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Return of viable cardiac function following sonographic cardiac standstill in pediatric cardiac arrest

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Abstract

Sonographic cardiac standstill during adult cardiac arrest is associated with failure to get to return to spontaneous circulation. This report documents three children whose cardiac function returned after standstill with extracorporeal membranous oxygenation (ECMO). Sonographic cardiac standstill may not predict cardiac death in children.

Keywords

CPR; echocardiography; ECMO; ultrasound; in-hospital cardiac arrest; respiratory arrest

Case 1

A 6 year-old male with a history of acute myelocytic leukemia in remission after bone marrow transplant was admitted to the PICU for hepatic graft versus host disease and respiratory insufficiency. While admitted he became dyspneic, unresponsive and pulseless. Cardiopulmonary resuscitation (CPR) was started immediately and ECMO cannulation was initiated given failure to achieve return of spontaneous circulation (ROSC). During cannulation, focused cardiac ultrasound (US) by an attending intensivist at the bedside (VSCAN 1.2, General Electric, Madison WI) revealed cardiac standstill (Figure 1, Video 1). Soon following ECMO cannulation cardiac contractions began, and within an hour his left ventricle (LV) demonstrated mild dysfunction (Video 2). He was decannulated from ECMO after 4 days with adequate cardiac function. However he had significant hypoxic-ischemic brain injury and ventilatory support was withdrawn 31 hours later at which time he died.

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Case 2

A 16 month-old female with double outlet right ventricle, Taussig-Bing variant, status post atrial switch, presented to the pediatric emergency department in respiratory distress from presumed congestive heart failure. During her ED course, she lost consciousness and had an systolic cardiac arrest. CPR was started immediately, and at 10 minutes into CPR ECMO cannulation was initiated and focused cardiac US by the attending intensivist demonstrated cardiac standstill. On ECMO, her EF progressively improved to 33% 10 days after arrest prior to decannulation (Figure 2), and remained near her pre-arrest baseline after decannulation. Post-ECMO she was sedated for ventilation but neurologically responsive and localized to stimulation. She ultimately succumbed to a second cardiac arrest 3 months later.

Case 3

A newborn was admitted to the NICU for respiratory failure, sepsis, and pulmonary hypertension. She required ventilation via high-frequency oscillation and inhaled nitric oxide. During her course, she went into asystolic cardiac arrest. CPR was started and ECMO cannulation was initiated, during which time focused cardiac US by the attending intensivist indicated cardiac standstill. After cannulation, focused cardiac US demonstrated severely depressed LV function that improved gradually. Several days into ECMO she developed hemothorax and hemoperitoneum, and manifested abdominal compartment syndrome. The family elected to withdraw support on day 5 of ECMO.

Ultrasound Findings and Technique

Subcostal 4-chamber images were obtained for each patient during the arrest to assess for reversible causes of arrest using the 1.7–3.8 MHz phased array transducer fixed to the handheld US device. Focused cardiac US in all three cases was performed by the same intensivist sonologist (ES), a testamur of the National Board of Echocardiography. Only the subcostal view was obtained during the focused cardiac US, as the placement of defibrillator pads precluded visualization in the parasternal and apical views. Cardiac standstill was seen in all three patients while focused cardiac US was performed during 10-second pulse checks.

After the events, LV diameter was assessed on recorded images in a video analysis program (Tracker 4.84, Aptos, CA). Six frames were selected from each loop and the left ventricular diameter (LVD) was measured (Table 1). The difference between largest and smallest LVD for each of the patients ranged between 0.3–0.4 mm and is likely artifactual, as this difference in distance is smaller than what can typically be measured by phased array transducers operating at low frequencies (minimum axial resolution typically 1.0 ± 0.1 mm).

Review of the literature

The quest for meaningful bedside predictors of cardiac arrest outcome is challenging, given that mortality predictors should be specific. Many clinicians consider terminating resuscitative efforts based on event-based assessments of resuscitation futility such as duration of arrest, and whether it was witnessed (1).

Focused cardiac US (2) by pediatric physicians is an emerging asset for managing critically ill children. Current evidence suggests a finding of no cardiac movement in adult cardiac arrest, or cardiac standstill, predicts failure to achieve ROSC. However, there have not been previous descriptions of cardiac activity following cardiac standstill in pediatric patients.

In multiple large adult series, cardiac standstill in out-of-hospital arrest was associated with failed ROSC before hospital admission in 94–100% of patients (3–5), and in these series the availability of ECMO is not described. Consequently some have suggested standstill could be a criterion for stopping adult cardiopulmonary resuscitation (CPR) (3,4). However standstill in pediatric cardiac arrest, particularly during in-hospital arrest, may not predict ROSC failure given differences in physiology, arrest epidemiology and possibly if ECMO is used promptly. In one series of 14 pediatric patients, cardiac standstill after out-of-hospital cardiac arrest was associated with universally fatal outcomes (7), though ECMO was not available (communications with author).

The three patients presented demonstrated standstill at the time of the first echocardiogram, and regained cardiac contractility on ECMO. Naturally, age and etiologies of arrest are potential reasons for why these children demonstrated different outcomes from adults. Twenty-seven percent of pediatric in-hospital cardiac arrest patients survive compared with 18% of adults (6). Since cardiac arrest in children is frequently due to respiratory failure (1), ECMO CPR could potentially restore oxygen delivery to the heart. Interestingly, Patient 2 had pre-arrest myocardial dysfunction, and her cardiac function recovered despite structural abnormalities.

Though these patients ultimately died, their deaths were not immediately due to a lack of ROSC after arrest. These findings suggest that children in cardiac standstill who achieve ROSC on ECMO may have a window of opportunity for cardiac resuscitation and potentially meaningful functional outcomes.

Cardiac standstill is being increasingly accepted among clinician sonologists as a predictor of ROSC failure in adults. However, this may not be the case in pediatric patients. Presently, there are no standards for evaluating standstill in terms of interpretation or duration of observation prior to cessation of CPR. These cases suggest that a better understanding of cardiac standstill is necessary before using it as a metric for cessation of CPR.

Conclusion

Cardiac standstill in children may not predict cardiac death in children. Further study of pediatric peri-arrest echocardiography in large series is needed to understand the physiology of the arresting heart, predictive metrics for patient outcomes, and potential measures for treatment.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Figure 1.
Subcostal 4-chamber view of the heart in patient of Case 1 during cardiac arrest. During the video the patient manifests cardiac standstill.

Ejection Fraction, Case 2

Figure 2.

Left ventricular ejection fraction (EF) of patient in Case 2 following extracorporeal membranous oxygenation (ECMO) cannulation. EF one month prior to arrest appears as a dashed line at 28% on Y-axis. ECMO decannulation occurred at Day 10.

Table 1

Left ventricular diameter (LVD) is expressed as mean $\pm$ standard error of the mean. Fractional shortening (FS) was obtained within an hour following ECMO cannulation. EF was obtained from diagnostic echocardiograms performed by pediatric echocardiography specialists.

	Case 1	Case 2	Case 3
Mean LVD (mm)	29.8 $\pm$ 0.1	33.9 $\pm$ 0.1	25.1 $\pm$ 0.1
LVD *	0.4 (1%)	0.4 (1%)	0.3 (1%)
Post-cannulation FCU FS	39%	5%	13%
ECMO Day 4 Echo EF	73%	27%	—

* LVD was calculated by subtracting the smallest from the largest LVD measured during the echocardiographic cine loop recorded during cardiac standstill.