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ORIGINAL RESEARCH

Pediatric Shock: The Magnitude, Its Determinants and Short-Term Outcome on Patients. A Cross-Sectional Hospital-Based Study

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Background: Pediatric shock is a potentially fatal illness which develops after a systemic circulatory system failure in children. It appears to be a common emergency in children and produces substantial morbidity and mortality particularly if there is no early identification and therapy. The extent and causes of shock-induced death among children in Ethiopia have not been sufficiently studied.

Objective: This study was conducted to evaluate the magnitude, determinants and short-term outcome of shock in pediatric patients who visited Ayder Comprehensive Specialized Hospital in Tigray, Northern Ethiopia.

Methods: From October 1, 2020, to July 30, 2022, an observational cross-sectional study was carried out at Ayder Comprehensive Specialized Hospital. The study included 132 children from the age of 1 month to 18 years. According to pediatric advanced life support guidelines, shock was diagnosed among patients. To gather information, a pretested questionnaire was employed. To examine the relationship between the independent variables and shock outcome, bivariate logistic regression was performed, and statistical significance was defined as a P-value of 0.05 or lower.

Results: The prevalence of shock was 2.2%. This study revealed 70.5% decompensated stage of shock. Mortality rate of shock was 45.5% (95% CI: 37.1–53.8). A delayed presentation by more than one week with an adjusted odd ratio (AOR) of 16.9 (95% CI: 2.3–123), type of shock other than hypovolemic shock with AOR of 8.3 (95% CI: 1.4–48), stage of shock with AOR of 27.8 (95% CI: 2.8–157), requirement of mechanical ventilation with AOR of 11 (95% CI: 2.6–53) and length of hospital stay less than three days with AOR of 9 (95% CI: 1.7–48) were identified as a predictor of mortality by shock in children.

Conclusion: According to this study, shock causes a high rate of child mortality. Independent predictors of mortality included delayed presentation, shock type, stage of shock, the need for mechanical ventilation, and brief hospital stay (less than three days).

Keywords: shock, children, cross-sectional study, Ayder Hospital

Background

Shock is an acute state of energy failure, due to inadequate glucose substrate and oxygen delivery at a cellular level to meet the metabolic needs of essential organs and tissues.

Adverse vascular, inflammatory, metabolic, cellular, endocrine, and systemic responses exacerbate physiologic instability if insufficient tissue perfusion continues.[1] Hypovolemic, distributive, cardiogenic, obstructive, and dissociative types are five broad classifications of shock.[1,2] Intensive treatment must be started quickly to manage shock in children. Most pediatric hospital deaths frequently happen within the first 24 hours of admission. Early goal-directed therapy is needed for shock, aimed at improving vital organ function and physiologic indications of perfusion within the first six hours of treatment, combined with an aggressive, systematic strategy to resuscitation.[3] Multiple organ system failure is the primary complication of shock and is linked to a higher death rate and longer hospital stays in survivors.[1,2]

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In developed countries, shock is thought to affect 2% of all hospitalized patients, and the death rate varies according to the type of shock and clinical circumstances.[1] However, shock in children is associated with a high morbidity and mortality rate in low- and middle-income countries, with prevalence ranging from 1.5–44.3% and mortality from 3.9–33.3%. Most deaths happen during the first 24 hours of admission, and most of them are avoidable.[4]

Preliminary studies and reports from hospitals in Ethiopia have shown that there is a high prevalence of shock and it is associated with high mortality. For example, a cross-sectional study done on admitted pediatric patients at a hospital located in South-Western Ethiopia, has showed that shock was the leading medical case which accounts for 17% of the admissions and a high mortality rate of up to 50%.[5] There is a paucity of data on short-term outcome of shock in children in Ethiopia, particularly in our study area. Therefore, this study was conducted to assess the magnitude of pediatric shock and to identify the factors associated with mortality among children attending the pediatric emergency outpatient unit of the hospital.

Methods and Materials

Study Area

Ayder Comprehensive Specialized Hospital is a referral and teaching hospital in Ethiopia's Tigray region, Mekelle and this study was conducted from October 1, 2020, to July 30, 2022.

Study Design

Institution-based cross-sectional study was conducted with patients aged between 1 month to 18 years and have visited to the hospital, department of pediatrics and child health.

Inclusion and Exclusion Criteria

Children from the age of 1 month up to 18 years old were included in the study. Patients or guardians who received medical advice were included in the study. Whereas those who did not receive medical advice were excluded from the study.

Sample Size Determination and Sampling Procedure

The sample size was determined using a single population proportion formula with a 95% confidence level, 5% margin of error as follows: $n = (Z) \times P(1-p)/(d) = (1.96) \times 0.09(1-0.09) \div (0.05) = 126$; where: n: is the minimum sample size required; p: prevalence of shock in children; Z: is the standard normal variable at (1-α) % confidence level and α is mostly 0.05 i.e. with 95% CI (z=1.96); d: is the margin of error to be tolerated (5%); n = 139 (10%).

Independent Variables

- Socio-demographic characteristics Age, Sex, residence, Attendant
- Clinical profile (Symptoms, Signs, duration of illness, Hospital stay)
- Shock characteristics (type, stage)
- Comorbidity
- ABCD of life, Vital signs and anthropometry
- Investigations and Measurements
  - CBC, RFT, LFT, Serum E
  - UOP, RBS
- Management of shock (Fluids, Antibiotics, Inotropic, Steroid, Invasive ventilations)

Data Collection Tools and Procedures

A semi-structured questionnaire that had been pretested was used to gather data. After being translated into Tigrigna, the local language, the questionnaire was pretested in English. Based on the PALS criteria, information was gathered from every child who had been diagnosed with shock. Age-specific ranges were used to interpret investigations and vital signs,

and the WHO curve was also used to interpret anthropometry results. The use of pretested questions helped to ensure the accuracy of the data. Ten patients who were enrolled in the study were given a pretest version of the questionnaire, and the language's clarity was examined. Each questionnaire was examined by the lead investigator prior to data entry.

Data Processing and Analysis

Data were first verified and coded before being put into EpiData Manager version 4.6.0.2. From there, they were exported to the Statistical Package and Service Solution (SPSS) version 23 for analysis. Frequency and percentages were used to express category variables. After being verified to have a normal distribution, those continuous variables were expressed as the mean plus standard deviation and median. First, bivariate logistic regression analysis was used to evaluate the factors that influence the short-term outcome of shock in children.

Operational and Standard Definitions

Shock: Inadequate tissue perfusion that results from the failure of the cardiovascular system to deliver sufficient oxygen and nutrients to sustain vital organ function; also called hypoperfusion or circulatory failure based on PALS criteria.

Short-term outcome: outcome during the hospital stay (i.e. improvement or death).

MODS; Presence of altered organ function (≥2 organs) such that homeostasis cannot be maintained without medical intervention (3).

Compensated shock: signs of shock and blood pressure is maintained/ normal (1).

Decompensated shock: signs of shock and hypotension /or altered mentation (1).

Ethical Approval and Consent to Participate

The Institutional Review Board (IRB) of Mekelle University's College of Health Sciences granted ethical approval (MU-IRB 1998/2022: ethical approval number). Informed consent was obtained from all guardians of study participants, both verbally and in writing.

The study has been conducted in accordance with the Amended Declaration of Helsinki.

Result

Out of a total 6112 visits to the Pediatric Emergency Outpatient Department (PEOPD), 134 participants were diagnosed with shock, two patients who went against medical advice were excluded, 132 patients were eligible for analysis and this gives a point prevalence 2.2%. The socio-demographic characteristics of study participants and caregivers were also analyzed, and the median age of the study participants was 6.45 years. Thirty-seven (28%) were infants, 38 (28.8%) were between the age of 1 and 5 years and 57 (43.2%) were above 5 years old. The male to female ratio was 1.3:1. More than half (55.3%) of the participants were from an urban area, 30 (22.7%) of the attendants were not educated and 88 (66.7%) of the participants were referred from other facility (Table 1).

Clinical Profile and Laboratory result of Participants

Among the patients included in the study, the most common symptom was vomiting, 103 (78%), followed by altered mentation, 91 (68.9%), fast breathing, 88 (66.7%), fever, 80 (60.6%), diarrhea, 76 (57.6%). A total of 72 (54.4%) of them were presenting after one week of illness, 34 (25.8%) presented within two days of illness. From the total of 132 cases, one-third (31.8%) of them had chronic medical illness. Those include cardiac 12 (28.6%), hematologic disease 11 (26.2%), diabetes mellitus 9 (21.4%), epilepsy 7 (16.7%), respiratory viral infection 2 (4.8%) and 1 (2.3%) with brain tumor. The most common clinical sign noticed was tachycardia 115 (87.1%), feeble pulse volume 111 (84.1%), positive sign of dehydration 98 (74.2%), tachypnea 94 (71.2%), saturation below 90% in 88 (66.7%), decreased urine output in 84 (63.4%), pallor in 68 (51.5%). Blood pressure measurement was taken for 58 (43.9%) and it was unrecordable in more than 20 (35.1%) of them. Nutritional assessment has showed that severe wasting was noticed in 55 (41.7%) of the total. Mean Glasgow Coma Scale (GCS) of participants was 12.5 (SD±2.6) and 19 (14.4%) patients were comatose at presentation (Table 2).

Table 1 Socio-Demographic Characteristics of Study Participants and Caregivers Among Pediatric Shock Patients

Variables	Category	Count(n)	Percentage (%)
Sex of the children	Male	75	56.8%
	Female	57	43.2%
Residence	Urban	73	55.3%
	Rural	59	44.7%
Age of participant	1 month-11 month	37	28%
	1–5 years	38	28.8%
	Above 5 years	57	43.2%
Mothers' educational status	No formal education	30	22.7%
	Primary	52	39.3%
	Secondary	36	27.4%
	Tertiary	14	10.6%
Referred from other health facility	Yes	88	66.7%
	No	44	33.3%

Table 2 Physical Finding and Measurements of Pediatric Shock Patients

Variables	Category	Count (%)	Variables	Category	Count (%)
HR	Tachycardia	115 (87.1%)	**W/L**	Normal	28 (21.1)
	Normal	15 (11.4%)		−2 and −3 Z score	53 (40.2%)
	Bradycardia	2(1.5%)		<3 Z score	51 (41.7%)
RR	Normal	32 (24.2%)	**Sign of dehydration**	Yes	98 (74.2%)
	Tachypnea	94 (71.2%)		No	34 (25.8%)
	Bradypnea	6(4.5%)		Normal	5(3.8%)
SPO_2	<90%	88 (66.7%)	**Pulse volume**	Feeble	111 (84.1%)
				Bounding	16 (12.1%)
	91% and above	44 (33.3%)	**Capillary refill**	<3 Second	15 (11.45%)
				3–5 Second	93 (70.5%)
				>5 Second	24 (18.2%)
BP	Not measured	75 (56.8%)	**UOP**	Normal	34 (25.8%)
	Unrecordable	20 (15.2%)		Oliguria	84 (63.6%)
	Hypotensive	33 (25%)		Polyuria	14 (10.6%)
	Normotensive	4(3%)	**GCS**	15	13 (9.8%)
TO	Hypothermic	50 (37.9%)		14–9	100 (75.8%)
	Febrile	49 (37.1%)		3–8	19 (14.4%)
	Normal	33 (25%)			
MUAC	Normal	32 (24.2%)	**RBS**	Normal	77 (58.3%)
	−2 and −3Z score	45 (34.1%)		Hypoglycemia	40 (30.3%)
	<−3 Z score	55 (41.7%)		Hyperglycemia	15 (11.4%)

Abbreviations: HR, heart rate; RR, respiratory rate: SPO_2, saturation of peripheral oxygen; BP, blood pressure; T0, temperature; MUAC, mid upper arm circumference; W/L, weight for length; OUP, urine output; GCS, Glasgow Coma Scale; RBS, random blood sugar.

A complete blood count was done for 87 (65.9%) of the cases. Hemoglobin blood test was performed in 93 (70.5%) cases and the result showed that 57 (61.3%) of them had low hemoglobin level. Creatinine level test was done in 94 (71.2%) cases and it showed an elevation in more than half 54 (57.4%) of them. Liver function test (LFT) was performed for only one-third of participants, and it was elevated in nearly half of them. Serum electrolyte (sodium and potassium) test was also performed in less than two-thirds (64.4%) of participants but only 11 participants had serum calcium determination and nine of them showed hypocalcemia (Table 3). We also analzed the electrolyte abnormalities among patients and the result showed cases with hypernatremia(77%), hyperkalmia(65%) and hypocalcemia(67%) have been associated with decompensated shock (Table 4).

Table 3 Laboratory Parameters of Pediatric Shock Patients

Variables	(n)	Category	Count (N)	Percentage
CBC	87 (66%)			
WBC		Leukocytosis	44	50.6%
		Normal	30	34.7%
		Leukopenia	13	14.9%
Hemoglobin		Normal	32	36.8%
		Anemia	55	63.2%
PLT		Thrombocytosis	19	21.8%
		Normal	33	37.9%
		Thrombocytopenia	35	40.2%
Cr	94 (71.2%)	Normal	40	42.6%
		Elevated	54	57.4%
LFT	42 (31.8%)	Normal	23	54.8%
		Elevated	19	45.2%
Na	85 (64.4%)	Hypernatremia	26	30.6%
		Normal	30	35.3%
		Hyponatremia	29	34.1%
Ka	85 (64.4%)	Hyperkalemia	23	27%
		Normal	28	33%
		Hypokalemia	34	40%
Ca	11 (8.3%)	Normal	2	18.2%
		Hypocalcemia	9	81.8%

Abbreviations: CBC, complete blood count; WBC, white blood cell; PLT, platelet; Cr, creatinine; LFT, liver function test; Na, sodium; Ka, potassium; Ca, calcium.

Table 4 Electrolyte Abnormality and Stage of Shock among Pediatric Patient

Variables	Compensated		Decompensated	
	Count (n)	%	Count (n)	%
Hypernatremia	6	23.1	20	76.9
Hyponatremia	13	44.8	16	55.2
Hyperkalemia	8	34.8	15	65.2
Hypokalemia	13	38.2	21	61.8
Hypocalcemia	3	33.3	6	66.7

Type, Stage and Management of Shock

The most common type of shock was hypovolemic shock (53%), followed by septic shock (34.4%), mixed (6.8%), cardiogenic and anaphylactic shock each accounting for 2.3%, respectively. Only one patient presented with obstructive shock. Out of the total 132 cases, 93 (70.5%) of them were in a decompensated stage. 44 (33.3%) of the participants had multi-organ failure. During the management of shock, 76 (57.6%) patients received crystalloid boluses and 56 (42.4%) cases were given both crystalloid and colloids. Out of the 60 (45.5%) cases who required inotropic, 61.7% of them took both dopamine and adrenalin, 18 (30%) dopamine only and 5(8.3%) adrenalin only, 37.9% of participants received steroid. 35.6% of the cases required mechanical ventilation. The time gap for the initiation of fluid after the patient arrived was determined and the mean duration was 24±10 minutes. The frequency of re-evaluation was a median of 1 hr. The median length of hospital stay was 7 days (Table 5 and Figure 1).

Table 5 Type, Stage and Management of Pediatric Shock Patients

Variables	Characteristics	Count(n)	Percentage
Type of shock	Hypovolemic	70	53%
	Septic	46	34.8%
	Mixed	9	6.8%
	Cardiogenic	3	2.3%
	Anaphylactic	3	2.3%
	Obstructive	1	0.8%
Stage of shock	Compensated	39	29.5%
	Decompensated	93	70.5%
Multi-organ dysfunction syndrome	Yes	44	33.3%
	No	88	66.7%
Fluids administration	Crystalloids only	76	57.6%
	Crystalloids and colloid	56	42.4%
Antibiotic administration	Started just on arrival	45	35.2%
	He/she was on antibiotic	83	64.8%
Inotropic administration	Yes	60	45.5%
	No	72	54.5%
Steroid administration	Yes	50	37.9%
	No	82	62.1%
Invasive ventilation provided	Yes	47	35.6%
	No	85	64.4%
Patient outcome	Improved	72	54.5%
	Dead	60	45.5%

Outcome of Shock in Pediatric Patients

The overall mortality of shock in this study was 45.5% (95% CI, 37.1–53.8). Out of those, 70.5% were in decompensated stage of shock. The proportion of death was higher in those above 5 years old (43.3%) followed by infants (30%) and

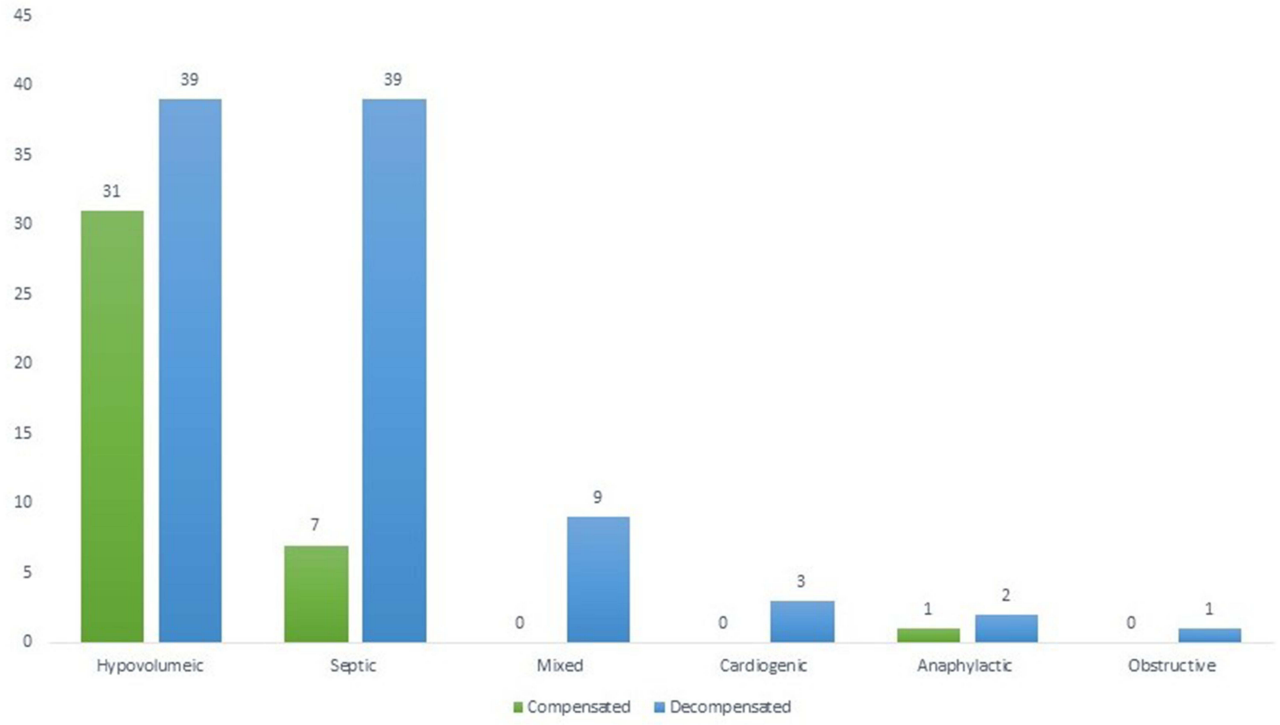

Figure 1 Type and stage of shock in children.

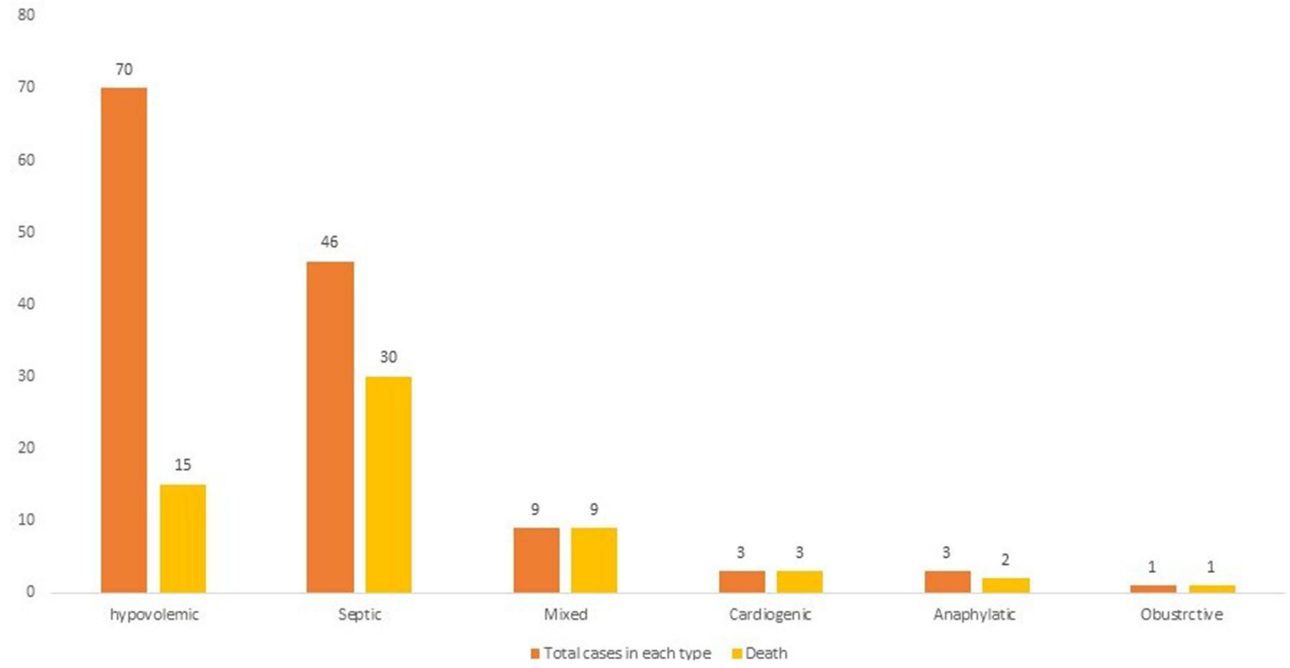

Figure 2 Type versus outcome of pediatric shock patients.

26.7% in those 1–5 years old. But the case fatality rate was higher among those infants (48.6%), followed by in those above 5 years (45.6%) and in 42.1% in those 1–5 years. Among the deaths, 70% of them were referred from other health facility. Mortality of mixed type cardiogenic and obstructive type of shock were 100%. Case fatality rate of septic and hypovolemic shock was 65.2% and 21.4%, respectively. 50% of mortality was due to septic shock (Figure 2).

Predictors of Mortality in Shock Among Pediatric Patients

A binary logistic regression analysis was performed to identify independent predictor or causes of mortality by shock among pediatric patients (Table 6) and our result has revealed that delayed presentation by more than one week with an adjusted odd ratio (AOR) of 16.9 (95% CI: 2.3–123), type of shock other than hypovolemic shock with AOR of 8.3 (95% CI: 1.4–48), stage of shock with AOR of 27.8 (95% CI: 2.8–157), requirement of mechanical ventilation with AOR of 11 (95% CI: 2.6–53) and length of hospital stay less than three days with AOR of 9 (95% CI: 1.7–48) were found to be predictors of mortality by shock.

Discussion

In this study, we have assessed and confirmed the magnitude and factors associated with mortality of shock in children who visited Ayder Comprehensive Specialized Hospital. The prevalence of shock was 2.2%, which is comparable to similar studies done on the prevalence of shock among all hospitalized infants, children and adult reported in developed countries which was 2%.[1] However, this prevalence is lower compared with reports from another studies; 4.3%;[6] 9%,[7] and 2.8%.[8] In this study, the most common type of shock was identified as hypovolemic shock (53%) secondary to dehydration following vomiting and diarrhea, followed by septic shock (34.8%), and mixed (6.8%). Only one patient with obstructive shock with massive pericardial and plural fluid was found. Our finding is supported by previous studies conducted elsewhere who have shown that the most common type of shock was hypovolemic shock which accounted for 45.9% cases followed by septic type (34.6%), cardiogenic type (17.3%) and distributed type (2%).[8] However, a previous study showed that, the prevalence based on type of shock was as follows, septic 28%, distributive 22%, septic (cardiogenic) type 17.5%, hypovolemic 15.7%, and cardiogenic shock 12%.[7] In our study there were 93 (70.5%) with decompensated stage of shock, which is higher than the previous studies done which were 40%,[8] and 57.9%.[7]

Table 6 Assessing Predictors of Mortality Among Pediatric Shock Patient Using Binary Logistic Regression

Variables		Outcome of Shock		Odds Ratio			
		Improved	Died	COR (95% CI)	P - value	AOR (95% CI)	P –value
Duration of illness	1–2 days	26 (76.5%)	8(23.5%)	1		1	
	8 and above	27 (37.5%)	45 (62.5%)	5.4 (2.213.6)	<0.001	16.9 (2.3–123)	0.005
Duration of hospital stay	1–3 days	9(24.3%)	28 (75.7%)	5(2–13)	<0.001	9(1.7–48)	0.008
	Above 10 days	37 (62.7%)	22 (37.3%)	1		1	
Underlying illness	Yes	18 (42.9%)	24 (57.1%)	2(0.9–4)	0.067	0.59 (0.15–2.4)	0.467
	No	54 (60%)	36 (40%)	1		1	
Type of shock	Hypovolemic	55 (78.6%)	15 (21%)	1		1	
	Others	17 (27.4%)	45 (72.6%)	9.7 (4.4–21.5)	<0.001	8.3 (1.4–48)	0.02
Stage of shock	Compensated	37 (94.9%)	2(5.1%)	1		1	
	Decompensated	35 (37.6%)	58 (62.4%)	30.6 (6.9–135)	<0.001	27.8 (2.8–157)	0.003
MODS	Yes	9(20.5%)	35 (79.5%)	9.8 (4.2–23.3)	<0.001	3(0.77–12)	0.110
	No	63 (71.6%)	25 (28.4%)	1		1	
Inotrope administration	Yes	17 (28.3%)	43 (71.1%)	8.2 (3.7–17.8)	<0.001	0.00 (00)	1
	No	55 (76.4%)	17 (23.6%)	1		1	
Steroid	Yes	14 (28%)	36 (72%)	6.2 (2.8–13)	<0.001	1(0.11–8)	0.994
	No	58 (70.7%)	24 (29.3.0%)	1		1	
Invasive ventilation provided	Yes	9(19.1%)	38 (80.9%)	12 (5–29)	<0.001	11 (2.6–53)	0.001
	No	63 (74.1%)	22 (25.9%)	1		1	

Abbreviation: MODS, multi-organ dysfunction syndrome.

In this study those with mixed, cardiogenic and obstructive type of shock were all in decompensated stage of shock. The decompensation in hypovolemic and septic was 55.7% (39/70) and 84.7% (39/46), respectively. This could be because 66.7% (88) of children included in the study were referrals from another hospital, with associated delay in recognition or transfer to our hospital for better management. Of the 42 (31.8%) children who received liver function test, 19 (45.2%) have elevated values, and 13 (68.4%) of them were from the decompensated category. Creatinine was done for 94 (71.2%) and was elevated in more than half 54 (57.4%) of the patients, and of those with elevated creatinine, 38 (70.4%) were in decompensated stage. Liver function tests were done only in less than one-third (31.8%) of participants and renal function tests were done in only 71.2% participants due to difficulty in obtaining blood samples and severity of shock at presentation, and shorter duration of stay in the hospital. The time gap for the initiation of fluid after the patient was diagnosed with shock was determined and the mean duration was 24 ± 10 minutes. This delay is significant for a shock patient which can contribute to morbidity and mortality, and it may be due to difficulty of accessing intravenous line, patient overload, or delay in detecting shock. The frequency of re-evaluation particularly vital signs was determined, and the median was 1 hr. Patients were followed after admission and the median length of hospital stay was 7 days. Furthermore, this study showed a statistically significant association between presence of underlying illness or chronic medical illness and mortality rate (P<0.001). In conclusion, the prevalence of shock was comparable with other studies, but the mortality rate was high where nearly half of the patients had died. Length of illness, type of shock, stage of shock, requirement of mechanical ventilation and duration of hospital stay were significantly associated with bad outcome of shock.

Data Sharing Statement

All data related to this study are contained in this paper.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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