Original Article

Clinical Predictors of Circulatory Failure and Coexisting Morbidities in Children Seen in an Emergency Room in Southern Nigeria

WE Sadoh[1,2], MT Abiodun[1,2]

[1]Department of Child Health, University of Benin Teaching Hospital, Benin City, Edo State, [2]Department of Child Health, School of Medicine, University of Benin, Benin City, Edo State, Nigeria

Received: 06-Feb-2022;
Revision: 05-Apr-2022;
Accepted: 14-Apr-2022;
Published: 16-Aug-2022

ABSTRACT

Background: Circulatory failure (shock) is a life-threatening emergency referring to a state of poor tissue perfusion and resultant anaerobic respiration at a cellular level. It is a common pathway for several severe pediatric morbidities. **Aim:** We evaluated the clinical predictors of shock and coexisting morbidities in acutely-ill children. **Patients and Methods:** This was a descriptive, cross-sectional study. Data were collected using a researcher-administered questionnaire eliciting demography, clinical features, diagnoses/differentials, and comorbidities. After binary analysis, multiple logistic regression identified variables that independently predict circulatory failure in the participants, using odds ratio (OR) and 95% confidence intervals (CI). **Results:** Five hundred and fifty-four children took part in the study. Their median age was 60 (IQR: 24–132) months, mean weight 16.3 ± 13.6 kg and mean height was 90.8 ± 33.2 cm; 53.7% of them were males while 46.3% were females. The incidence of shock was 14.3% among the participants on arrival at the emergency room. Febrile seizure (14.9%), dehydration (4.7%), pallor (3.1%), and coma (1.8%) were the clinical findings significantly associated with shock ($P < 0.05$). Leading underlying diagnoses and comorbidities associated with shock were severe malaria (85.4%) and severe sepsis (25.0%) ($P \leq 0.01$). Also, seizure (OR = 0.07, 95% CI: 0.04–0.13; $P \leq 0.001$) and severe sepsis (OR = 0.31, 95% CI: 0.15–0.65; $P = 0.002$) were independent predictors of circulatory failure. **Conclusion:** The presence of acute neurologic morbidities and severe infection predicts circulatory failure in the pediatric emergency setting. Early detection and prompt treatment will forestall shock-related complications in affected children.

KEYWORDS: *Circulatory failure, clinical predictors, comorbidities*

INTRODUCTION

Circulatory failure (shock) is a life-threatening cardiovascular emergency often encountered in children emergency rooms. It refers to a state of poor tissue perfusion and resultant anaerobic respiration at a cellular level.[1] It is a common pathway for several pediatric morbidities during severe illnesses.[1-3] It represents 14.3% to 25% of pediatric emergency admissions in several series.[4-6] It can also develop during admission for other noncardiovascular systemic illnesses.[5] Shock is often classified as hypovolemic, cardiogenic or distributive including anaphylactic, neurogenic, and septic shock based on underlying etiologies.[7,8] Depending on its severity, shock can be described as compensated or decompensated manifesting with hypotension and end-organ dysfunction.[7,9]

The early clinical features of shock are mainly in the cardiovascular system including tachycardia, small volume pulse, widened pulse pressure, and prolonged capillary refill time due to increased sympathetic stimulation of the vasculature and consequent vasoconstriction.[7,10] When these compensatory

Access this article online

Quick Response Code:

Website: www.njcponline.com

DOI: 10.4103/njcp.njcp_99_22

Address for correspondence: Dr. MT Abiodun, Department of Child Health, University of Benin Teaching Hospital, Benin City, Edo State, Nigeria.
E-mail: moses.abiodun@uniben.edu

How to cite this article: Sadoh WE, Abiodun MT. Clinical predictors of circulatory failure and coexisting morbidities in children seen in an emergency room in Southern Nigeria. Niger J Clin Pract 2022;25:1295-300.

mechanisms fail, hypotension, absent peripheral pulses, and systemic hypo-perfusion occur leading to widespread manifestations like altered sensorium, gut ischemia, and renal failure as well as respiratory compromise.[10,11] Without optimal management, prolonged hypotension will eventually lead to adrenal insufficiency and irreversible multi-organ damage.[12,13]

Coexisting morbidities often influence the clinical course and outcome of pediatric shock.[14,15] Also, some commodities can predispose to the development of shock in children who had stable cardiovascular systems at presentation in the emergency room.[5] Gadappa and Behera[16] in India evaluated 78 mechanically ventilated children with Shock and found their leading systemic morbidities, which include respiratory (30.7%), cardiovascular (21.8%), neurological (17.9%), and gastrointestinal disorders (14.1%). Overall mortality in the cohort was 73.1%.[16] Likewise, Dhanawade and Kurade[17] in a 3-year review in a tertiary hospital reported that pneumonia was a leading cause of decompensated septic shock and need for mechanical ventilation, which were significantly associated with mortality among their participants ($P < 0.05$). Again, in a multi-center study in Kenya, Mbevi *et al*.[18] found that the diagnosis of hypovolemic shock usually co-existed with other clinical diagnoses especially pneumonia or malaria and such patients had an increased risk of death (OR = 1.9; 95% CI, 1.2–2.9; $P = 0.008$).[18] This implies that commodities can significantly influence the severity and outcome of circulatory failure in children.

Consequently, it is desirable to assess the clinical characteristics and comorbid disorders seen in children with circulatory failure in our setting. We also sought to evaluate the relative contributions of various comorbidities to the presence of shock at presentation or its occurrence early on admission. This will enable proactive care and early detection of shock in at-risk children.

Methods

This study took place in the Children Emergency Rooms (CHERs) of the University of Benin Teaching Hospital (UBTH), in Southern Nigeria. The study period was from October 2018 to March 2019.

Study design

This study adopted a descriptive, cross-sectional design.

Participants

These children took part in a shock project evaluating the treatment and outcome of circulatory failure in the emergency unit. They were all children admitted with severe illnesses into CHER. Details of their demography and pre-hospital care have been described.[4]

Inclusion criteria

Children aged 1 month to 18 years with features of a critical or severe illness during the study period. A critical illness was defined as the presence of an acute life-threatening disorder, which requires an emergent or urgent intervention to prevent death.[19]

Exclusion criteria

Ill children without features of severe illnesses were excluded. Also, neonates were not recruited into this study because they were managed in a separate unit.

Sample size

The minimum sample size was determined using the formula for cross-sectional study[20]: $N = Z_{1}^{2}{}_{-\alpha}$ (P) (1-P)/d^2; where, Z_{1-}^{α} = normal standard deviation for confidence level of 95% = 1.96. *P* = Proportion of critically ill children with circulatory failure (we assumed 50%); d = margin of error to be tolerated (fixed at 5%).[20] This was adjusted for a 10% nonresponse rate. Altogether, 554 children were recruited during the study period.

Sampling method

This was a total population study of all eligible children admitted into CHER during the study period; they were purposively selected and recruited into the study following parental consent.

Data collection

Data were collected using a researcher-administered questionnaire comprising sections on baseline/clinical characteristics, diagnosis of shock, differential diagnoses, and coexisting morbidities. Blood pressure measurements with a Mercury sphygmomanometer were taken using standard procedures with pediatric cuffs.[21] Circulatory failure was defined based on WHO criteria (cold extremities, prolonged capillary refill >3 seconds, and fast and weak pulse) or the presence of hypotension (systolic BP <70 mmHg in infants or <70 + 2 *n*, where *n* = age in years for under-10-year-old children).[19,22] Also, a complete review of clinical documentations on the participants at admission was done.

Statistical analysis

Descriptive and inferential analyses of the data were performed using the IBM Statistical Package for Social Sciences (SPSS) version 26.0 for windows. Categorical variables were described using frequencies and percentages, while continuous variables such as age, anthropometry, duration of illness, and vital signs were described using means and standard deviations. The incidence of circulatory failure was derived from the proportion of affected participants. Bivariate

analysis (Pearson Chi-square) was performed to detect any significant association between the descriptive variables and circulatory failure. Clinical features and comorbidities that were significant on binary analysis were then subjected to multivariate logistic regression to identify independent predictors of circulatory failure in the participants, using adjusted odds ratio (aOR) and 95% confidence intervals (CI). $P < 0.05$ was considered significant.

Ethical consideration

Ethical clearance for the shock project was obtained from the Research and Ethics Committee of the College of Medical Sciences, University of Benin (CMS/REC/2018/020). Informed consent was obtained from the parents/guardians of the children.

Results

Baseline characteristics of the participants (*N* = 554)

Five hundred and fifty-four acutely-ill children participated in the study. Their median age was 60 (24–132) months, mean weight 16.3 ± 13.6 kg, and mean height was 90.8 ± 33.2 cm; 53.7% of them were males while 46.3% were females. A majority (42.2%) of the children were in the lower social-economic class, 34.6% of them were in the middle class while 23.2% were in the upper class. Most of the children (80.0%) presented to the emergency room coming directly from home, 10.1% from private clinics, and 9.9% from public hospitals. The Median (IQR) duration of illness of the children was 4 (2.7) days before admission. The incidence of shock was 14.3% among the participants on arrival at CHER. Also, 13 (2.4%) of the participants had episodes of circulatory failure while on admission.

Clinical features and comorbid diagnoses

The mean vital signs of the participants were as follows: Temperature 37.5 ± 2.1°C, pulse rate 125.8 ± 27.2 bpm and 47.8 ± 18.3 cpm. Also, their mean SPO_2 was 89.0 ± 14.1. Other clinical findings in the participants include febrile seizure (14.9%), dehydration (4.7%), dyspnea (3.5%), pallor (3.1%), and coma (1.8%). The leading underlying diagnoses and comorbidities among them were severe malaria (85.4%) and severe sepsis (25.0%). Sixteen participants had chronic underlying morbidities as follows: Sickle cell disorder (8), epilepsy (2), chronic kidney disease (*2,* one has hypertensive emergency), congenital heart disease (2), nephrotic syndrome (1), and newly-diagnosed diabetes mellitus (1). Other clinical findings and coexisting morbidities in the participants are shown on Table 1.

Table 1: Clinical features and Comorbid diagnoses among the participants (*n*=554)

Clinical features/ Comorbid diagnoses	Frequency, *n*	Percentage (%)
Clinical Features		
Fever	476	85.9
Dehydration	26	4.7
Pallor	17	3.1
Dyspnea	19	3.5
Febrile seizure	82	14.9
Coma	10	1.8
Cyanosis	1	0.2
Others*	97	17.5
Comorbid diagnoses		
DIC	1	0.2
Heart failure	2	0.4
Gastroenteritis	91	16.6
Severe malaria	229	85.4
Severe sepsis	67	25.0
Myocarditis	1	0.2
SVT	1	0.2
Others[‡]	16	2.9

SVT: Supraventricular tachycardia; DIC: Disseminated Intravascular Coagulopathy. *cough, diarrhea, vomiting, oliguria (2); [‡]Sickle cell disorder (8), epilepsy (2), chronic kidney disease (2), congenital heart disease (2), nephrotic syndrome (1), diabetes mellitus (1)

Clinical features and comorbidities associated with shock

Table 2 shows a comparison of clinical features/comorbidities between children with and without shock in CHER. The frequencies of dehydration, pallor, febrile seizure, and coma were significantly different between these two sub-groups ($P < 0.05$). Also, the presence of severe malaria ($P = 0.01$) and severe sepsis ($P < 0.001$) differs significantly between them. Severe sepsis was associated with the development of shock while on admission ($P = 0.05$). Disseminated intravascular coagulopathy, gastroenteritis, and cardiovascular comorbid diagnoses were not significantly associated with shock among the participants. Also, none of the participants with chronic underlying morbidities presented with circulatory failure.

Multivariate analysis for predictors of circulatory failure

Using a multiple logistic regression, the predictive value of variables that were significant on bivariate analysis was determined. Febrile seizure (OR = 0.07, 95% CI: 0.04–0.13; $P \leq 0.001$) and severe sepsis (OR = 0.31, 95% CI: 0.15–0.65; $P = 0.002$) were independently associated with circulatory failure [Table 3]. However, dehydration, pallor, coma, and severe malaria did not independently predict the presence of circulatory

Table 2: Comparison of clinical features/comorbid diagnoses between children with and without shock in CHER

Clinical features/ comorbidities	Shock at Presentation		χ^2	*P*
	No	Yes		
Clinical features				
Dehydration	16 (61.5)	10 (38.5)	13.023	0.02
Pallor	9 (52.9)	8 (47.1)	15.385	<0.001
Dyspnea	14 (73.7)	5 (26.3)	2.326	0.171
Febrile seizure	38 (46.3)	44 (53.7)	121.887	<0.001
Coma	3 (30.0)	7 (70.0)	25.817	<0.001
Cyanosis	1 (100.0)	0 (0.0)	0.167	1.000
Comorbid diagnoses				
DIC	0 (0.0)	1 (100.0)	6.011	0.143
Gastroenteritis	74 (81.3)	17 (18.7)	1.791	0.181
Heart failure	1 (50.0)	1 (50.0)	2.091	0.266
Severe malaria	186 (81.2)	43 (18.8)	6.653	0.010
Severe sepsis	44 (65.7)	23 (34.3)	25.249	<0.001
Myocarditis	0 (0.0)	1 (100.0)	6.654	0.131
SVT	0 (0.0)	1 (100.0)	6.654	0.131

SVT: Supraventricular tachycardia; DIC: Disseminated Intravascular Coagulopathy

Table 3: Multivariate logistic regression analysis for shock at presentation by selected clinical features and comorbid diagnosis

clinical features/ comorbid diagnosis	Frequency (%)	*P*	O.R	95% C.I.
Dehydration	10 (38.5)	0.979	0.98	0.19-5.13
Pallor	8 (47.1)	0.927	1.12	0.11-11.54
Dyspnea	5 (26.3)	0.644	1.59	0.22-11.27
Febrile seizure	44 (53.7)	0.000	0.07	0.04-0.13
Coma	7 (70.0)	0.459	0.41	0.04-4.34
Gastroenteritis	17 (18.7)	0.949	0.97	0.43-2.23
Severe malaria	43 (18.8)	0.595	0.85	0.46-1.57
Severe sepsis	23 (34.3)	0.002	0.31	0.15-0.65

failure in the participants at presentation or while on admission.

Discussion

This study found that sepsis and severe malaria were the leading clinical diagnoses of the participants and several clinical features including pallor and convulsions were significantly associated with circulatory failure, being the severity criteria of these diseases.[23,24] The multi-organ manifestations of malaria and bacterial sepsis in children often involve circulatory, hematological, and neurologic dysfunctions.[24,25] In a prospective study of clinical manifestations of childhood severe malaria in Tanzania, Kalinga *et al*.[26] found that convulsion and compensated shock were the most common symptoms among the participants. Likewise, Vekaria-Hirani *et al*.[5] and Humoodi *et al*.[27] reported high incidence of shock in septic children their intensive care unit. Severe childhood illnesses often have multi-systemic effects, especially in the younger age groups including microbe-related or toxin-mediated neurologic dysfunction and peripheral vasodilation with shock.[25,28] The development of shock in febrile illnesses is often due to the sustained release of pro-inflammatory cytokines and vasoactive substances. Hence, the circulatory failure in malaria and sepsis constitutes a defining criterion of their severity.[24,25] Consequently, it is pertinent to closely monitor children with neurologic emergencies for a concurrent or evolving circulatory dysfunction.[5,10]

It is remarkable that every one of the few children with disseminated intravascular coagulopathy (DIC), myocarditis, and supraventricular tachycardia (SVT) in this study also had circulatory failure. Myocarditis and SVT are recognized causes of cardiogenic shock in the literature.[29,30] Hence, while providing emergency cardiovascular care to children, the possibility of these underlying morbidities should be considered.[31] Also, convulsion remains one of the significant independent predictors of circulatory failure in this study, comparable to earlier reports.[5,10] This highlights the need to forestall circulatory dysfunction in such children whenever they are encountered in emergency units.

Gastroenteritis was not a significant predictor of shock in this study, but a prior sub-analysis of affected children showed that those who received oral rehydration salts at home were likely to present in the emergency room with circulation failure, perhaps due to delayed presentation.[4] Nonetheless, gastrointestinal fluid loss is a major risk factor for hypovolemic shock while infections can predispose to distributive shock with their sequelae.[7,9] Again, congestive cardiac failure was not significantly associated with circulatory failure in this study, perhaps due to the short duration of the underlying illnesses without severe inflammatory myocardial damage in these participants. Conversely, in a recent study, Caro-Patón *et al*.[32] found that children with multisystem inflammatory syndrome associated with SARS-CoV-2 infection were at risk of myocardial injury and cardiogenic shock.

The strength of this study includes a large sample size enhancing its validity and clinical relevance to pediatric emergency practice in all settings. However, its limitation is that the cross-sectional design adopted in this study cannot fully elucidate the nature of the relationship between circulatory failure and the comorbidities as either causal, concurrent, or consequent; for instance, DIC can be a cause of shock as well as its complication.[7] Hence, a prospective study on each comorbidity utilizing a cohort design will

enable the computation of attributable risk of circulatory failure.

Conclusions

Acute neurologic and sepsis-related morbidities are significantly associated with circulatory failure in pediatric emergency settings. It is pertinent to monitor such patients for evolving signs of circulatory dysfunction at presentation and while on admission; this will ensure early detection and prompt treatment of circulatory failure in order to prevent shock-related complications in affected children.

Data availability statement

The completed questionnaires and excel spreadsheet of the research reported in this article are available from the authors on request.

Acknowledgements

The authors thank Benjamin Nandom (pediatric registrar) and Seun Adeola (research assistant) who participated in data collection and Enosakhare Okungbowa (biostatistician/Lecturer).

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Pasman EA. Shock in Pediatrics. Medscape. 2015. Available from: https://emedicine.medscape.com/article/1833578-overview. [Last accessed on 2021 Jan 20].
2. McKiernan CA, Lieberman SA. Circulatory shock in children: An overview. Pediatr Rev 2005;26:451-60.
3. Prout A, Talisa V, Mayr F, Yende S. Pediatric sepsis and septic shock: Risk factors and comorbid conditions. Crit Care Med 2016;44:409. doi: 10.1097/01.ccm.0000510007.49298.b2.
4. Abiodun MT, Sadoh WE. Socio-demographic characteristics and pre-hospital care of children with circulatory failure in a children's emergency room in Southern Nigeria. Pan Afr Med J 2021;40:65.
5. Vekaria-Hirani V, Kumar R, Musoke RN, Wafula EM, Chipkophe IN. Prevalence and management of septic shock among children admitted at the Kenyatta national hospital, longitudinal survey. Int J Pediatr 2019;2019:1502963.
6. Crouse HL, Torres F, Vaides H, Walsh MT, Ishigami EM, Cruz AT, *et al*. Impact of an Emergency triage assessment and treatment (ETAT)-based triage process in the paediatric emergency department of a Guatemalan public hospital. Paediatr Int Child Health 2016;36:219-24.
7. Pasman EA. Shock in Pediatrics Treatment & Management. Medscape. https://emedicine.medscape.com/article/1833578-treatment. [Last accessed on 2021 Jan 20].
8. Summers RL, Baker SD, Sterling SA, Porter JM, Jones AE. Characterization of the spectrum of hemodynamic profiles in trauma patients with acute neurogenic shock. J Crit Care 2013;28:531.e1-5.
9. Fisher JD, Nelson DG, Beyersdorf H, Satkowiak LJ. Clinical spectrum of shock in the pediatric emergency department. Pediatr Emerg Care 2010;26:622-5.
10. Cecconi M, De Backer D, Antonelli M, Beale R, Bakker J, Hofer C, *et al*. Consensus on circulatory shock and hemodynamic monitoring. Task force of the European society of intensive care medicine. Intensive Care Med 2014;40:1795-815.
11. Vincent J-L, Ince C, Bakker J. Clinical review: Circulatory shock --An update: A tribute to professor max Harry Weil. Critical Care 2012;16:239.
12. Annane D, Pastores SM, Rochwerg B, Arlt W, Balk RA, Beishuizen A, *et al*. Guidelines for the diagnosis and management of Critical illness-related corticosteroid insufficiency (CIRCI) in critically ill patients (Part I): Society of critical care medicine (SCCM) and European society of intensive care medicine (ESICM) 2017. Crit Care Med 2017;45:2078-88.
13. Jentzer JC, Vallabhajosyula S, Khanna AK, Chawla LS, Busse LW, Kashani KB. Management of refractory vasodilatory shock. Chest 2018;154:416-26.
14. Oluwafemi RO, Abiodun MT. Morbidity and mortality pattern at the emergency paediatric unit of mother and child hospital Akure, Nigeria. Ann Biomed Sci 2016;15:151-9.
15. Paul N, Yaguo-Ide L. Severe falciparum Malaria: Prevalence, comorbidities and outcome in children in Port Harcourt, Nigeria. Int J Med Sci 2019;6:5-13.
16. Gadappa SM, Behera MK. Clinical profile and outcome of shock in mechanically ventilated patients in pediatric intensive care unit of tertiary care centre. Int J Res Med Sci 2019;7:71-6. doi: 10.18203/2320 6012.ijrms20185065.
17. Dhanawade S, Kurade A. Clinical profile and outcome of septic shock in children admitted to a tertiary care referral hospital. Int J Pediatr Res 2016;3:225-30.
18. Mbevi G, Ayieko P, Irimu G, Akech S, English M, Clinical Information Network authors. Prevalence, aetiology, treatment and outcomes of shock in children admitted to Kenyan hospitals. BMC Med 2016;14:184.
19. World Health Organisation. Updated guideline: Paediatric emergency triage, assessment and treatment (ETAT). https://apps.who.int/iris/handle/10665/204463. [Last accessed on 2019 Apr 26].
20. Charan J, Biswas T. How to calculate sample size for different study designs in medical research? Indian J Psychol Med 2013;35:121-6.
21. Ogedegbe G, Pickering T. Principles and techniques of blood pressure measurement. Cardiol Clin 2010;28:571-86.
22. Chameides, L, Ashcraft J, editors. Pediatric Avanced Life Support (Pals) Provider Manual (Aha, Pediatric Advanced Life Support (Pals) Provider Manual). American Heart Association/ American Academy of Pediatrics. Part 2. 2011. p. 18-22.
23. Sehgal M, Ladd HJ, Totapally B. Trends in epidemiology and microbiology of severe sepsis and septic shock in children. Hosp Pediatr 2020;10:1021-30.
24. Maitland K. Management of severe paediatric malaria in resource-limited settings. BMC Med 2015;3;13:42.
25. Weiss SL, Peters MJ, Alhazzani W, Agus MSD, Flori HR, Inwald DP, *et al*. Surviving sepsis campaign international guidelines for the management of septic shock and sepsis-associated organ dysfunction in children. Intensive Care Med 2020;46(Suppl 1):10-67.
26. Kalinga A, Mayige M, Kagaruki G, Shao A, Mwakyusa B, Jacob F, *et al*. Clinical manifestations and outcomes of severe malaria among children admitted at Rungwe and Kyela district hospitals in

South-Western Tanzania. Tanzan J Health Res 2012;14:3-8.
27. Humoodi MO, Aldabbagh MA, Salem MM, Al Talhi YM, Osman SM, Bakhsh M, *et al*. Epidemiology of pediatric sepsis in the pediatric intensive care unit of King Abdulaziz Medical City, Jeddah, Saudi Arabia. BMC Pediatr 2021;21:222.
28. Jarczak D, Kluge S, Nierhaus A. Sepsis-pathophysiology and therapeutic concepts. Front Med (Lausanne) 2021;8:628302.
29. Fung RCM, Hon KL, Leung AKC. Acute myocarditis in children: An overview of treatment and recent patents. Recent Pat Inflamm Allergy Drug Discov 2020;14:106-16.
30. Sarton R, Fournier E, Iriart X, Thomas J, Jalal Z, Thambo JB, *et al*. Predictive factors of cardiogenic shock in children with supraventricular tachycardia. Arch Cardiovasc Dis Suppl 2018;10:135.
31. Van de Voorde P, Turner NM, Djakow J, de Lucas N, Martinez-Mejias A, Biarent D, *et al*. European resuscitation council guidelines 2021: Paediatric life support. Resuscitation 2021;161:327-87.
32. Caro-Patón GL, de Azagra-Garde AM, García-Salido A, Cabrero-Hernández M, Tamariz A, Nieto-Moro M. Shock and myocardial injury in children with multisystem inflammatory syndrome associated with SARS-CoV-2 infection: What we know. Case series and review of the literature. J Intensive Care Med 2021;36:392-403.