during pediatric ECPR were associated with worse survival.[24] Emerging data, particularly in pediatric ECPR, highlights the

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need for fewer and shorter CC pauses during ECMO cannulation. Characterization of these pauses is limited and methods for reducing them remains unclear.

This study had two primary goals: quantify the number and duration of CC pauses during the entirety of ECPR and implement quality improvement (QI) initiatives to reduce CC pauses during ECMO cannulation (the surgical phase of ECPR). We hypothesized that CC pauses were longer in the surgical phase of ECPR compared with the medical phase and that QI initiatives could improve CC metrics during the surgical phase of ECPR.

Methods

Our two-part study included a retrospective evaluation of chest compression pause metrics during pediatric ECPR followed by a prospective assessment of the effect of quality improvement interventions on CC pauses during ECPR. All children less than 18 years old with a cardiac arrest and ECPR activation in the PICU within a quaternary care, urban academic hospital were screened. The hospital includes 41 PICU beds within two general medical/surgical units and one cardiothoracic surgical ICU. PICU arrest and ECMO databases maintained for quality review identified ECPR events within the study period spanning from April 2016 to August 2023. Exclusion criteria included: ECPR telemetry data not collected, uninterpretable telemetry data (due to significant artifact or disconnection during the ECPR event), unknown timing of transition from the medical to surgical phase of ECPR, cannulation outside of the PICU. Events were included if cannulation was attempted during CPR, telemetry data was obtained for the duration of the ECPR event, and artifact did not inhibit the ability to measure pauses throughout the entire event. Exclusion rationale for specific ECPR events is detailed in Supplemental Figure 1. Three ECPR events which occurred during the five-month long QI implementation period were excluded to allow for a wash-out period. This project received a “Not Human Subjects research” designation from the Columbia University Institutional Review Board. The SQUIRE guidelines were followed for reporting of this quality improvement research.[25]

Following an in hospital PICU cardiac arrest, printed Phillips telemetry data are routinely collected and stored in a secured location for internal resuscitation review and debriefing. Invasive arterial blood pressure monitoring can be used as a surrogate for CC quality,[24,26] providing time-series data that shows when CC pauses are occurring and allows for quantification of pauses and overall CCF during arrests. Telemetry data was retrieved within seven days after ECPR, with minute-by-minute arterial line, EKG, end-tidal carbon dioxide and respiratory plethysmography tracings. Each ECPR event was analyzed by a primary author (EI) who calculated pause duration and frequency. The first four events were reviewed together by two authors (EI/AS) to establish consistent interpretation of chest compression pauses. Twenty percent of the total events were randomly selected and reviewed for accuracy between reviewers; there was 100% concordance in the number of pauses, and 91.4% agreement between the duration of pauses. For the rare situations in subsequent events in which telemetry data was less clear, two authors (EI/AS) reviewed the telemetry data together. All pauses lasting longer than 3 seconds were included for analysis, as given the granularity of the telemetry printouts, pauses 3 seconds or greater were consistently identifiable. Telemetry data were chosen to evaluate CC metrics over defibrillator CC measurements, as defibrillator pads are often removed during the surgical phase of ECPR. The primary outcome metric was CCF, and secondary outcomes included individual longest pause and median pause duration. Additional data collected included patient demographic data, arrest location, outcome, and total time for ECPR and ECMO cannulation. Total ECPR duration, surgical phase of ECPR duration, survival to decannulation and survival to hospital discharge were identified as balancing measures.

Total ECPR duration was the time from the initiation of chest compressions to the end of the resuscitation designated by either return of spontaneous circulation, death, or achieving full support on ECMO. Death during cannulation attempt (or termination of cannulation) may be the result of inability to achieve a sufficient ECMO flow or persistently acidotic pH despite the placement of cannulae. Each ECPR event was split into two discreet portions: medical phase (the conventional CPR period prior to beginning ECMO cannulation) and surgical phase (during which ECMO cannulation occurred). The sterile draping of the patient demarcated the surgical phase from medical phase. Thus, the medical phase was defined as the time chest compressions began to the time sterile draping was placed on the patient. The surgical phase was the time period from when the patient was sterilely draped to the end of the resuscitation as identified above.

The pre-intervention period included a retrospective data review of all ECPR events which met inclusion criteria between April 2016 and July 2021. Peripheral and central ECMO cannulations require different surgeons and techniques so variability in CC pauses could be challenging to compare between the two groups. However, pre-intervention data analysis demonstrated similar CC pause metrics between peripheral and central cannulations (Supplemental Figure 2) and after discussion with key ECPR stakeholders, it was identified that poor communication during extended CC pauses existed in both cannulation strategies. As a result, QI initiatives established applied to both central and peripheral ECMO cannulation and we analyzed central and peripheral ECPR events together.

From August 1, 2021 to December 31, 2021, QI initiatives were implemented, allowing for a 5-month washout period. The QI interventions included: (1) Sharing baseline CC pause data with key stakeholders, including PICU and cardiology attendings/fellows and pediatric and cardiothoracic surgeons, (2) Discussion and obtaining buy-in with key stakeholders regarding methods to reduce length of CC pauses during cannulation and (3) Creation of an ECPR protocol to improve communication and reduce CC pauses using expected verbal prompts like counting pause time out loud (Figure 1). Pre-intervention data demonstrating long CC pauses during

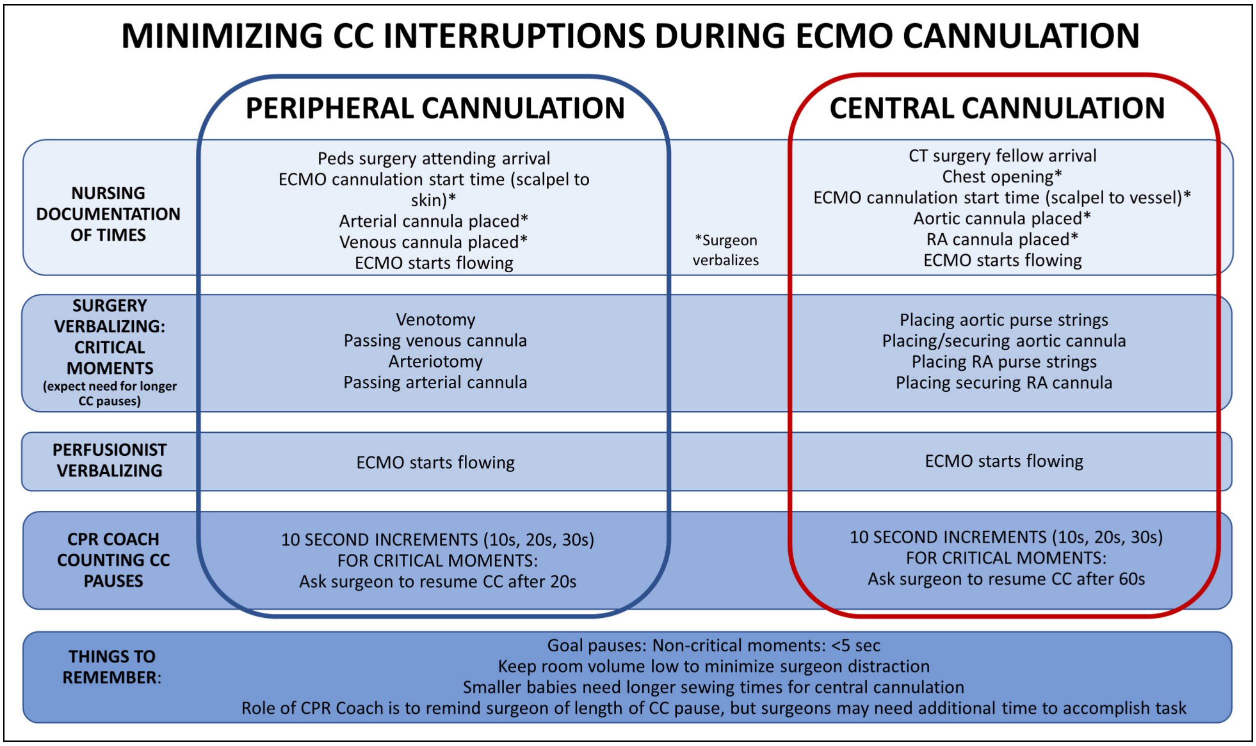

Figure 1. ECPR Communication Aid, with emphasis on spoken communication of CC pause duration between PICU and surgery.

the surgical phase of ECPR were presented to key stakeholders, and we agreed as a team that the goal of reducing CC pauses while not prolonging the surgical phase of ECPR was achievable. Both the medical and surgical teams agreed to expect verbal communication of CC pauses length at expected intervals of every 10 seconds (s). Interdisciplinary ECPR simulations (occurring every other month) reinforced this communication. New surgical and pediatric critical care fellows were oriented yearly to the communication device and the expectation of audible counting of CC pause duration. The post-intervention period included prospective ECPR data collection from January 2022 to August 2023.

Statistical Analysis

For this observational study with ECPR events collected both retrospectively and prospectively, no power analysis was performed. Patient demographics and event characteristics are reported pre- and post-intervention. An analysis of the pre-intervention cohort demonstrated no statistical difference between central and peripheral cannulations regarding CC pause metrics, thus both cannulation types were combined for analysis throughout this paper (Supplemental Figure 2). Categorical data were represented by counts and percentages, and continuous data as mean and standard deviation (SD) or median and interquartile range (IQR) depending on normality of distribution. Pre- and post-intervention characteristics were compared using Fisher exact, Wilcoxon rank sum, or independent t-tests. A run chart evaluated trends in the primary outcome, CCF during the surgical phase of ECPR, throughout the study period.

CCF, median CC pause duration, and longest CC pause were compared pre- and post-intervention via Wilcoxon rank sum test. A significance level of 0.05 was used for all analyses.

Results

After meeting inclusion criteria, 11 ECPR events pre-intervention were compared with 14 events post-intervention (Supplemental Figure 1.) No significant differences in patient or event characteristics were identified between the pre- and post-intervention groups (Tables 1 and 2). Of note, one patient had two distinct ECPR events during the post-intervention period; thus Table 1 includes 13 patients while Table 2 includes 14 events. Sixty-four percent of ECPR events occurred at night (6pm – 6am) in the post-intervention group, compared with 36% in the pre-intervention group ($P = .2$). Forty-five percent of patients were cannulated centrally in the pre-intervention group compared to 14% post-intervention ($P = .2$). The Pediatric Logistic Organ Dysfunction Score (PELOD-2) upon ICU admission was 4.7 for the post-intervention group compared with 3.6 pre-intervention ($P = .4$).[27] The post-intervention group included 3 ECPR events (divided between 2 patients, both of whom ultimately died before PICU discharge) resulting from pulmonary hypertensive crises, whereas pre-intervention there were no patients with pulmonary hypertension.

Retrospective review of the 11 ECPR events meeting pre-intervention inclusion criteria demonstrated inferior CC pause

Table 1. Patient Characteristics, pre- and post-Intervention.

Variable	Pre-Intervention	Post-Intervention	P
Total number of patients	11	13	
Median Age, *years (IQR)*	1.7 (0.5-7.6)	1.2 (0.6-2)	.7
Age, *n (%)*			1
Neonate (0-28 days)	0 (0)	0 (0)	
Infant (29 days – 12 months)	5 (45)	6 (46)	
Child (1 year – 18 years)	6 (54)	7 (54)	
Sex, *n (%)*			.4
Female	6 (54)	4 (31)	
Male	5 (45)	9 (69)	
Race/Ethnicity, *n (%)*			.6
Black	2 (18)	4 (31)	
White	8 (73)	6 (46)	
Hispanic	1 (9)	3 (23)	
Illness Category, *n (%)*			.5
Medical Non-cardiac	2 (18)	1 (8)	
Medical Cardiac	5 (45)	6 (46)	
Pulmonary HTN	0 (0)	2 (15)	
Surgical Non-cardiac	0 (0)	1 (8)	
Surgical Cardiac	4 (36)	3 (23)	
PELOD-2 at ICU Admission, *mean (SD)*	3.6 (1.9)	4.7 (3.9)	.4

metrics (CC pause length, longest CC pause, and CCF) during the surgical phase of ECPR when compared to the medical phase, with *P* values ranging from .003 to .02. These metrics included both peripheral and central ECMO cannulations. When comparing peripheral and central cannulation pre-intervention CC pause metrics, no statistical difference existed in either the medical or surgical phases of ECPR (Supplemental Figure 2).

When comparing pre- and post-intervention CC metrics during the medical phase of ECPR, no significant differences existed in median CC pause duration, longest CC pause or CCF (Table 3).

During the surgical phase of ECPR, overall CCF improved post-intervention from a median of 66% (IQR 62-80) to 81% (IQR 73-85) ($P = .02$). The run-chart in Figure 2 demonstrates this higher median CCF during the surgical phase of ECPR in the post-intervention period. When analyzing individual ECPR events, 27% (3/11) of pre-intervention events achieved a CCF during the surgical ECPR phase greater than 80%, compared with 58% (7/12) in the post-intervention group ($P = .13$). A statistically significant reduction in median CC pause length from 20 s (IQR 12-24) pre-intervention to 10.5 s (IQR 9-13) post-intervention ($P = .01$) was demonstrated during the surgical phase of ECPR (Table 3). The median longest CC pause during the surgical phase of ECPR was 60 s (IQR 55-180) pre-intervention compared with 57 s (IQR 42-70) post-intervention ($P = .2$). During the surgical phase of ECPR, the individual longest CC pause pre-intervention was 337 s compared with 120 s post-intervention.

Balancing measures, including total ECPR duration, duration of surgical phase of ECPR, survival to decannulation and to hospital discharge were unchanged pre- and post-

Table 2. ECPR Event Characteristics, pre- and post-Intervention.

ECPR Event Characteristics			
Variable	Pre-Intervention (*n* = 11)	Post-Intervention (*n* = 14)	P
Location, *n (%)*			
Medical-Surgical ICU	3 (27)	5 (36)	.7
Cardiac ICU	8 (73)	9 (64)	
Time of Week, *n (%)*			
Weekday	8 (73)	9 (64)	1
Weekend	3 (27)	5 (36)	
Time of Day, *n (%)*			
Day (6a-6p)	7 (64)	5 (36)	.2
Night (6p-6a)	4 (36)	9 (64)	
pH Prior to ECPR[a], *mean (SD)*	7.36 (0.1)	7.23 (0.2)	.1
Invasive Mechanical Ventilation (pre-arrest), *n (%)*	6 (54)	8 (57)	1
Initial Rhythm, *n (%)*			
PEA	6 (54)	7 (50)	.2
Bradycardia	3 (27)	7 (50)	
VT/VF	2 (18)	0 (0)	
Cannulation Site, *n (%)*			
Central	5 (45)	2 (14)	.2
Peripheral	6 (55)	12 (86)	
Internal Jugular/Carotid	4	7	
Femoral	2	5	
Immediate ECPR Outcome, *n (%)*			
Cannulation to ECMO	7 (64)	10 (71)	1
Termination of Cannulation	4 (36)	4 (29)	
Survival to ECMO Decannulation[b], *n (%)*	7 (100)	7 (70)	.2
Survival to Hospital Discharge, *n (%)*	5 (45)	3 (21)	.4
Total CC Duration, minutes, *mean (SD)*	72 (41)	69 (26)	.9
Medical ECPR (Pre-Cannulation)	28 (14)	28 (18)	.7
Surgical ECPR (During Cannulation)	44 (33)	41 (19)	.8

apH: Available for all pre-intervention ECPR and 11/14 post-intervention
b Survival to decannulation: Denominator used is number of successful ECMO cannulations

intervention (Table 2). Of the patients successfully cannulated to ECMO during ECPR, 100% pre-intervention versus 70% post-intervention survived to decannulation ($P = .2$). Survival to hospital discharge was 45% pre-intervention compared with 21% post-intervention ($P = .4$).

Discussion

Implementation of simple QI initiatives improved CC metrics during the surgical phase of ECPR. Initiatives included sharing baseline CC pause data, discussions to obtain buy-in

Table 3. Comparison of Chest Compression (CC) Pause Metrics pre- and post-intervention, during the Medical and Surgical Phase of ECPR (Medical Phase of ECPR: CC pre-ECMO Cannulation; Surgical Phase of ECPR: CC During ECMO Cannulation).

	Medical Phase of ECPR			Surgical Phase of ECPR		
CPR Metric	Pre-Intervention	Post-Intervention	*P*-value	Pre-Intervention	Post-Intervention	*P*-value
CC Pause Length, seconds Median (IQR)	10 (8-14)	9 (6-12)	.1	20 (12-24)	10.5 (9-13)	.01
Longest CC Pause, seconds Median (IQR)	37 (22-49)	27 (20-36)	.3	60 (55-180)	57 (42-70)	.2
CCF, % Median (IQR)	87 (85-89)	88 (87-92)	.1	66 (62-80)	81 (73-85)	.02

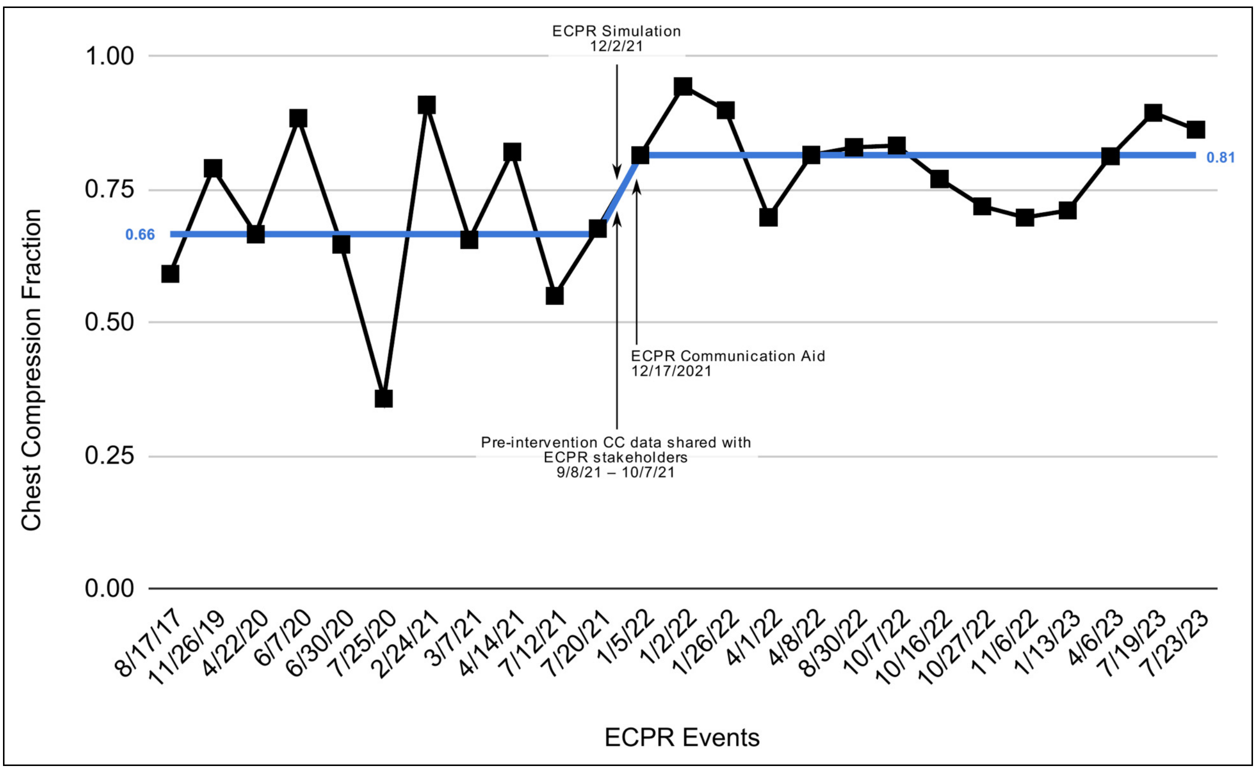

Figure 2. Run chart depicting CCF during the surgical phase of each ECPR event. Blue line indicates median CCF pre-intervention (66%, IQR 62-80) and post-intervention (81%, IQR 73-85). Study design, quality improvement interventions (pre-intervention CC data review with ECPR stakeholders to obtain buy-in and distribution of a novel ECPR communication aid), and reinforcement of expected communication with interdisciplinary simulations occurred between August and December 2021.

among key stakeholders, and creation of an ECPR communication tool (Figure 1). These interventions were designed to improve communication during ECPR, when coordination between specialties is the key to successful ECMO cannulation. We demonstrated statistically significant improvements in median CC pause length and CCF during the surgical phase of ECPR. CCF during cannulation improved from 66% to 81%, achieving the expert recommended target of a CCF greater than 80%.[9]

Video recordings of pediatric resuscitations suggest longer pauses occur during pediatric ECPR than conventional CPR,[22] with adult and pediatric studies demonstrating correlation between prolonged pauses and decreased survival.[8,11,15,16,24,27,28] A recent pediatric study found both that every 5-s increase in CC pause duration during IHCAs was associated with lower chance of survival with favorable neurologic outcome, and that the number of long pauses was associated with lower probability of return of spontaneous circulation.[29] In addition, the retrospective analysis of pediatric ECPR events by Han et al showed that both patient survival and favorable neurologic outcome were associated with shorter and less variable CC pauses.[24] While our data did not demonstrate a statistically significant reduction in the longest ECPR pause post-intervention, the range for median longest CC pause was narrower post-intervention (IQR 42-70 s) compared with pre-intervention (IQR 55-180 s), suggesting that our QI interventions may have reduced some of the longest pauses measured in the pre-intervention cohort. Similarly, the difference between the individual longest CC pause pre- (337 s) and post-intervention (120 s) during the surgical phase of ECPR could be clinically significant. Based on earlier studies, even a 5 s reduction in the longest pause may yield clinical significance, reinforcing the potential importance of reduction in longest CC pause length.[13,15,16,29]

Large CPR databases typically lack the granularity to determine precisely when transition from the medical to surgical ECPR phase occurs, making interpretation of ECPR CC pause metrics difficult. ECPR requires a sterile surgical field and bulky monitoring devices are commonly removed, making surgical phase CC pause metrics challenging to analyze uniformly across multiple centers. Our collection of telemetry data with arterial monitoring allowed for the quantification of CC pause metrics throughout the entirety of ECPR, adding to the growing body of work demonstrating the need for improvement in CPR quality during the surgical portion of ECPR. We offer QI interventions that address long CC pauses reflected in both our data and recently published work.[24,29]

The American Heart Association guidelines for high-quality CPR include the recommendation that CC pauses last no more than 10 s.[11,12,14–16,29] Longer pauses during key moments of the surgical phase of ECPR (such as arteriotomy or venotomy) might be impossible to eliminate. Disrupting cannulating surgeons' focus and prolonging the surgical phase of ECPR must be avoided with any ECPR intervention. CC pauses during the surgical phase of ECPR in our post-intervention group were shorter, while the total ECPR and surgical phase durations were unchanged, demonstrating that simple QI interventions aimed at improving communication can minimize CC pause lengths and improve CCF without sacrificing cannulation speed.

The major QI interventions used in this study were neither time consuming nor cost-intensive. Sharing baseline data between the medical and surgical teams led to collaborative discussions and creation of a standardized protocol for communication during ECPR. Vocalizing CC pause duration and ensuring all team members' awareness of crucial moments in both peripheral and central cannulation were identified as opportunities for improvement during initial discussions. While interdisciplinary ECPR simulations reinforced the main QI interventions, it was standardizing vocal communication that led to a shared mental model between the medical and surgical teams: the surgical team understood the overall need for shorter CC pauses and the medical team understood that longer pauses were necessary surrounding key surgical steps. After our interventions, there was a quantifiable improvement in CC pause metrics by data measured and additionally, a shared mental model for communication between the two teams. The initiatives implemented in this study continue to be routinely reviewed after ECPR events at our institution, with the ongoing goal of maintaining a high standard of communication between ECMO team members.

Establishing the expected norm that CC pauses would be counted out loud was an iterative process, with allowances for surgical preference. At our institution, two different surgical teams (cardiothoracic and pediatric surgeons) cannulate during ECPR, depending on patient factors. Both surgical teams were integrally involved in this study, allowing for generalizability across other hospital settings where one or both surgical specialties cannulate. For example, cardiothoracic surgeons requested the allowance for longer pause duration during central cannulation, before prompting the surgeons to resume compressions (Figure 1). Some surgeons requested different volume or interval levels for counting pauses out loud for a given ECPR event, which was honored by the medical team to facilitate a smoother cannulation. Individual ECPR events were reviewed via debriefings to allow feedback for both the surgical and medical teams. This formalized communication during ECPR has led to improved awareness by both teams of the length of CC pauses and improved responsiveness to the need to resume compressions. Our experience suggests that these QI interventions are applicable to both central and peripheral cannulations and to teams with a variety of interdisciplinary participants.

Although our interventions resulted in a significant improvement in CPR metrics during the surgical phase of ECPR, mortality was not improved in the post-intervention group. As discussed previously, prior studies have demonstrated a correlation between longer CC pauses and worse mortality, underscoring the importance of reduction in CC pause duration.[13,15,16,24,28,29] With the rarity of ECPR, this study was not powered to show a difference in mortality. Additionally, despite no statistically significant difference in patient or event characteristics, even a few challenging cases could skew mortality with such small patient numbers. For example, our post-intervention cohort included 3 ECPR events preceded by pulmonary hypertensive crises, a condition which carries a particularly poor prognosis.[30,31] Similarly, the post-intervention group trended toward a higher mean PELOD-2 score on ICU admission compared to the pre-intervention group. Finally, our ECMO surgical team is not in house overnight, with more junior surgeons cannulating at night. While the duration of cannulation did not vary significantly pre- and post-intervention, suggesting the nighttime cannulations were not dramatically longer, other factors such as bleeding during cannulation and effective cannula placement may be impacted by surgeon experience and contribute to mortality. Nearly twice as many events occurred at night post-intervention compared to pre-intervention. These factors may have affected mortality outcomes despite the measured improved CPR quality.

Limitations

First, as pediatric ECPR is a rare event, this study's sample size was too small to determine an effect on mortality. While CC pause duration was reduced and no identifiable balancing measures were affected by our interventions, a number of patient and event factors (severity of organ dysfunction, etiology of arrest, and time of arrest) likely contributed to higher mortality in the post-intervention group. Unfortunately, databases with larger patient numbers lack the granularity to assess CC pauses as we required. A deeper exploration into the correlation of ECPR pauses and mortality via a multicenter effort would result in more patient volume and allow changes in mortality or neurologic outcome to be detected.

Second, the number of eligible events in the pre-intervention period was low (20% of total ECPR events) because of challenges collecting thorough telemetry data retrospectively. Our institution changed EMR platforms in February 2020 which also restricted the data we could obtain for some events. In addition, this limited data collection on outcomes such as neurologic status which would be important to explore further. Detailed record keeping was essential to obtain the granularity needed for this study, but limited events that we were able to analyze retrospectively to those with complete data collected.

Finally, the ECPR events described in this study included both central and peripheral cannulations, as well as cannulation via neck and femoral vessels. The pre-intervention cohort demonstrated no difference in CC pause metrics or total event duration when comparing peripheral and central cannulations. While, different surgical approaches and patient populations may ultimately require varying surgical strategies, our initial data showed they were statistically similar for a combined analysis. Differences between the two approaches and the way each strategy impacts CC pause metrics could be a source of further exploration for future studies.

Conclusion

ECPR offers a potentially life-saving therapy to children who experience a cardiac arrest. This study quantified ECPR CC pause metrics and offered feasible interventions to minimize CC pauses during the surgical phase of ECPR without prolonging total ECPR duration. Future work is required to evaluate the impact of these interventions on mortality and would benefit from a multicenter initiative.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Supplemental Material

Supplemental material for this article is available online.

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