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Clinical paper

Are chest compression quality metrics different in children with and without congenital heart disease? A report from the pediatric resuscitation quality collaborative

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ABSTRACT

Objective: To evaluate the association of CPR quality metrics with survival outcomes in children with and without congenital heart disease experiencing in-hospital cardiac arrest.
Design: Retrospective cohort study of data from the Pediatric Resuscitation Quality (pediRES-Q) Collaborative.
Setting: 28 participating sites.
Patients: Patients who were < 18 years of age at time of arrest, ≥ 37 weeks gestational age, with ≥ 1 min of monitor-defibrillator chest compression quality metric data recorded.
Interventions: None.
Measurements and Main Results: There were a total of 742 index in-hospital cardiac arrest events in 675 unique patients analyzed between July 2015 and August 2021. Amongst these events, 205 (27.6%) occurred in patients with congenital heart disease and 537 (72.4%) in patients without congenital heart disease. After adjusting for age and use of extracorporeal CPR during arrest, children with congenital heart disease were less likely to have chest compression depth that met compliance with American Heart Association guidelines than children without congenital heart disease. Despite differences in CC depth, the presence of congenital heart disease was not associated with return of spontaneous circulation, survival to hospital discharge, or SHD with favorable neurologic outcome on multivariable logistic mixed effects modeling.
Conclusions: In a large multi-center international pediatric resuscitation collaborative, patients with congenital heart disease compared to those without were less likely to have guideline-compliant CC depth yet no differences in return of spontaneous circulation, survival to hospital discharge or survival to discharge with favorable neurologic outcome were observed on multivariable analysis.

Introduction

Approximately half of children with heart disease that experience in-hospital cardiac arrest (IHCA) survive to discharge.[1] Several risk factors in children with heart disease are associated with worse outcomes after IHCA, such as medical (vs. surgical) cardiac illness category, older age,

Abbreviations: IHCA, in hospital cardiac arrest; CHD, congenital heart disease; CPR, cardiopulmonary resuscitation; AHA, American Heart Association; CC, chest compression; ECPR, extracorporeal cardiopulmonary resuscitation; ECMO, extracorporeal membrane oxygenation; ROC, return of circulation; ROSC, return of spontaneous circulation; SHD, survival to hospital discharge; PCPC, Pediatric Cerebral Performance Category; IQR, interquartile range.

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longer duration of CPR, repeat IHCA, single vs. biventricular anatomy, and certain cardiac surgical procedures (Norwood or Stage 1 procedure).[2–4] Few data inform how congenital heart disease affects survival or cardiopulmonary resuscitation (CPR) quality. Traditional models for survival outcomes after IHCA have utilized Utstein-style illness categorization such as cardiac (medical/surgical) and non-cardiac (medical/surgical) groupings. These illness categories fail to capture the impact of congenital heart disease on outcomes, since congenital heart disease may be included in both medical and surgical cardiac illness groups.

Many factors limit effective CPR in children with congenital heart disease depending on their underlying anatomy/physiology, including parallel systemic and pulmonary circulations, restrictive right ventricular physiology, and pulmonary hypertension. The American Heart Association (AHA) scientific statement on CPR in children with cardiac disease[5] highlights challenges in the management of children with congenital heart disease during IHCA. A lack of understanding of how best to perform CPR in children with congenital heart disease has led the authors to investigate the impact of congenital heart disease on CPR quality metrics and survival outcomes after IHCA. Differences in CPR quality metrics between children with and without congenital heart disease may potentially exist secondary to 1) changes in chest wall compliance after cardiac surgery and 2) physiologic considerations depending on the patient's underlying cardiac anatomy. We hypothesize that the presence of congenital heart disease will be associated with a difference in CPR quality metrics (rate, depth, chest compression fraction) but will not be associated with survival outcomes.

Methods

This was a retrospective cohort study using data from the Pediatric Resuscitation Quality (pediRES-Q) Collaborative (ClinicalTrials.gov: NCT02708134), a large international multi-center network of children's hospitals that collects data on pediatric cardiac arrests and chest compression (CC) quality metrics. The study was approved by the Children's Hospital of Philadelphia IRB and each hospital's institutional review or research ethics board (Approval number 15–012099, under the study title "Quality of Pediatric Resuscitation in a Multicenter Collaborative: an Observational Study"). See Supplemental Digital Content 1 for a list of sites and number of events. There was a waiver of consent per United States Code of Federal Regulations 45 CFR 46.116(d) and 45 CFR 46.408(a). Data use agreements were obtained for each institution and compliance with the Health Insurance Portability and Accountability Act was maintained.

For each IHCA event, we collected data on prospectively selected variables. Pre-arrest characteristics included patient demographics, admission type (cardiac surgical [post-operative following cardiac surgery at the time of the event] vs. cardiac medical [primary diagnosis of medical illness that is cardiovascular at the time of the event]), congenital heart disease (defined as structural heart defect present at birth with its presence or absence, and reported by each site), single ventricle anatomy (disorders affecting one lower chamber of the heart that is smaller, underdeveloped, or missing a valve), IHCA etiology, and interventions in place at the onset of IHCA. Intra-arrest data including CC quality [depth, rate and fraction], timing of IHCA, presence of invasive monitoring prior to the onset of IHCA, initial rhythm, duration of CC and use of extracorporeal CPR (ECPR). CC quality metric data were recorded using the ZOLL R-series monitor-defibrillator (ZOLL Medical, Chelmsford, MA) and dual sensor defibrillator pads, placed on the anterior (chest) and posterior (back) of the patient. Accelerometer-based technology recorded CC rate, depth and fraction and mitigated depth artifact caused by mattress deflection during CC.

Inclusion and exclusion criteria

We included patients $<$ 18 years of age at time of arrest, $\geq$ 37 weeks gestational age, with $\geq$ 1 min of monitor-defibrillator CC quality metric data recorded. We excluded patients with out-of-hospital cardiac arrest, on extracorporeal membrane oxygenation (ECMO) at the start of the arrest, or if there were limitations to CPR in place or had less than 33.3 % of CC quality metric data captured by the monitor-defibrillator. In analysis of CC epochs, we excluded events if only apical anterior placement defibrillator pads were used or compression values if accelerometer depths of $<$ 1 cm or $>$ 8 cm for children $<$ than 8 years and $>$ 10 cm for children equal to or $>$ 8 years old were recorded, as this was likely artifact.

Definition of cardiopulmonary resuscitation quality metrics

Epochs were defined as 60 s increments of CC metric data. We recorded compliance of each epoch with the AHA 2020 guidelines for basic life support with the predefined targets of CC rate 100–120 per minute; CC depth $\geq$ 3.4 cm for $<$ 1 year of age and $\geq$ 4.4 cm for 1 to $<$ 8 years of age, and 4.5–6.6 cm for 8 to $<$ 18 years of age ($\pm$10 % guideline depth); and CC fraction $\geq$ 80 %. CC fraction refers to the percentage of time during a CPR event that CC were performed without interruption. Compliance for each event was defined as $\geq$ 60 % of event epochs meeting AHA guideline targets.

Outcome measures

Outcome measures included return of spontaneous circulation (ROSC), return of circulation with or without ECMO (ROC), survival to hospital discharge (SHD) and SHD with favorable neurological outcome. ROSC and ROC are reported at the event-level. SHD and favorable neurologic outcome are reported at the patient-level for index (first in-hospital) IHCA events. ROSC was defined if spontaneous circulation was achieved for a period of at least 20 min with no further need for CC. ROC was defined as either achieving ROSC or successful cannulation to ECMO achieving effective circulation during the IHCA event. SHD with favorable neurologic outcome was prospectively defined as a Pediatric Cerebral Performance Category (PCPC) score of 1, 2 or 3, or no change from pre-arrest PCPC, at the time of hospital discharge. We used an alternate definition of SHD with favorable neurologic outcome of PCPC score of 1 or 2 or no change from pre-arrest PCPC, at the time of hospital discharge for a sensitivity analysis.

Statistical analysis

Demographic and clinical characteristics are presented as median (interquartile range) for continuous variables and percentages for categorical variables. For each event, we calculated CC mechanics quality metrics of median CC rate, depth, and fraction, CC rate compliance, depth compliance, fraction compliance, and overall compliance. We report CC quality metrics by age groups and congenital heart disease status. Comparison between patients with and without congenital heart disease were analyzed by the Wilcoxon Rank Sign test or Chi-square test. Univariate logistic regression models were created to assess the association between various risk factors and outcomes. Risk factors that had a p value $\leq$ 0.05 were included in the multivariable logistic regression model.

Multivariable logistic mixed effects models were utilized to assess the relationship between presence of congenital heart disease and outcomes while accounting for the clustering effect of site/patient. Potential covariates included age group, illness category, immediate cause of arrest, pre-existing condition: metastatic or hematologic malignancy or septicemia, pre-existing condition: congenital malformation, initial cardiac rhythm (shockable vs. non-shockable) epinephrine dose (2–4 vs. 0–1, and 5 + vs. 0–1 doses), administration of atropine, fluid bolus, inhaled nitric oxide, time of day, day of week, arrest duration, intervention in place at time of first CC. For each outcome, a set of covariates were included depending on the sample size included in the model (see

Table 3 footnote for model-specific covariates). Arrests clustering within site were adjusted for all outcomes. Moreover, arrests clustering within patients (i.e. recurrent arrests in the same patient) were accounted for in the two event-level models ROSC model and ROC.

Linear mixed-effect models were employed to assess the effect congenital heart disease had between the diagnostic group (medical cardiac vs. surgical cardiac), and CPR quality metrics, while controlling for clustering effect of sites. Age group was adjusted in these models.

Results

There was a total of 742 events amongst 675 patients with 16,781 or more evaluable 60-sec epochs of CC metrics with complete data from 28 participating sites (1–89 events per site, median 15, IQR[7–12]from the pediRES-Q Collaborative (Fig. 1). Data was collected between 15th July 2015 and 9th August 2021.Of the 742 events, 205 (27.6 %) had congenital heart disease and 537 (72.4 %) did not have congenital heart disease.

Table 1 and Supplementary Digital Content 2 summarize patient demographics and event characteristics respectively, analyzed by the presence of congenital heart disease. Patients with congenital heart disease compared to those without were more likely to be younger, have a congenital non-cardiac malformation, arrhythmia as the cause of the arrest, longer CPR duration, while less likely to receive a fluid bolus during the event. Patients with congenital heart disease were more likely

Table 1
Patient Demographics.

Characteristics	*Total*	*CHD*	*Non-CHD*	*P value*
N (%)	742	205 (27.6)	537 (72.4)	–
Age at arrest, years (median, IQR)	2.67 (0.67, 9.92)	0.80 (0.33, 3.70)	4.22 (0.90, 11.95)	0<.001
Male (N, %)	425 (57)	112 (55)	313 (58)	0.41
Pre-existing Conditions [may have > 1 reported at time of event] (N, %)				
Cardiac Malformation	205 (28)	205 (100)	0 (0)	–
Congenital Malformation (Non-cardiac)	131 (18)	58 (28)	73 (14)	0<.001
Hypotension/ Hypoperfusion	246 (33)	71 (35)	175 (33)	0.60
Metabolic/Electrolyte Abnormality	180 (24)	43 (21)	137 (26)	0.21
Metastatic or Hematologic Malignancy	69 (9)	1 (0)	68 (13)	0<.001
Renal insufficiency	127 (17)	33 (16)	94 (18)	0.67
Respiratory insufficiency	480 (65)	137 (67)	343 (64)	0.49
Septicemia	110 (15)	20 (10)	90 (17)	0.02
Illness category (N, %)				
Medical cardiac	167 (23)	91 (44)	76 (14)	0<.001
Medical non-cardiac	385 (52)	23 (11)	362 (67)	
Surgical cardiac	92 (12)	84 (41)	8 (1)	
Surgical non-cardiac	59 (8)	7 (3)	52 (10)	
Trauma	39 (5)	0 (0)	39 (7)	

Abbreviations: CHD: Congenital Heart Disease.

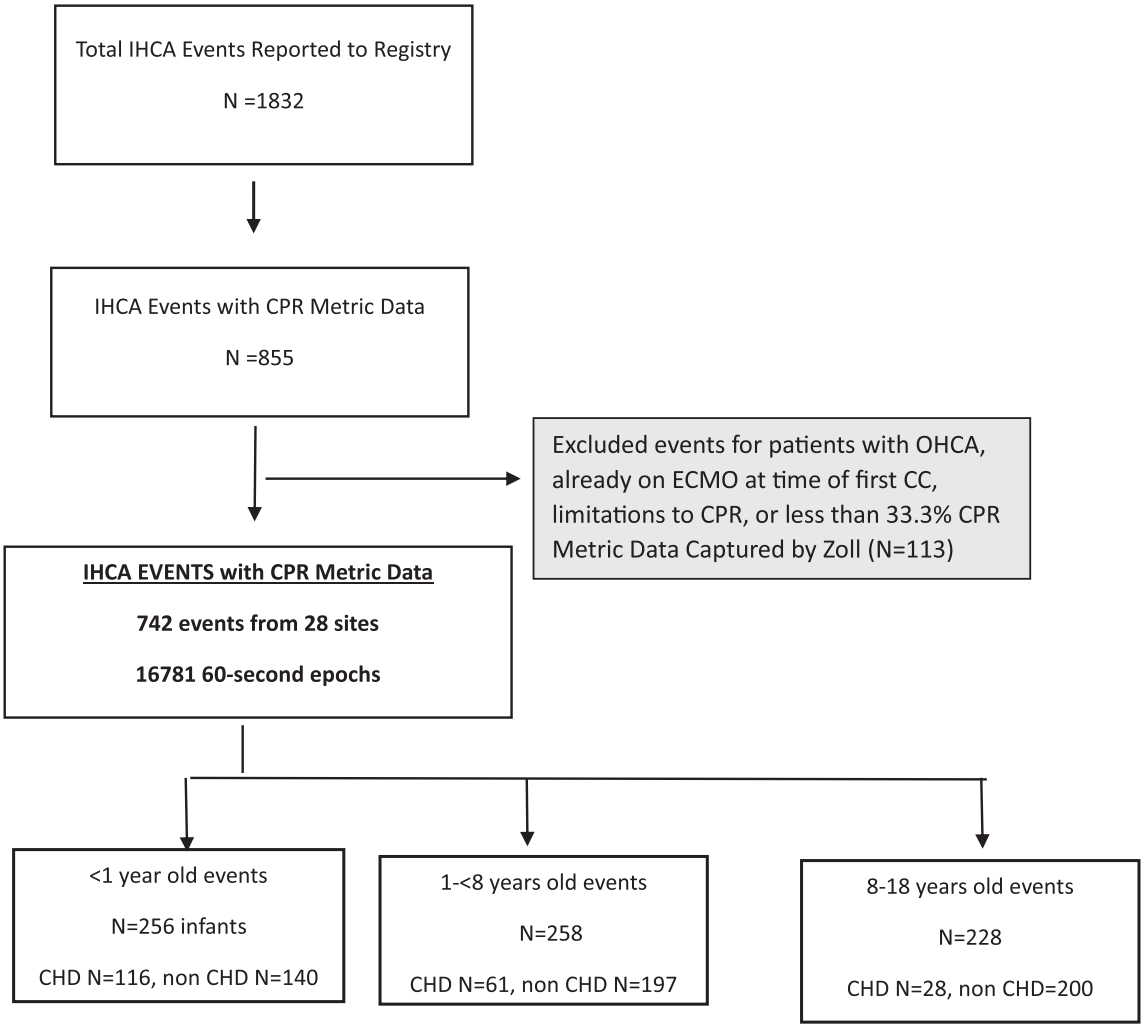

Fig. 1. Utstein style consort diagram. Abbreviations: IHCA = in hospital cardiac arrest, OHCA = out of hospital cardiac arrest, CC = chest compressions, CPR = cardiopulmonary resuscitation, CHD = congenital heart disease.

to receive the following interventions during the event: atropine, inhaled nitric oxide, 5 + doses of epinephrine, have an arterial line in place at the time of arrest, and ROC with ECMO. Patients with congenital heart disease compared to those without were less likely to have metastatic or hematologic malignancy and septicemia at the time of the IHCA or have respiratory decompensation as the cause of the arrest. Patients with single ventricle anatomy comprised 37 % of the congenital heart disease group.

Table 2 summarizes CC quality metrics and outcomes analyzed by the presence of congenital heart disease for all age groups. Since patients with congenital heart disease were younger, had higher rates of ECPR and arterial lines in place, had longer CPR duration, and more epinephrine doses, which can affect CC quality metrics, we adjusted for these variables. Table 2 reflects all age groups and shows that events with patients with congenital heart disease had lower absolute CC fraction although no differences in absolute CC rate. Patients with congenital heart disease compared to those without had lower absolute CC depth and guideline compliant depth. Overall compliance between both groups was low. Events in patients with congenital heart disease compared to those without were less likely to achieve ROSC, but more likely to have ROC with ECMO, SHD and SHD with favorable neurologic outcome (primary definition). Supplementary Digital Content 3 summarizes CC quality metrics and outcomes analyzed by individual age groups, adjusting for confounding variables as was done for the overall cohort. For the 1- <8-year age group, events with patients with congenital heart disease had lower absolute depth and depth compliance. For the 8–18-year age group, events with patients with congenital heart disease had lower CC fraction compliance and rate compliance. For each of the age groups, there were lower rates of ROSC and higher rates of ROC with ECMO.

Table 3 displays the multivariable logistic regression model to determine the effect of the presence of congenital heart disease on outcomes. Confounding variables included in the models are referenced in Table 3. In the multivariable analysis, patients with congenital heart disease compared to those without had no difference in ROSC, ROC with

Table 2
CPR Metrics and Outcomes between Patients with Congenital Heart Disease and those without Congenital Heart Disease.

CPR Metrics/Outcomes	*Total*	*CHD*	*Non-CHD*	*P value*
N	742	205 (27.6)	537 (72.4)	–
CPR Metric				
CC rate (median (IQR))	115 (110, 121)	114 (109, 121)	115 (110, 120)	0.10
CC depth (median (IQR))[#]	3.73 (2.81, 5.24)	3.01 (2.41, 3.90)	4.28 (3.03, 5.60)	0<.001
CCF (median (IQR))	91 (81, 97)	89 (77, 96)	92 (82, 97)	0.15
Rate compliance (N, %)	465 (63)	116 (57)	349 (65)	0.11
Depth compliance (N, %)	186 (27)	26 (14)	160 (32)	0.004
CCF compliance (N, %)	497 (67)	120 (59)	377 (70)	0.08
Overall compliance (N, %)[#]	64 (9)	9 (5)	55 (11)	0.28
CCF and CC rate compliance (N, %)	252 (34)	53 (26)	199 (37)	0.12
Outcome				
ROSC (N, %)	388 (52)	92 (45)	296 (55)	0.01
ROC with ECMO (N, %)	124 (17)	56 (27)	68 (13)	0<.001
ROSC + ROC with ECMO (N, %)	512 (69)	148 (72)	364 (68)	0.25
SHD (N, %)[†]	193 (35)	70 (44)	123 (31)	0.004
SHD with favorable neurologic outcome: primary definition (N, %) [†]	153 (29)	58 (38)	95 (25)	0.003
SHD with favorable neurologic outcome: secondary definition (N, %) [†]	167 (24)	56 (28)	111 (22)	0.08

Abbreviations: CHD: congenital heart disease, ROSC: return of spontaneous circulation, ROC: return of circulation, ECMO: extracorporeal membrane oxygenation, SHD: Survival to Hospital Discharge. [#]Events with single sensor for <=8 years, Dual accelerometer incorrect sensor position documented were excluded for depth related analysis. [†]SHD comparison was conducted on index events only (<1 year N = 185, 1-<8 Years N = 200, 8–18 years N = 174). SHD with favorable neurologic outcome comparison was conducted on index events with neurologic outcome information; 23 events with missing favorable neurologic outcome primary definition; 25 events with missing favorable neurologic outcome secondary definition were excluded from the analyses. P values for the Wilcoxon rank-sum test or exact chi-square test were reported for outcomes. For median rate/depth/CCF, p values from the linear regression models adjusting for age at arrest, ECPR during arrest, and arterial line in place were reported. For compliance, p values from the logistic regression model adjusting for age at arrest, ECPR during arrest and arterial line in place, CPR duration, and number of epinephrine doses were reported.

Table 3
Multivariable Logistic Regression Model.

Survival Outcomes	*Adjusted Odds Ratio (CHD vs. non-CHD)*	*95 % CI*	*P value*
Event level analysis (all events)			
ROSC [a]	0.97	(0.44,2.13)	0.94
ROSC + ROC with ECMO [b]	0.96	(0.58,1.58)	0.87
Patient level Analysis (Index events only)			
Survival to Hospital Discharge [c]	0.87	(0.36,2.13)	0.76
SHD with favorable neurologic outcome (definition 1)[d]	1.16	(0.48,2.81)	0.74
SHD with favorable neurologic outcome (definition 2) [e]	0.76	(0.31,1.87)	0.55

[a] The regression model was controlled for age groups, illness categories, Pre-existing condition: Congenital Malformation (Non-cardiac), Pre-existing condition: Metastatic or Hematologic Malignancy or Septicemia, Immediate Cause of Arrest: Arrhythmia, Immediate Cause of Arrest: Hypoxia/Respiratory decompensation, Initial cardiac rhythm, first documented shockable/non-shockable rhythm, Epinephrine dose, Atropine, Fluid bolus, Inhaled nitric oxide, time of day/week, **arterial line presence, CPR duration**, Intervention in place at time of first CC: Dialysis/extracorporeal filtration therapy, CC depth compliance and clustering in site/patient.

[b] The regression model was controlled for **age groups**, illness categories, Pre-existing condition: Metastatic or Hematologic Malignancy or Septicemia, Immediate Cause of Arrest: Arrhythmia, Immediate Cause of Arrest: Hypoxia/Respiratory decompensation, first documented shockable/non-shockable rhythm, **epinephrine dose,** Atropine, Fluid bolus, Inhaled nitric oxide, arterial line presence, **CPR duration**, **intervention in place at time of first CC: Dialysis/extracorporeal filtration therapy,** CC depth compliance and clustering in site/patient.

[c] The regression model was controlled for **age groups, illness categories**, **Pre-existing condition: Metastatic or Hematologic Malignancy or Septicemia,** Immediate Cause of Arrest: Arrhythmia, Immediate Cause of Arrest: Hypoxia/Respiratory decompensation, **first documented shockable/non-shockable rhythm**, Epinephrine dose, Atropine, **Fluid bolus**, arterial line presence, **CPR duration**, **ROC with ECMO**, **intervention in place at time of first CC: Dialysis/extracorporeal filtration therapy, CC depth compliance,** and clustering in site.

[d] The regression model was controlled for **age groups, illness categories**, **Pre-existing condition: Metastatic or Hematologic Malignancy or Septicemia, first documented shockable/non-shockable rhythm,** Epinephrine dose, **Fluid bolus**, arterial line presence, **CPR duration**, **ROC with ECMO**, **intervention in place at time of first CC: Dialysis/extracorporeal filtration therapy, CC depth compliance,** and clustering in site. 23 patients with missing neurologic outcome information were excluded from the analysis.

[e] The regression model was controlled for **age groups, illness categories**, **Pre-existing condition: Metastatic or Hematologic Malignancy or Septicemia,** first documented shockable/non-shockable rhythm, **Fluid bolus**, arterial line presence, **CPR duration**, **ROC with ECMO**, **intervention in place at time of first CC: Dialysis/extracorporeal filtration therapy,** CC depth compliance and clustering in site. 25 patients with missing neurologic outcome information were excluded from the analysis. **The bolded variables are ones that are significant at a level ≤ 0.05.**

ECMO, SHD, or SHD with favorable neurologic outcome (primary or alternative definition).

Although the presence of congenital heart disease was not associated with any outcomes in the multivariable model, we observed a significant association of several additional variables with outcomes (see Supplemental Digital Content 4). Higher rates of SHD were observed for younger age, surgical cardiac vs. medical cardiac illness category, absence of pre-existing metastatic or hematologic malignancy or septicemia, absence of fluid bolus use during CPR event, shorter duration of CPR, ROC with ECMO, absence of dialysis/extracorporeal filtration therapy, and decreased CC depth compliance. Similar results were seen with SHD with favorable neurologic outcome (primary and alternate definitions).

Table 4 summarizes CC quality metrics by congenital heart disease presence and survival status. After adjusting for confounding variables, amongst patients with congenital heart disease, those with SHD were less likely to have combined CC rate and fraction guideline compliance compared to non-survivors. Amongst patients without congenital heart disease, survivors to hospital discharge were less likely to have CC fraction, depth and overall guideline compliance compared to non-survivors.

To assess how the presence of congenital heart disease influenced the relationship between illness category (medical cardiac vs. surgical cardiac) and CPR quality, we evaluated CPR quality metrics and outcomes in the medical cardiac vs. surgical cardiac groups and created a linear mixed effects model (Fig. 2). This model failed to show a significant relationship between illness categories and the CPR quality metrics with the presence of congenital heart disease.

Discussion

In this multicenter retrospective cohort study, children with congenital heart disease experiencing IHCA were less likely to receive guideline-compliant CC depth than children without congenital heart disease. Multivariable analysis failed to reveal a significant association between congenital heart disease and ROSC, SHD, or SHD with favorable neurologic outcome. Our study is the first to evaluate if the presence of congenital heart disease impacts the association of measured CPR quality metrics with outcomes, regardless of illness category, and is consistent with other studies that the presence of congenital heart disease is not associated with survival outcomes when adjusting for key confounders. [3,6]

Several notable differences in demographics and event characteristics of patients with and without congenital heart disease were observed in this analysis which may impact outcomes. Many of these are consistent with prior reports showing the presence of congenital heart disease is associated with genetic syndromes and congenital non-cardiac malformations, and can contribute to significant perioperative morbidity. [7,8–9] In addition, as the majority of hospitalized children with congenital heart disease undergo congenital heart surgery, 41 % of patients with congenital heart disease in our cohort were post-operative. The high percentage of post-surgical patients in the congenital heart disease group parallels other differences such as younger age (higher complexity surgeries in neonates are more common), presence of an arterial line, increased rates of ROC with ECMO and longer duration of CPR. [2] Patients without congenital heart disease also had higher rates of oncologic processes and septicemia and lower rates of shockable rhythms, factors associated with worse outcomes.

In the overall cohort, after adjusting for confounding variables, patients with congenital heart disease compared to those without congenital heart disease had lower absolute CC depth and depth compliance. When evaluating these differences by age groups, only the events in patients with congenital heart disease in the 1-<8 year age group showed differences in absolute depth and depth compliance. It is unclear why events in patients with congenital heart disease have lower absolute depth and depth compliance. Differences in chest wall compliance, how clinicians provide CPR given the patient's underlying cardiac anatomy and physiology, and concern for fresh suture and intrathoracic lines could potentially explain these differences.

Although our multivariable logistic regression model did not reveal associations between congenital heart disease and survival outcomes, our study confirms prior literature showing shorter CPR duration, younger age, surgical cardiac disease (vs. medical cardiac), and ROC with ECMO [11–12] to be associated with improved SHD. Markers of pre-existing illness severity, such as malignancy and septicemia, dialysis/extracorporeal filtration therapy in place at the time of first CC, and presence of an indwelling arterial line were shown to be risk factors for mortality.

When we evaluated the effects of CC quality metrics by presence of congenital heart disease and survival, patients with congenital heart disease had a survival benefit if they had lower CC fraction and rate compliance, and patients without congenital heart disease had a survival benefit if they had lower CC fraction, depth, and overall compliance. It is unclear why decreased CC fraction and rate compliance is associated with a survival benefit, yet our results confirm those seen in two studies of adult patients with an out-of-hospital cardiac arrest which showed an inverse relationship between CC fraction and outcomes. [10–11] In combination, these findings suggest that current AHA guidelines pertaining to CC fraction and rate may need to be re-evaluated, and that CPR targets remain unclear for patients with and without congenital heart disease.

Our linear mixed effects model did not show an impact of congenital heart disease on the relationship between illness category (surgical cardiac and medical cardiac) and CPR quality metrics. This confirms the results of a recent study which demonstrated that there were no CPR quality differences between medical cardiac and surgical cardiac illness groups. [6] Our results show that surgical cardiac illness category compared to medical cardiac illness category is associated with improved survival, which is consistent with prior literature, but the results of our linear mixed effects model suggest that the presence of

Table 4
Chest Compression Quality metrics by Congenital Heart Disease Status and Survival to Hospital Discharge.

	Congenital Heart Disease			*Non Congenital Heart Disease*		
CC Quality Metrics	***SHD***	***Non SHD***	***P value***	***SHD***	***Non SHD***	***P value***
N	70 (12.5)	89 (15.9)	–	123 (22.0)	277 (49.6)	–
Rate compliance (N, %)	35 (50)	56 (63)	0.06	81 (66)	180 (65)	0.90
Depth compliance (N, %)[#]	7 (11)	14 (17)	1.00	31 (27)	87 (35)	0.04
CCF compliance (N, %)	34 (49)	56 (63)	0.26	71 (58)	197 (71)	0.02
Overall compliance (N, %)[#]	1 (2)	6 (7)	0.24	7 (6)	29 (12)	0.04
CCF and CC rate compliance (N, %)	9 (13)	29 (33)	0.004	37 (30)	103 (37)	0.06

Only index events (N = 559) are listed. Abbreviations: CC: chest compression, CCF: chest compression fraction. P values from the logistic regression model adjusting for age at arrest and ECPR during arrest were reported.

[#] Events(n = 50) with single sensor for <=8y, Dual AA, Incorrect sensor position documented were excluded for depth related analysis. P values from the logistic regression model adjusting for age at arrest and ECPR during arrest, and arterial line, duration of arrest and number of epinephrine doses in place were reported except for overall compliance in congenital heart disease and CCF and CC rate compliance. Because of the small number of overall compliances in congenital heart disease, multivariable analysis was not conducted and p value from Fisher's exact test was reported. Because of the relatively small number of patients achieving CCF and CC rate compliance, the stepwise logistic regression model was employed. The p values of the final multivariable logistic regression model adjusting for age at arrest and duration of arrest were reported.

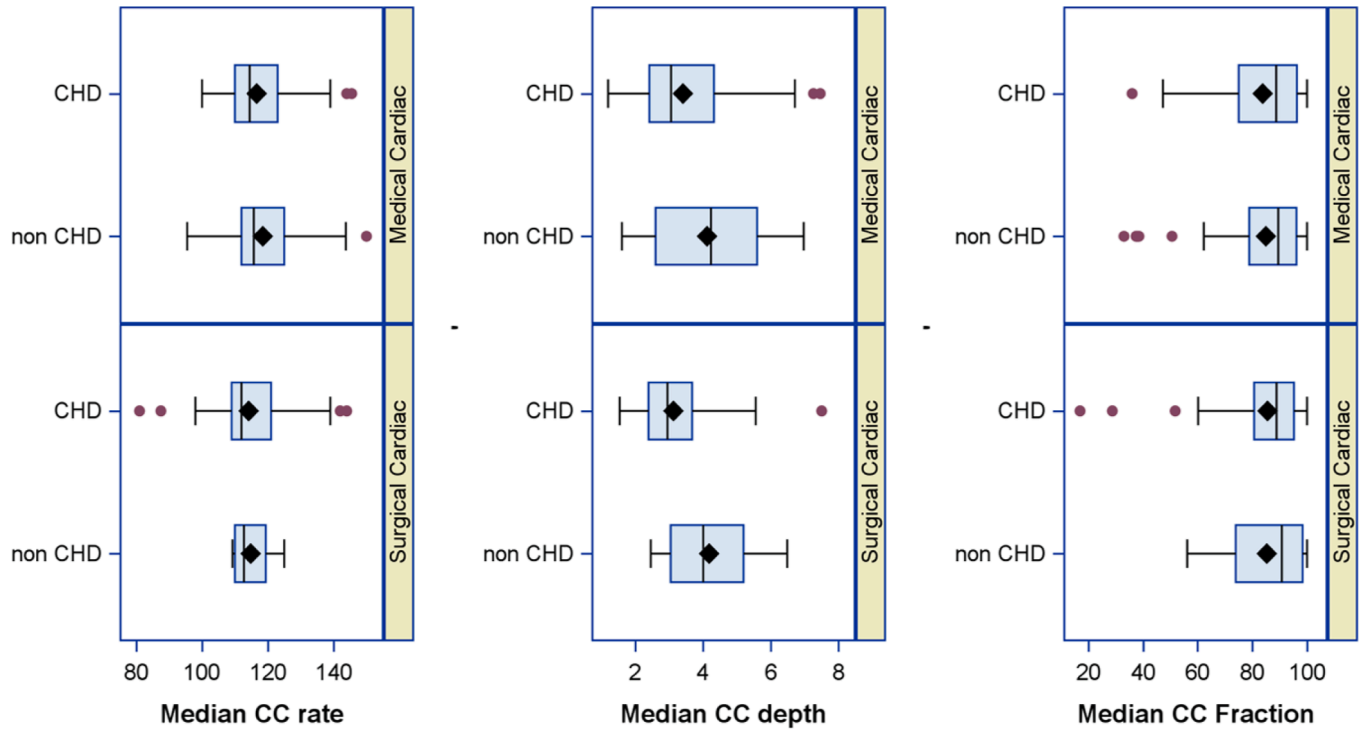

Fig. 2. Boxplots of chest Compression metrics by CHD status and diagnosis group. We employed linear mixed effet models with interation term to evaluate the effect of CHD on diagnostic group(medical cardiac vs. surgical cardiac) and CPR quality. The p-values associated with the interation term indicate that the presence of CHD did not influence the relationship between diagnosos group and CC rate, depth, and fraction. (p values are 0.81, 0.73 and 0.82 for rate, depth and fraction. respectively). Abbreviation: CC: Chest compression, CCF:chest compression fraction, CHD: congential heart disease * Analysis is based on supplementary digital content 3 with medical cardiac n = 167 and surgical cardiac n = 92.

congenital heart disease and illness category or not co-linear. [2,12] This may suggest a stronger influence of post surgical status on IHCA outcomes than whether the patient has congenital heart disease.

Limitations

Hospitals that contribute data to the pediRES-Q collaborative are dedicated to improved CPR quality in children and may be a skewed representation. IHCA events that are reported are ones of sufficient duration such that defibrillator pads have been placed. Therefore, these events may be skewed toward events that are longer. Patients with open chests were excluded given the inability to place defibrillator pads in the anterior posterior position, which skews our cohort toward older children, since typically infants are the patients with delayed sternal closure after cardiac surgery. Although we know that 37 % of the congenital heart disease group had single ventricle anatomy, and prior studies show single ventricle physiology as a risk factor for mortality after IHCA, we did not evaluate how the presence of single ventricle physiology affected outcomes or CPR quality. Future studies should evaluate whether differences in CPR quality metrics in patients with single ventricle and other cardiac co-morbidities are associated with outcomes after IHCA.

Conclusion

In a multi-center international pediatric resuscitation collaborative, after adjusting for potential confounders, patients with congenital heart disease compared to those without were less likely to have AHA guideline-compliant CC depth. Multivariable analysis failed to reveal any association between the presence of congenital heart disease and ROSC, SHD or SHD with favorable neurologic outcome. Future studies should evaluate differences in CPR quality metrics and outcomes in subgroups of patients with various forms of congenital heart disease.

Author contributions

P Yu: Methodology, Formal analysis, Writing – original draft, Writing – review & editing. J Lasa: Methodology, Writing – review & editing, Supervision. X Zhang: Formal analysis, Project administration, Writing – review & editing. H Griffis: Formal analysis, Project administration, Writing – review & editing. T Sweberg: Writing – review & editing, I Esangbedo: Writing – review & editing. A Ranganathan: Data curation, Writing – review & editing, Project administration. V Nadkarni: Writing – review & editing, Project administration, Supervision. T Raymond: Conceptualization, Methodology, Writing – review & editing, Supervision.

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CRediT authorship contribution statement

Priscilla Yu: Writing – review & editing, Writing – original draft, Methodology, Formal analysis. **Javier J Lasa:** Writing – review & editing, Supervision, Methodology. **Xuemei Zhang:** Writing – review & editing, Project administration, Formal analysis. **Heather Griffis:** Writing – review & editing, Project administration, Formal analysis. **Todd Sweberg:** Writing – review & editing. **Ivie Esangbedo:** Writing – review & editing. **Abhay Ranganathan:** Writing – review & editing, Project administration, Data curation. **Vinay Nadkarni:** Writing – review & editing, Supervision, Project administration. **Tia Raymond:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resplu.2024.100802.

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