Cardiovascular Dysfunction Criteria in Critically Ill Children: The PODIUM Consensus Conference

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abstract

CONTEXT: Cardiovascular dysfunction is associated with poor outcomes in critically ill children.

OBJECTIVE: We aim to derive an evidence-informed, consensus-based definition of cardiovascular dysfunction in critically ill children.

DATA SOURCES: Electronic searches of PubMed and Embase were conducted from January 1992 to January 2020 using medical subject heading terms and text words to define concepts of cardiovascular dysfunction, pediatric critical illness, and outcomes of interest.

STUDY SELECTION: Studies were included if they evaluated critically ill children with cardiovascular dysfunction and assessment and/or scoring tools to screen for cardiovascular dysfunction and assessed mortality, functional status, organ-specific, or other patient-centered outcomes. Studies of adults, premature infants (≤36 weeks gestational age), animals, reviews and/or commentaries, case series (sample size ≤10), and non–English-language studies were excluded. Studies of children with cyanotic congenital heart disease or cardiovascular dysfunction after cardiopulmonary bypass were excluded.

DATA EXTRACTION: Data were abstracted from each eligible study into a standard data extraction form, along with risk-of-bias assessment by a task force member.

RESULTS: Cardiovascular dysfunction was defined by 9 elements, including 4 which indicate severe cardiovascular dysfunction. Cardiopulmonary arrest (>5 minutes) or mechanical circulatory support independently define severe cardiovascular dysfunction, whereas tachycardia, hypotension, vasoactive-inotropic score, lactate, troponin I, central venous oxygen saturation, and echocardiographic estimation of left ventricular ejection fraction were included in any combination. There was expert agreement (>80%) on the definition.

LIMITATIONS: All included studies were observational and many were retrospective.

CONCLUSIONS: The Pediatric Organ Dysfunction Information Update Mandate panel propose this evidence-informed definition of cardiovascular dysfunction.

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Cardiovascular dysfunction is common during childhood critical illness because of the complex interplay between myocardial and endothelial function. This dysfunction may manifest as vasoplegia, left ventricular (LV), right ventricular (RV), or biventricular systolic and/or diastolic dysfunction.[1] Independent of etiology, cardiovascular dysfunction during critical illness may result in inadequate delivery of oxygen to tissues. Reduced delivery of oxygen is associated with increased risk of morbidity, mortality, and need for high-resource therapies, such as extracorporeal life support (ECLS) and/or mechanical circulatory support (MCS).[2] Although there are no randomized clinical trials to support this, it is likely that early recognition and appropriate management of cardiovascular dysfunction would reduce morbidity and mortality in critically ill children. Physical examination, vital signs, laboratory tests, and imaging studies can be used to assist in the diagnosis of cardiovascular dysfunction; however, utilization of these diagnostic tools is variable.[3] There is a lack of consensus on how to investigate and ultimately define life-threatening cardiovascular dysfunction in pediatric critical care.

Critically ill children with cardiovascular dysfunction can be broadly separated into 2 populations: those who develop cardiovascular dysfunction associated with critical illness and those who develop critical illness in the setting of preexisting primary structural or functional cardiac abnormalities. Here, we used existing scientific evidence and an expert consensus panel to define cardiovascular dysfunction in critically ill children that can be applied broadly in clinical practice, as well as for scientific inquiry. We have targeted this definition to patients without underlying cyanotic congenital heart disease (CHD) who have cardiovascular dysfunction in the setting of critical illness. This definition is not intended to assess or grade post–cardiopulmonary bypass (post-CPB) impaired cardiac output or inflammatory state. Thus, we have also excluded consideration of children who underwent CPB during ICU admission before developing cardiovascular dysfunction.

METHODS

The Pediatric Organ Dysfunction Information Update Mandate (PODIUM) collaborative sought to develop evidence-based criteria for organ dysfunction in critically ill children. In the present article, we report on the systematic review on acute cardiovascular dysfunction scoring tools performed as part of PODIUM, provide a critical evaluation of the available literature, and propose evidence-based criteria for acute cardiovascular dysfunction in critically ill children, as well as recommendations for future research. In the PODIUM Executive Summary, we detail Population, Interventions, Comparators, and Outcomes questions, search strategies, study inclusion and exclusion criteria, and processes for risk-of-bias assessment and data abstraction and synthesis and for drafting and developing agreement for criteria indicating acute cardiovascular dysfunction.[4]

RESULTS

Of 6737 unique citations published between 1992 and 2020, 175 studies were eligible for inclusion, as shown in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart (Fig 1). Data tables (Supplemental Tables 1 and 2), supplemental references (Supplemental Tables 3–6), and risk-of-bias assessment summaries (Supplemental Fig 1) are detailed in the Supplemental Information.

The criteria incorporated into the definition of cardiovascular dysfunction in critically ill children are shown in Table 1. As noted above, these criteria were informed by medical literature, excluding children with underlying cyanotic CHD and those who underwent CPB during the ICU admission. Elements not incorporated into the current definition of cardiovascular dysfunction (because they did not reach expert panel agreement) are shown in Table 2. These data elements, however, represent important criteria for further investigation.

Clinical Criteria Included in Definition

Cardiovascular dysfunction in critically ill children is defined as presence of 1) cardiac arrest for >5 minutes and/or 2) MCS or 3) at least 2 abnormal criteria of heart rate (HR), systolic blood pressure (BP), vasoactive-inotrope score, lactate, central venous oxygen saturation, troponin I, or echocardiographic estimation of left ventricular ejection fraction (LVEF) (Table 1).

Cardiac Arrest

Any patient with cardiac arrest for >5 minutes, under any circumstances, will be considered to have severe cardiovascular dysfunction. Post–cardiac arrest myocardial dysfunction occurs even in the absence of an underlying cardiac cause for the arrest and is associated with early mortality.[5–7] This pragmatic approach reflects the underlying cardiovascular dysfunction inherent when return of circulation is not rapidly achieved with administration of advanced life support therapies, as well as the

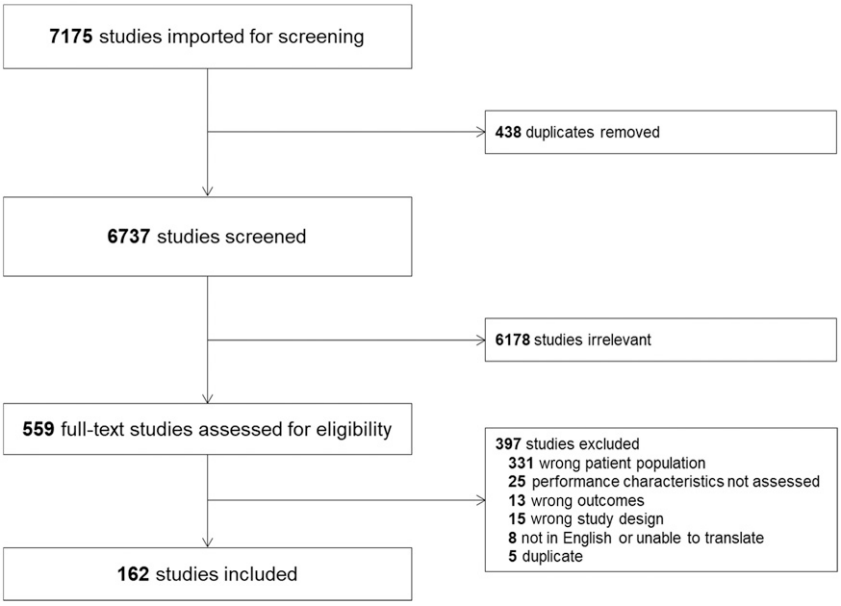

FIGURE 1
Study flow diagram according to the Preferred Reporting Items for Systematic review and Meta-Analysis Protocols recommendations.

resulting cardiovascular dysfunction from prolonged cardiopulmonary resuscitation.

MCS

Any patient supported with MCS, including venoarterial ECMO or temporary or durable ventricular assistance device (VAD), will be considered to have severe cardiovascular dysfunction. In neonates and children managed on ECMO for cardiac indications, survival to hospital discharge remains low (45% and 57%, respectively).[8] Heart transplant–free survival for children managed with durable VADs remains <10% at 12 months.[9] The pragmatic approach of defining severe cardiovascular dysfunction due to the presence of MCS alone reflects the underlying cardiovascular dysfunction inherent with the requirement for this support.

HR and Systolic BP

HR is an element of many combination early warning scores, as well as descriptive and predictive models for mortality in critical illness, contributing to the explanatory power of the multivariable models.[10–12] During critical illness, HR has been shown to be associated with cardiovascular dysfunction and is used as an indirect indicator of severity of illness or response to therapies: (1) in diverse settings, including consideration for escalation of care (transport to a specialist center or admission to ICU), classification of severity of injury, and indications for and response to blood transfusions; (2) in diverse populations, including inpatients on general wards, in the emergency department (ED), cardiac catheterization laboratory, and PICU; and (3) in diverse diagnoses, such as trauma, bone marrow transplant, sepsis, acute heart failure, pulmonary hypertension, and requirement for MCS.[12,13] When we consider BP, hypotension is included in predictive models of mortality in critical illness, descriptive and prognostic tools, and early warning scores.[10–12] A low systolic BP has similarly been shown to be associated with cardiovascular dysfunction and outcomes, including referral to transport teams for escalation of care, severity of injury, blood transfusion, PICU admission, cardiopulmonary arrest, and mortality within populations, including inpatient hospital wards and PICUs, as well as patients with specific diagnoses (including trauma, bone marrow transplantation, sepsis, myocarditis, acute heart failure, and need for MCS).[11]

To estimate age-appropriate cutoffs for abnormal HR and BP, we elected to assign patients to cohorts on the basis of ages with similar normative ranges, informed by previous guidelines and scores (Table 1).[11] The HR and BP cutoffs incorporated into the definition were estimated as 2 SDs outside observed range for age cohorts in a

TABLE 1 PODIUM: Criteria for Cardiovascular Dysfunction in Critically Ill Children

Organ System	Criterion for Organ Dysfunction	Suggested Thresholds	Conditions	Severity
CV	Cardiac arrest	NA	Cardiac arrest for >5 mins from any etiology Even if the cardiopulmonary arrest occurred from dislodged ETT (or hypoxic respiratory failure precipitating cardiac failure), if the cardiac arrest is not reversible, then some element of cardiovascular dysfunction should be presumed to be present.	Severe
CV	Venoarterial ECLS, temporary or durable LVAD, or RVAD support	NA	None	Severe
CV	HR	>2 SD above normal for age	Confirmed sinus rhythm, when present at the same time as any of the other criteria for CV organ dysfunction	Not graded
		0–7 d: HR >180 >1 wk to 1 mo: HR >180 >1 mo to <1 y: HR >180 1 y to <6 y: HR >160 6 y to <13 y: HR >150 13 to <18 y: HR >130		
CV	SBP	> 2 SD below normal for age	When present at the same time as any of the other criteria for CV organ dysfunction	Not graded
		0–7 d: SBP <50 >1 wk to 1 mo: SBP <70 >1 mo to <1 y: SBP <75 1 y to <6 y: SBP <75 6 y to <13 y: SBP <80 13 y to <18 y: SBP <80		
CV	VIS[a]	≥5	When present at the same time as any of the other criteria for CV organ dysfunction	Not graded
CV	Serum lactate	≥3 to <5 mmol/L	When present at the same time as any of the other criteria for CV organ dysfunction	Nonsevere
		≥5 mmol/L	When present at the same time as any of the other criteria for CV organ dysfunction	Severe
CV	Serum troponin I	0.6–2.0 ng/mL	When present at the same time as any of the other criteria for CV organ dysfunction	Nonsevere
		>2.0 ng/mL	When present at the same time as any of the other criteria for CV organ dysfunction	Severe
CV	Central venous oxygen saturation	<70%	When present at the same time as any of the other criteria for CV organ dysfunction In patients without cyanotic CHD Ideally sampled from right atrium or pulmonary artery in a patient without intracardiac abnormalities but proximal SVC and IVC acceptable. Whole-blood laboratory assay as standard, but consider validated continuous invasive monitoring	Not graded
CV	Echocardiographic estimation of LVEF	30% to <50%	When present at the same time as any of the other criteria for CV organ dysfunction	Nonsevere
		<30%	When present at the same time as any of the other criteria for CV organ dysfunction	Severe

Criteria for cardiovascular dysfunction in patients who have cardiovascular dysfunction in the setting of critical illness, excluding patients with underlying CHD and those who underwent CPB during the ICU admission before cardiovascular dysfunction (these criteria are not intended to assess or grade post-CPB impaired cardiac output or inflammatory state). CV, cardiovascular; ETT, endotracheal tube; IVC, inferior vena cava; NA, not applicable; RVAD, right ventricular assist device; SBP, systolic blood pressure; SVC, superior vena cava.

[a] Vasoactive inotropic score 5 dopamine dose (lg/kg/min) 1 dobutamine dose (lg/kg/min) 1 100 × epinephrine dose (lg/kg/min) 1 10 × milrinone dose (lg/kg/min) 1 10 000 × vasopressin dose (U/kg/min) 1 100 × norepinephrine dose (lg/kg/min).

TABLE 2 Clinical Criteria for Further Study in Cardiovascular Dysfunction in Pediatric Critical Illness

Criteria	No. Studies	Types of Studies	Setting	Patient Population	Outcomes Studied
Capillary refill time	5	Retrospective, prospective, case-control, cross-sectional, case series, and observational	PICU, newborns, in-hospital patients (CHEWS score assessment), and sepsis	Neonates and pediatric inpatients	Correlation with BP; not independently associated with mortality, may form part of a composite score predicting need for escalation of care
Composite prediction scores of adverse event (eg, PEWS)	8	Retrospective, prospective, case-control, cross-sectional, case series, and observational	Inpatients on floor, PICU, and PICU-transport system	Inpatients on floor, bone marrow transplant, meningococcal sepsis, and acute heart failure patients with MCS	Respiratory or cardiac arrest, death, or unexpected admission to the PICU
Lactate clearance	5	Retrospective, prospective, case-control, cross-sectional, case series, and observational	PICU and NICU	PICU, NICU, sepsis, meningococcal sepsis, and birth asphyxia	Mortality
NIRS cerebral	2	Retrospective, prospective, case-control, cross-sectional, case series, and observational	NICU-admitted ECMO	CDH	Cannulated to ECMO
NIRS somatic <70%	3	Retrospective, prospective, case-control, cross-sectional, case series, and observational	PICU and mixed PICU	All patients	Combined outcome of resuscitation requirement (mortality, ECMO, volume resuscitation, and NIV)
BNP or NT-pro BNP	21	Retrospective, prospective, case-control, cross-sectional, case series, and observational	PICU, NICU, mixed PICUs, inpatient ward, and ED	PICU, NICU, sepsis, meningococcal sepsis, enterovirus, birth asphyxia, DCM, myocarditis, acute decompensated heart failure, and malaria	Mortality, ventricular dysfunction by echo, severe heart failure, and composite adverse event outcomes

BNP, brain natriuretic peptide; CHEWS, Children's Hospital Early Warning System; DCM, dilated cardiomyopathy; ECMO, extracorporeal membrane oxygenation; NIRS, near infrared spectroscopy; NIV, noninvasive ventilation; NT-pro BNP, N-terminal pro–brain natriuretic peptide; PEWS, Pediatric Early Warning System.

critically ill pediatric population.[14] Elevated HR and low systolic BP will contribute, in combination with at least 1 other abnormal criterion, to the criteria for cardiovascular dysfunction in critically ill children.

Vasoactive-Inotropic Score

Supportive care, such as tracheal intubation, ventilation, sedation, neuromuscular blockade, vasoactive-inotropic infusions, and MCS, has the potential to modulate vital signs and end-organ findings associated with cardiovascular dysfunction in critical illness. Of these, only vasoactive-inotropic infusions and MCS are specific to the cardiovascular system and so are included in the definition criteria. Higher vasoactive-inotropic doses administered in the post-CPB period have been associated with adverse outcomes in infants and children with CHD.[15,16] The vasoactive-inotropic score (VIS) was initially established in this population as a dose-dependent marker associated with morbidity and mortality.[15] VIS is calculated using the following formula: dopamine dose (micrograms per kilogram per minute) + dobutamine dose (micrograms per kilogram per minute) + 100 × epinephrine dose (micrograms per kilogram per minute) + 10 × milrinone dose (micrograms per kilogram per minute) + 10 000 × vasopressin dose (units per kilogram per minute) + 100 × norepinephrine dose (micrograms per kilogram per minute).[16] Vasoactive-inotropic infusion doses were incorporated into studies of patients with cardiomyopathy and myocarditis, as well as some assessments of general critical illness.[17,18] Subsequently, VIS has been specifically assessed in critically ill children without CHD and has been shown to be associated with cardiovascular dysfunction and cortisol levels, as well as outcomes, including duration of ventilation, ICU length of stay, cardiopulmonary arrest, use of ECLS,

and mortality before hospital discharge among general PICU patients and those with sepsis.[18] For every unit increase in VIS at 12 hours, there was a 14% increased odds of having the composite outcome of cardiopulmonary arrest, ECLS, or mortality before hospital discharge.[18] At 48 hours, VIS revealed the strongest correlation with ICU length of stay and ventilator days. For every unit increase in VIS at 48 hours, there was a 13% increase in ICU length of stay and 8% increase in ventilator days. In systemic illness associated with sepsis, the median VIS was 5 to 6, which is much lower than in the post-CPB population[16]; hence, we included an informed cutoff VIS of ≥5 to contribute, in combination with other abnormal criteria, to the definition of cardiovascular dysfunction in critically ill children.

Biomarkers of Cardiovascular Dysfunction

Laboratory-derived markers of cardiac injury, congestive heart failure, inadequate systemic oxygen delivery (or increased oxygen extraction to compensate for low cardiac output), and secondary organ dysfunction, such as acute kidney and hepatic injury, are often assessed in critical illness. We excluded assessment of secondary organ dysfunction from our definition elements because these will be captured within alternative organ-specific elements. Elevated lactate, elevated troponin I, and low mixed (central) venous oxygen saturation are included, in combination with at least 1 other abnormal criterion, in the definition of cardiovascular dysfunction in critically ill children.

Lactate

Lactate, resulting from inadequate oxygen delivery to tissues and anaerobic metabolism, is incorporated into pediatric sepsis guidelines and Pediatric Logistic Organ Dysfunction 2 (PELOD-2) score and has been combined with the Pediatric Risk of Mortality (PRISM) III score to improve explanatory power for the outcome of mortality associated with critical illness.[11,19] Lactate levels during critical illness have been associated with cardiovascular dysfunction and outcomes of septic shock, hospital length of stay >10 days, mortality before ICU or hospital discharge, and 18- to 24-month neurodevelopmental outcomes within specific populations, including inpatients, ED, NICU, and mixed PICUs, as well as those with specific diagnoses, including suspected sepsis, sepsis, malaria, birth asphyxia, acute heart failure, out-of-hospital cardiac arrest, and respiratory disease managed with MCS.[11,19–23] Measurements were variably taken at specified timepoints related to admission,[19,20,22–24] reported as maximum during a given time frame,[21] or expressed as clearance of lactate burden over time.[20] Studies have consistently revealed lactate <2 mmol/L to be an important negative predictor of mortality, whereas higher lactate levels (>3 mmol/L, >4 mmol/L, >5 mmol/L, >5.5 mmol/L, >10 mmol/L, and >25 mmol/L) were associated with mortality, with a relatively linear relationship when multiple cutoffs were assessed in the same analysis.[11,19,21,23] In children with suspected sepsis, lactate measurements >3 mmol/L and >4 mmol/L at PICU admission, respectively, were associated with septic shock diagnosis and hospital length of stay >10 days.[25] In newborn infants with perinatal hypoxia, lactate levels >8.7 mmol/L were associated with hypoxic-ischemic encephalopathy (HIE) of grade ≥2.[21] In a prospectively managed cohort of patients with neonatal respiratory disease supported with ECLS, peak lactate >15 mmol/L was associated with the composite adverse outcome: death from any cause before 18- to 24-month follow-up or evidence of neurologic disability at 18 to 24 months.[23] Informed by studies revealing gradation of association with poor outcomes, we included lactate 3 to <5 mmol/L (nonsevere) and lactate ≥5 mmol/L (severe), in association with another abnormal criteria, for the definition of cardiovascular dysfunction in critically ill children.

Troponin I

Troponin I is released from damaged myocardium in the setting of ischemia, injury, or illness. Troponin I levels during critical illness have been associated with cardiovascular dysfunction evaluated by echocardiogram and outcomes of adverse neurodevelopmental status, respiratory failure, and mortality before hospital discharge within populations in the ED and NICU and unselected patients in mixed PICUs, as well as those with specific diagnoses of myocarditis, sepsis, birth asphyxia, enterovirus infection, respiratory syncytial virus (RSV) bronchiolitis, scorpion envenomation, trauma, and cardiopulmonary arrest after submersion.[1,26] Measurements were variably taken at specified timepoints related to birth or admission. Detectable troponin I levels at PICU admission in unselected patients were associated with mortality.[26] Troponin I levels correlated with impaired ventricular systolic function in studies of patients with sepsis, birth asphyxia, and scorpion envenomation. In patients with sepsis, higher troponin I levels were predictive of LVEF

<50% by echocardiographic criteria. In infants with HIE, cord blood troponin I level was associated with mortality and neurodevelopmental outcome at 18 to 24 months.[27] In children presenting with RSV bronchiolitis, troponin I level was positively associated with requirement for intubation and ventilation.[28] Informed by studies revealing gradation of association with poor outcomes, we included troponin I 0.6 to 2.0 ng/mL (nonsevere) and troponin I >2.0 ng/mL (severe), in association with another abnormal criteria, for definition of cardiovascular dysfunction in critically ill children.

Central Venous Oxygen Saturation

Central (or mixed) venous oxygen saturation ($ScvO_2$), when compared with arterial oxygen saturation (or the arteriovenous oxygen saturation difference), reflects the degree of oxygen extraction by the tissues. Under circumstances of impaired or inadequate cardiac output, critically ill patients partially compensate for reduced oxygen delivery with increased tissue oxygen extraction, reflected by lower $ScvO_2$. Ideally sampled from right atrium or pulmonary artery (proximal superior and inferior vena cava acceptable) in patients without intracardiac abnormalities, whole-blood co-oximetry is considered standard. Validated continuous invasive monitoring via central venous catheters are acceptable surrogates. During critical illness, $ScvO_2$ has been shown to be associated with cardiovascular dysfunction and in-hospital mortality in a general population of critically ill children and in patients with a diagnosis of sepsis.[29] Children with sepsis who did not achieve $ScvO_2$ >70% after 6 hours of resuscitation were more likely to die during hospital admission.[29] We included an informed cutoff $ScvO_2$ <70% to contribute to the definition of cardiovascular dysfunction in critically ill children, in combination with another abnormal criteria.

Echocardiographic Assessment of LVEF

Echocardiographic assessment of cardiac structure and function remains a mainstay of assessment of the critically ill patient. LV systolic dysfunction, as evidenced by reduced ejection fraction (LVEF) during critical illness, has been associated with outcomes of heart transplantation, MCS, and in-hospital mortality within populations, including hospital inpatients, ED, NICU, mixed PICUs, and those with diagnoses of myocarditis, sepsis, enterovirus, RSV bronchiolitis, birth asphyxia, scorpion envenomation, and trauma.[17] In patients with meningococcal sepsis, LVEF <30% was associated with mortality. There was significant variability in the studies assessed; studies in children with myocarditis, sepsis, and birth asphyxia informed suggested thresholds. In studies of patients with myocarditis, survivors had higher LVEF than nonsurvivors, with odds of survival increasing per 10% in LVEF >30%.[17] Informed by studies revealing gradation of association with poor outcomes, we included LVEF 30% to <50% (nonsevere) and LVEF <30% (severe), in association with another abnormal criteria, for definition of cardiovascular dysfunction in critically ill children.

Incorporating Multiple Criteria for the Definition of Cardiovascular Dysfunction

Cardiovascular dysfunction in critical illness includes both myocardial and endothelial components. If the primary insult is related to systolic or diastolic myocardial dysfunction, then functional assessment with echocardiography may be ideal. However, continuous monitoring is not feasible, so the clinician is unable to readily trend responses to treatment such as vasodilation or diuresis.[17] The majority of criteria included in the definition of cardiovascular dysfunction in critically ill children reflect pathophysiologic responses to some perturbation in either myocardial or endothelial function. Unlike other organs, there are limited data for any individual criterion that captures the clinical state. As such, the preexisting multiorgan dysfunction definitions have included a requirement for >1 criterion to be present to meet the definition of cardiovascular dysfunction.[30,31] We have, thus, incorporated similar recommendations to include at least 2 of the following to meet the definition of cardiovascular dysfunction: elevated HR, low systolic BP, elevated VIS, elevated lactate, elevated troponin, low central venous oxygen saturation, or reduced LVEF.

Limitations

All included studies were observational, and many were retrospective. Studies included populations from international centers and inpatients on general wards, in EDs, in the cardiac catheterization laboratory, and in the PICU, and representing patients with diverse diagnoses, such as trauma, bone marrow transplant, sepsis, acute heart failure, pulmonary hypertension, and requirement for MCS. The international burden of disease associated with severe sepsis in the critically ill pediatric population, and prioritization of research targeting

this diagnosis, may have resulted in overrepresentation in this population informing the cardiovascular dysfunction definition.

CONCLUSIONS

We propose an evidence-informed consensus definition for cardiovascular dysfunction in critically ill children (without underlying CHD or recent CPB) in which the vital signs, vasoactive-inotropic support, biomarkers, measures of oxygen extraction, and echocardiography are considered. Cardiopulmonary arrest (of >5 minutes) and use of MCS independently define severe cardiovascular dysfunction, whereas the other criteria define cardiovascular dysfunction when ≥2 abnormal elements are identified. Cardiopulmonary arrest, use of MCS, elevated troponin I (>2 ng/mL), elevated lactate (≥5 mmol/L), and severely impaired LVEF measured by 2-D echocardiography (<30%) indicate severe cardiovascular dysfunction.

ABBREVIATIONS

BP: blood pressure
CHD: congenital heart disease
CPB: cardiopulmonary bypass
ED: emergency department
ECLS: extracorporeal life support
HR: heart rate
HIE: hypoxic-ischemic encephalopathy
LV: left ventricular
LVEF: left ventricular ejection fraction
MCS: mechanical circulatory support
PELOD-2: Pediatric Logistic Organ Dysfunction 2
PRISM: Pediatric Risk of Mortality
PODIUM: Pediatric Organ Dysfunction Information Update Mandate
RV: right ventricular
RSV: respiratory syncytial virus
$ScvO_2$: central (or mixed) venous oxygen saturation
VIS: vasoactive-inotropic score
VAD: ventricular assist device

Drs Alexander, Checchia, Ryerson, Bohn, Eckerle, Gaies, Laussen, Jeffries, Thiagarajan, Shekerdemian, Bembea, Zimmerman, and Kissoon conceptualized and designed the study, collected data, interpreted the data to generate criteria for organ dysfunction, voted on and revised cardiovascular organ dysfunction criteria, and reviewed and revised the manuscript; Dr Alexander drafted the initial manuscript and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

The guidelines/recommendations in this article are not American Academy of Pediatrics policy, and publication herein does not imply endorsement.

DOI: https://doi.org/10.1542/peds.2021-052888

Accepted for publication Sep 24, 2021

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PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: Boston Children's Hospital Division of Cardiac Intensive Care (Drs Alexander, Laussen, and Thiagarajan), Texas Children's Hospital (Drs Checchia and Shekerdemian), University of Michigan Department of Pediatrics (Dr Gaies), British Columbia Children's Hospital (Dr Kissoon), and Howard Jeffries, MD, contributed funds toward publication cost for this article. Funded by National Institutes of Health National Institute of Neurological Disorders and Stroke grant R01NS106292 (Dr Bembea). Funded by the National Institutes of Health (NIH).

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

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