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ORIGINAL RESEARCH

Descriptive characteristics of pediatric patients after cardiopulmonary resuscitation

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Abstract

Background: In the pediatrics, post-cardiac arrest syndrome represents a major cause of admission to intensive care. This study aimed to evaluate the demographics, clinical interventions, and outcomes of patients with post-cardiac arrest syndrome managed with evidence-based treatments in pediatric intensive care unit (PICU). **Methods**: A retrospective, single-center study, included patients hospitalized in PICU after cardiopulmonary resuscitation (CPR; out-of-hospital or in-hospital arrest) between ages of 1 month to less than 18 years from 01 January to 31 December, 2021. The following factors were assessed: demographics, cause of cardiac arrest, length of hospital stay, Pediatric Risk of Mortality Score III (PRISM III), detailed neurological examination, hospital status, arrest site duration, daytime and weekday or weekend status, CPR process, examinations and treatments. **Results**: The study included 60 patients (mean age: 51.21 ± 56.29 months). The mean PRISM III score was 66.01 ± 29.22, with an average hospital stay of 25.55 ± 41.96 days and a survival rate of 35%. Cardiac arrest characteristics showed asystole as the initial rhythm in 58.3% of patients. Arrests occurred predominantly during the day (81.7%) and on weekdays (70.0%). Most events were out-of-hospital (81.7%), with only 18.3% occurring in-hospital. Discharge status was significantly associated with PRISM III score ($p < 0.001$, odds ratio (OR) = 1.05), light reflex presence ($p = 0.001$, OR = 13.66), abnormal chest X-ray ($p = 0.016$, OR = 6.18), multiple organ failure ($p = 0.003$, OR = 8.43), respiratory failure ($p = 0.021$, OR = 7.67), and tracheostomy requirement ($p = 0.040$, OR = 19.00). **Conclusions**: Higher PRISM III scores, absent light reflex, abnormal chest X-ray, multiple organ failure, respiratory failure, and tracheostomy were significantly associated with poor discharge outcomes. Despite evidence-based care, the 35% survival rate underscores the need for improved post-resuscitation strategies in pediatric cardiac arrest cases.

Keywords

Cardiopulmonary resuscitation; Pediatric; Intensive care; Mortality; Neurological sequelae

1. Introduction

Cardiopulmonary resuscitation (CPR) is a life-saving procedure used in the most critical and dramatic emergencies to restore the hemodynamics of the vital organs (*i.e.*, heart, lungs and brain) in patients with cardiac arrest. Rescue interventions are performed using either basic life support (without tools or drugs) and advanced life support (using medical devices and drugs) methods [1]. Pediatric cardiac arrest represents a relatively uncommon yet severe manifestation, particularly among infants and young children. In contrast to adult patients, for whom primary cardiac dysrhythmia constitutes the most frequent etiological factor in cardiac arrest, pediatric patients experience cardiovascular collapse with high frequency after initial respiratory arrest. The outcomes for pediatric cardiac arrest, whether occurring in a hospital setting or elsewhere, remain poor compared with adults, which is due to a relatively low proportion of survivors of cardiac arrest compared with the adult population [2, 3].

A study of pediatric out-of-hospital cardiac arrests (OHCA) in Denmark, revealed a median incidence of OHCA of 4.2 per 100,000 persons at risk. In 48.6% of cases, a presumed reversible cause was identified and the 30-day survival was 40%. Another study in Australia examined the epidemiology of pediatric OHCA and reported that 42.5% of the deaths were due to cardiac causes, with a survival rate of 11.3%. Given that OHCA in children affects 3.7–4.2 per 100,000 children per year in Europe and Australia, and that survival in this population is low, it is important to consider whether racial, ethnic and sociodemographic disparities exist in the OHCA population. To date, no study has synthesized the existing literature to examine the overall disparities in OHCA risk, processes and outcomes [4–6]. Fukuda *et al*. [7] analyzed data from 2012–2017 using the government-initiated registry in Japan and reported a 1-month survival rate of 17%. Additionally, cardiac arrest in children is a rare and unexpected event that frequently results in death or poor functional prognosis for survivors [8–10]. The low death rate from in-hospital cardiac arrest (IHCA) might be due to early recognition and treatment, more effective use of evidence-based resuscitation guidelines, or the establishment of resuscitation teams in hospitals. The necessity for studies of this nature is twofold: first, to characterise both OHCA and IHCA, and second, to determine the influencing factors.

Return of spontaneous circulation (ROSC) is necessary to ensure survival and to prevent the development of neurological sequelae. The rate of ROSC is determined by factors, including age, underlying disease, time to CPR, effective and current CPR implementation, and availability of specialist resuscitation teams [11–13]. Patients resuscitated after CPR should be treated in the pediatric intensive care unit (PICU) by pediatric advanced life support (PALS) recommendations for post-resuscitation care [14].

The aim of our study was to investigate the underlying causes, demographic characteristics, and medical and clinical interventions that affect the course of patients with post-cardiac arrest syndrome admitted to the PICU. Subsequently, an investigation was undertaken to ascertain, considering the influence of environmental factors, differences in OHCA or IHCA, and laboratory and clinical data on clinical discharge and outcomes.

2. Materials and methods

This retrospective, single-center study included patients admitted to the PICU following CPR, due to OHCA or IHCA. Between 01 January and 31 December 2021, all patients with OHCA and IHCA aged between 1 month and 18 years (aged 18 not included) were included. The study encompasses patients who achieved ROSC prior to PICU admission and were subsequently treated by the same physician team. During the study period, the pediatric intensive care team comprised a pediatric intensive care specialist and six pediatricians during daytime hours. During weekends and off-duty hours, two of the 15 pediatricians were on duty in the PICU. The on-duty doctors were always two members of this team of 15. The pediatric intensive care specialist was always consulted on patient management and with each new patient admission. Patients admitted to the PICU for reasons unrelated to CPR on the specified dates and those who underwent CPR during their treatment in the PICU were excluded from the study (Fig. 1).

The study hospital is an 800-bed training and research facility and a third-level public hospital, and has a 52-bed PICU with an average annual admission rate of 1400 patients. Given the heterogeneous nature of the population served by the hospital and the high volume of patients treated annually, we decided that a single year's worth of data would be analyzed. In Türkiye, the hospital where the study was conducted is the largest hospital in the city and is the center with the largest PICU. It should be noted that the hospital does not have a primary trauma and cardiovascular surgery center. However, it is the only center in the city with a PICU, pediatric nephrology, and cardiology specialist. Consequently, it is the primary facility to which patients are transferred from the field in cases of OHCA. Based on Turkish Statistical Institute (06 February 2024) data; the city's population in 2024 was approximately 2.2 million, with an annual growth rate of 2%.

To conduct a retrospective analysis, the data pertaining to the patients was sourced from the electronic records and patient files of the hospital. All patient data included the first examinations taken at the time of admission to the PICU. For outcomes and sequelae examination, we used in-PICU analysis. The demographic characteristics, etiologies, other medical histories, comorbidities, length of stay in PICU, Glasgow Coma Scale (GCS), Pediatric Risk of Mortality Score III (PRISM III), pupillary reactivities, arrest rhythm, arrest place and duration, day (10:00 PM)–night (10:00 AM) status, CPR duration, medications and procedures, examinations and treatments (*e.g.*, dialysis, cerebral antiedema treatment with hypertonic saline and mannitol, radiological imaging studies, organ failures, *etc.*) and mortality and morbidity or sequelae were evaluated from the patient electronic files. The procedures, medications, and tests performed in the CPR process were investigated for the effect on outcomes. Additionally, after the ROSC period in PICU management was evaluated for its effects on discharge status, mortality and sequelae development.

In 2008, the term post-cardiac arrest syndrome (PCAS) was formally defined for the international resuscitation community in a scientific statement published by the International Liaison Committee on Resuscitation. This statement addressed chiefly adult PCAS, highlighting the pathophysiology and the need for continued multisystem support after ROSC. The statement delineated four components of PCAS that have since been widely accepted as key components of the syndrome: post-cardiac arrest brain injury, post-cardiac arrest myocardial dysfunction, systemic ischemia or reperfusion response, and persistent precipitating pathophysiology. It is imperative to note that the management of PCAS requires multisystem support during each of the phases [13].

After the cardiac arrest treatment period, it is suggested that the core body temperature should be 37.5 °C or lower. Drawing upon the extant evidence and international resuscitation guidelines for comatose infants and children following cardiac arrest, it is reasonable to propose the use of one of two temperature targets: normothermia or hypothermia. Normothermia (36–37.5 °C) is recommended for 3–5 days. Therapeutic hypothermia (targeted range 32–34 °C) is recommended for 2 days followed by 3 days of normothermia. Patients receiving therapeutic hypothermia are at increased risk of shivering, coagulopathy with bleeding, hyponatremia, arrhythmias, myocardial dysfunction and cold diuresis that can cause hyponatremia and electrolyte imbalance [3, 13]. Therefore, given its reduced side effect profile compared with therapeutic hypothermia, the recommendation is for normothermia. In our study, therapeutic hypothermia was not preferred due to its clinical disadvantages.

In our retrospectively designed study, our data were standardized as hospital status (IHCA and OHCA), patient analyses, pre-event, cardiac arrest, and after ROSC process and outcome, considering Utstein-style reporting templates [15].

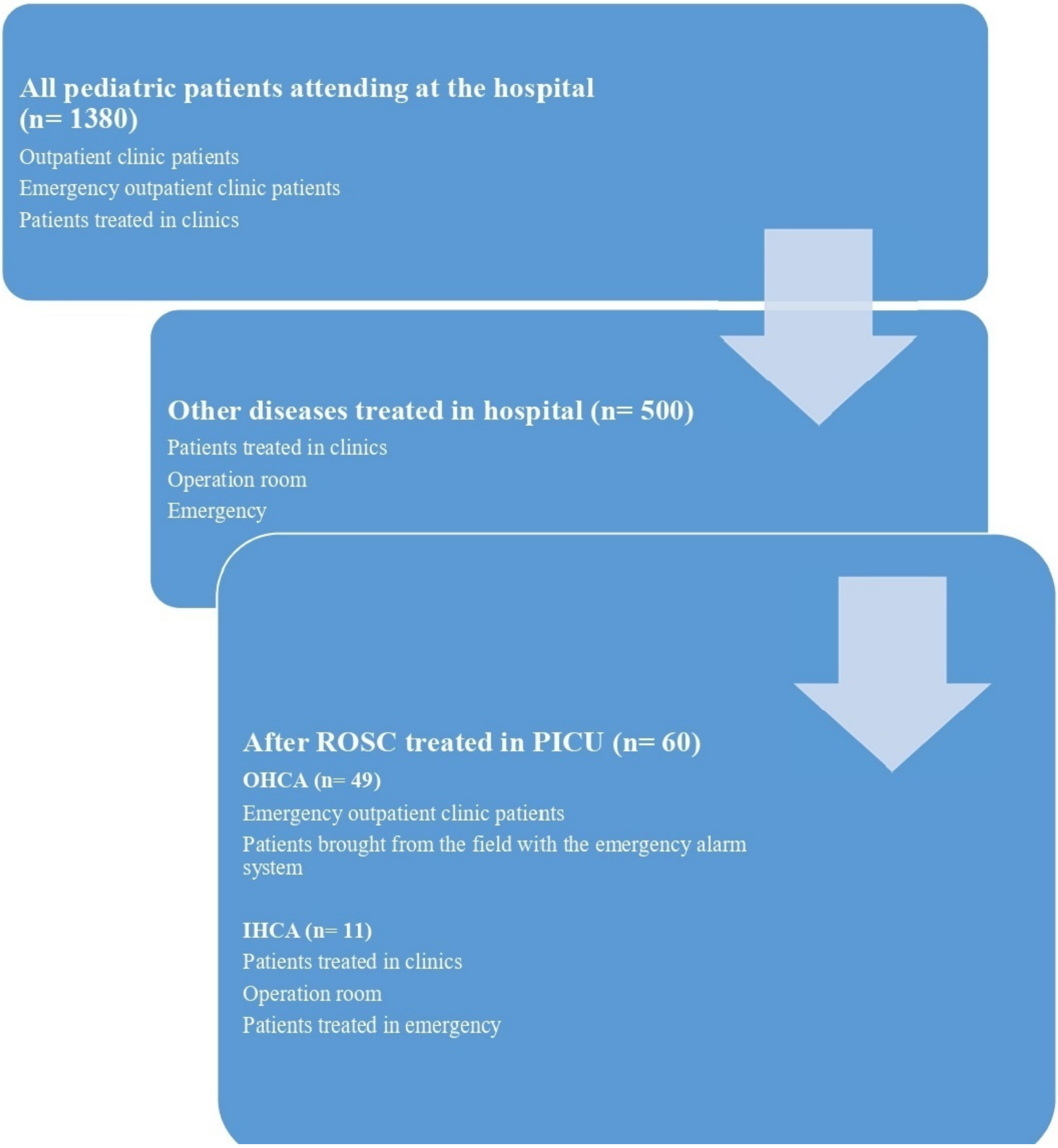

FIGURE 1. Methodology of patient selection and inclusion. ROSC: return of spontaneous circulation; PICU: pediatric intensive care unit; OHCA: out-of-hospital cardiac arrests; IHCA: in-hospital cardiac arrest.

In determining the main diagnosis, if it was an IHCA, the first hospitalization diagnosis was accepted as the main diagnosis. For OHCAs, anamnesis information obtained from the family or the witnesses of the event was taken as the basis of the diagnosis.

In Türkiye, there is a code blue application for in-hospital emergencies where our study was conducted. A team is available at all times during the week for pediatrics. In addition, the ministry has an emergency referral chain system that works in coordination with the emergency ambulance system in the case of OHCA and quickly transfers life-risk cases to the most comprehensive hospital. However, based on the socioeconomic development study in 2017, the relative rankings and levels of the provinces were determined. By establishing a balance between regional capacity and potential and individual welfare, the development levels of the provinces were established as six levels based on the selected variables. The study city is in the sixth and last level, indicating that it is economically inadequate. In addition, due to its high fertility rate (19.9% in 2019–2020 years), the city's contribution to the population and social migration throughout the country is gradually increasing [16].

While determining the cause of cardiac arrest, the initial arrest rhythm and clinical symptoms during the development of the arrest were taken as the basis. If the patient exhibited a cardiac rhythm disorder other than normal sinus rhythm during the initial monitoring, the event was classified as cardiac arrest. The period from the moment no pulse was detected in each patient was considered as arrest, and the rhythm seen at the first monitorization was considered the first rhythm. Respiratory arrest was defined as the absence of respiratory effort for more than 20 seconds and the presence of mucosal cyanosis. In the definition of organ failures, normal expected laboratory and clinical follow-up values according to age were taken as a basis. In the post-resuscitation ICU, management was performed according to PALS guideline recommendations [14]. This guideline included maintaining normothermia, normoglycemia, normocarbia, providing appropriate mechanical ventilation, monitoring for convulsions, and monitoring GCS and brainstem reflexes. Organ failures that continued after the start of reperfusion after the first 24 hours were accepted. The Pediatric Organ Dysfunction Information Update Mandate (PODIUM) criteria, a contemporary scoring system devised for use in patients who are critically ill, were used to ascertain the extent of organ failure in the participating patients [17]. Furthermore, the progression of neurological sequelae was acknowledged as the ultimate neurological condition observed in patients who survived post-CPR, as determined by the Cerebral Performance Category (CPC) score for sequelae. Central nervous system (CNS)-related sequelae were determined in accordance with the CPC score, and these patients were examined as part of the surviving patient cohort. Before discharge, regression or loss of ability in clinical examination or radiological findings compared with the pre-arrest period were defined as sequelae. Some patients were deceased or exhibited unstable hemodynamics, precluding the performance of certain applications in the examination and treatment management. The status of patients who survived the study was evaluated at the time of their discharge from the PICU, and their data were incorporated into the final analysis. Considering the stated considerations, it is evident that the data presented in the tables do not encompass the entirety of patients included in the study.

The statistical analysis was performed with SPSS for Windows 22.0 (IBM SPSS 26, SPSS Inc., Chicago, IL, USA). The normal distribution and conformity of the variables were analyzed with the Kolmogorov-Smirnov test. The descriptives were reported as mean and standard deviation (SD) for continuous data, and as percentage and frequency for categorical variables belonging to sociodemographic and clinical information. Pearson's chi-squared test or Fisher's exact test were used to compare categorical variables. The Mann-Whitney U test compared the age and length of stay between the time in and out of the hospital with cardiac arrest. To ascertain the factors affecting the mortality status of the patients included in the study (IHCA and OHCA), a logistic regression analysis was performed. A p-value less than 0.05 was considered statistically significant.

3. Results

The study included only patients whose primary reason for admission to the PICU was post-resuscitative care following ROSC, and these constituted 60 (10%) of the total number of admissions to the PICU. Of these 60 patients (20 (33.3%) female and 40 (66.7%) male) who were hospitalized following ROSC, the mean age was 51.21 $\pm$ 56.29 months. The mean PRISM III score of the patients at the time of hospitalization was 66.01 $\pm$ 29.22. The mortality rate among the study patients was 65% and the mean hospital stay was 25.55 $\pm$ 41.96 days. Analysis of the primary reasons for hospitalization in patients who experienced IHCA revealed that 49 patients (81.7%) were admitted due to respiratory conditions, including pneumonia, bronchiolitis, aspiration and drowning. 25 (41.7%) patients experienced cardiac arrest due to respiratory failure. Additionally, 34 (56.7%) patients had no prior history of chronic diseases or comorbidities and were previously considered healthy before hospitalization. The demographic and prognostic data are shown in Table 1.

During the initial assessment upon admission to the PICU, 56 (93.3%) patients had a GCS score $<$8, 8.3% exhibited anisocoria and 41.7% showed an absence of the light reflex. In 35 (58.3%) of arrests, the initial rhythm was asystole; CPR duration $<$15 min in 33 (55%), $>$15 min in 18 (30%) and $>$30 min in 9 (15%); arrest time during the day was in 49 (81.7%) patients and 11 (18.3%) at night; on weekdays in 42 (70%) patients and weekends in 18 (30%); and 49 (81.7%) patients had OHCA and 11 (18.3%) had IHCA. CPR was administered in the pediatric emergency department in approximately half of the cases. The mean number of adrenaline pushes during CPR was 2.42 $\pm$ 1.50 and the mean number of bicarbonate administration dose was 0.89 $\pm$ 0.60. There was only one (1.7%) patient who underwent electrical shock. At the time of arrest, one (1.7%) patient was intubated and 19 (31.7%) patients had an intravenous (IV) line. The characteristics of the CPR applied to the patients and the clinical findings at the first presentation of the patients are given in Table 2.

Considering the PICU follow-up period, the findings of first chest X-ray, use of a central venous catheter (CVC), and the development of organ failure and respective dialysis required (continuous venovenous hemodiafiltration (CVVHDF) and peritoneal dialysis (PD)) were shown in Table 3. No brain imaging was performed in 25 (41.7%) patients. The types of brain imaging and use of antiedema and antiepileptic treatments were also shown. Regarding the hospitalization process of the surviving patients, the first extubation was attempted at 10.35 $\pm$ 9.35 days. Tracheostomy was performed in four (16.7%) patients but was unsuccessful. In addition, seven (30.4%) patients developed CNS sequelae based on the CPC score (Table 3).

The PRISM III score ($p < 0.001$, odds ratio (OR) = 1.05), the presence of light reflex ($p = 0.001$, OR = 13.66), chest X-ray findings of infiltration ($p = 0.016$, OR = 6.18), multiple organ failure ($p = 0.003$, OR = 8.43), respiratory failure ($p = 0.021$, OR = 7.67), and the need for tracheostomy ($p = 0.040$, OR = 19.00) were significantly associated with mortality. On the contrary, other clinical signs and symptoms, laboratories, and interventions had no statistical association with the mortality. The conditions associated with the mortality of patients are shown in Table 4.

Descriptives, clinical data and outcomes were examined and compared with outcomes and mortality at IHCA and OHCA, based on Utstein-style reporting templates and CPC scores (Table 5). There were statistically significant differences with age ($p = 0.002$) and CPR location ($p < 0.001$) between IHCA and OHCA.

TABLE 1. Patient demographics and prognostic data.

Specifications	Mean ± SD n = 60 (%)	Median (min–max)
Age (mon)	51.21 ± 56.29	26.0 (1–192)
Length of stay (d)	25.55 ± 41.96	9.5 (1–198)
PRISM III	66.01 ± 29.22	66.0 (10–100)
Sex		
Girl	20 (33.3%)	
Boy	40 (66.7%)	
Discharge status		
Discharged home	4 (6.7%)	
Referral to the pediatric ward	17 (28.3%)	
Death	39 (65.0%)	
Main diagnosis		
Respiratory failure	25 (41.7%)	
Drowning	11 (18.3%)	
Electrical shock	4 (6.7%)	
Status epilepticus	3 (5.0%)	
Sepsis	3 (5.0%)	
Acute gastroenteritis	3 (5.0%)	
Trauma	2 (3.3%)	
Idiopathic	2 (3.3%)	
Postoperative	1 (1.7%)	
Hanging	1 (1.7%)	
Insect bite	1 (1.7%)	
Fall from height	1 (1.7%)	
Anaphylaxis	1 (1.7%)	
Intoxication	1 (1.7%)	
Congenital metabolic disease	1 (1.7%)	
Cause of cardiac arrest		
Respiratory	49 (81.7%)	
Cardiac	11 (18.3%)	
Comorbidity		
No	34 (56.7%)	
Yes	26 (43.3%)	

PRISM III: pediatric risk of mortality score III; SD: standard deviation; min: minimum; max: maximum.

TABLE 2. CPR interventions and clinical findings at first admission.

Clinical examination and procedures	Mean ± SD n (%)
GCS	
<8	56 (93.3%)
>8	4 (6.7%)
Pupillary	
Anisochoric	5 (8.3%)
Isochoric	55 (91.7%)
Pupillary light reflexes	
Yes	35 (58.3%)
No	25 (41.7%)

TABLE 2. Continued.

Clinical examination and procedures	Mean ± SD n (%)
Arrest rhythm	
Asystole	35 (58.3%)
Bradycardia	24 (40.0%)
Tachycardia	1 (1.7%)
CPR duration (min)	
<15	33 (55.0%)
15–30	18 (30.0%)
>30	9 (15.0%)
Adrenaline doses (0.01 mg/kg/dose)	2.42 ± 1.50
The time-to-first dose of adrenaline (min)	5.05 ± 1.02
Bicarbonate doses (1 mEq/kg/dose)	0.89 ± 0.60
Arrest time	
Night	11 (18.3%)
Day	49 (81.7%)
Arrest day	
Weekday	42 (70.0%)
Weekend	18 (30.0%)
CPR intervention site	
Emergency	30 (50.0%)
Clinics	7 (11.7%)
Another health center	9 (15.0%)
Operation room	1 (1.7%)
Outside	13 (21.7%)
Arrest place	
In-hospital	11 (18.3%)
Out-of-hospital	49 (81.7%)
Intubation status at the beginning of arrest time	
Yes	1 (1.7%)
No	59 (98.3%)
Intravenous line presence at the beginning of arrest time	
Yes	19 (31.7%)
No	41 (68.3%)
Presence of intubation	
Yes	58 (96.7%)
No	2 (3.3%)
Defibrillation	
Yes	1 (1.7%)
No	59 (98.3%)

CPR: cardiopulmonary resuscitation; GCS: Glasgow coma scale; SD: standard deviation.

TABLE 3. Clinical findings, interventions and outcomes at post-resuscitation care.

Post-arrest evaluations	Mean ± SD n (%)
Pathological chest X-ray	
No	20 (33.3%)
Yes	40 (66.6%)
Central venous catheter	
No	15 (25.0%)
Yes	45 (75.0%)
Organ failure	
No	17 (28.3%)
Yes	43 (71.7%)
Dialysis	
No	56 (93.3%)
Yes	4 (6.7%)
Antiedema treatment use	
No	24 (40.0%)
Yes	36 (60.0%)
Antiepileptic	
No	40 (66.7%)
Yes	20 (33.3%)
Extubation time (d)	10.35 ± 9.35
Tracheostomy	
No	20 (83.3%)
Yes	4 (16.7%)
CNS sequelae	
No	16 (69.6%)
Yes	7 (30.4%)
CNS imaging	
No	25 (41.7%)
Yes	45 (58.3%)

CNS: central nervous system; SD: standard deviation.

TABLE 4. Factors influencing mortality.

Variables	B	SE	Wald	*p* value	Odds ratio	95% CI for odds ratio	
						Lower	Upper
Age	−0.01	0.01	3.55	0.060	0.99	0.98	1.00
Gender	0.00	0.57	0.00	1.000	1.00	0.32	3.08
Admission season	–	–	1.00	0.801	–	–	–
Summer *vs.* Spring	−0.46	0.76	0.37	0.543	0.63	0.14	2.81
Summer *vs.* Autumn	−0.46	0.76	0.37	0.543	0.63	0.14	2.81
Summer *vs.* Winter	0.16	0.72	0.05	0.821	1.18	0.28	4.88
Comorbidities	0.33	0.55	0.36	0.549	1.39	0.47	4.11
PRISM III	−0.05	0.01	14.48	<0.001	1.05	1.03	1.08
GCS	−1.85	1.19	2.41	0.121	0.16	0.02	1.63
Pupillary isochoric	−20.72	17,974.84	0.00	0.999	0.00	0.00	0.00
Light reflex positivity	−2.61	0.81	10.38	0.001	13.66	2.78	67.00

TABLE 4. Continued.

Variables	B	SE	Wald	*p* value	Odds ratio	95% CI for odds ratio	
						Lower	Upper
Cause of cardiac arrest	1.05	0.83	1.57	0.210	2.85	0.55	14.64
Initial arrest rhythm	–	–	0.01	0.997	–	–	–
Asystole *vs.* Bradycardia	−21.85	40,192.10	0.00	1.000	0.00	0.00	–
Asystole *vs.* ST	−21.90	40,192.10	0.00	1.000	0.00	0.00	–
Duration of arrest	–	–	2.01	0.366	–	–	–
Adrenalin	0.24	0.42	0.31	0.575	1.27	0.55	2.91
Bicarbonate	−20.77	13,217.15	0.00	0.999	0.00	0.00	–
Arrest time	−1.05	0.83	1.57	0.210	0.35	0.07	1.80
Arrest day	−0.58	0.58	1.00	0.318	0.56	0.18	1.75
CPR location	–	–	1.80	0.773	–	–	–
Outside *vs.* ED	0.94	0.75	1.54	0.215	2.55	0.58	11.18
Outside *vs.* Clinics	0.29	1.06	0.07	0.787	1.33	0.17	10.74
Outside *vs.* Other hospital	0.51	0.97	0.28	0.597	1.67	0.25	11.07
Outside *vs.* Operation room	−20.00	40,192.97	0.00	1.000	0.00	0.00	–
IHCA *vs.* OHCA	0.44	0.74	0.35	0.554	1.55	0.36	6.59
Intubation status	20.61	40,192.99	0.00	1.000	0.00	0.00	–
Intravenous line	−0.45	0.57	0.61	0.434	0.64	0.21	1.96
Defibrillation	20.61	40,192.99	0.00	1.000	0.00	0.00	–
IMV *vs.* NIV	0.64	1.44	0.20	0.656	1.90	0.11	32.01
Anormal chest X-ray	–	–	7.11	0.068	–	–	–
Normal *vs.* Infiltration	1.82	0.75	5.86	0.016	6.18	1.41	27.02
Normal *vs.* PE	0.44	0.90	0.23	0.630	1.55	0.26	9.08
Normal *vs.* Ptx	22.94	23,205.42	0.00	0.999	0.00	0.00	–
Catheter requirement	–	–	2.05	0.359	–	–	–
No *vs.* Jugular	−0.52	0.62	0.70	0.402	0.59	0.18	2.00
No *vs.* Femoral	−1.66	1.20	1.92	0.166	0.19	0.02	1.99
Organ failure	–	–	10.59	0.060	–	–	–
Multiple *vs.* None	2.13	0.71	9.07	0.003	8.43	2.11	33.77
Multiple *vs.* Renal	−19.68	40,192.97	0.00	1.000	0.00	0.00	–
Multiple *vs.* Liver	−19.68	17,974.84	0.00	0.999	0.00	0.00	–
Multiple *vs.* Lung	2.04	0.88	5.34	0.021	7.67	1.36	43.13
Multiple *vs.* Cardiac	−19.68	40,192.97	0.00	1.000	0.00	0.00	–
Dialysis	–	–	0.00	1.000	–	–	–
Antiedema	–	–	1.62	0.445	–	–	–
Antiepileptic	−1.08	0.64	2.83	0.092	0.34	0.10	1.20
Extubation time	0.00	0.07	0.00	0.944	1.00	0.88	1.15
Tracheostomy	2.94	1.43	4.22	0.040	19.00	1.15	314.97

Logistic regression analysis used and $p < 0.05$ considered significant.
B: beta; CI: confidence interval; CPR: cardiopulmonary resuscitation; ED: emergency department; GCS: Glasgow coma score; IHCA: in-hospital cardiac arrest; IMV: invasive mechanical ventilation; NIV: non-invasive mechanical ventilation; OHCA: out-of-hospital cardiac arrest; PE: pulmonary edema; PRISM III: pediatric risk of mortality score III; Ptx: pneumothorax; SE: standard error; ST: sinus tachycardia.

TABLE 5. Descriptives, clinical aspects and outcomes based on Utstein-style reporting templates for IHCA and OHCA.

Descriptives	IHCA	OHCA	*p* value
	Min–Max (IQR) n (%)	Min–Max (IQR) n (%)	
Age (mon)	1–192 (35)	1–192 (75)	0.002
Length of hospital stay (d)	1–98 (26)	1–198 (37)	0.263
Sex			
Boy	6 (54.5%)	34 (69.4%)	0.345
Girl	5 (30.6%)	15 (45.5%)	
Primary diseases			
Medical	10 (90.9%)	46 (93.9%)	0.566
Surgical	1 (9.1%)	3 (6.1%)	
Arrest time			
Night	4 (36.4%)	7 (14.3%)	0.087
Day	7 (63.6%)	42 (85.7%)	
CPR location			
Emergency	2 (18.2%)	28 (57.1%)	<0.001
Clinics	7 (63.6%)	0 (0.0%)	
Another hospital	0 (0.0%)	9 (18.4%)	
Operation room	1 (9.1%)	0 (0.0%)	
Outside	1 (9.1%)	12 (24.5%)	
Cause of arrest			
Cardiac	4 (36.4%)	7 (14.3%)	0.087
Respiratory	7 (63.6%)	42 (85.7%)	
First arrest rhythm			
Asystole	6 (54.5%)	29 (59.2%)	0.836
Bradycardia	5 (45.5%)	19 (38.8%)	
Sinus tachycardia	0 (0.0%)	1 (2.0%)	
Arrest duration			
<15 min	9 (81.8%)	24 (49.0%)	0.110
15–30 min	2 (18.2%)	16 (32.7%)	
>30 min	0 (0.0%)	9 (18.4%)	
Defibrillation			
No	11 (100%)	48 (98%)	0.633
Yes	0 (0.0%)	1 (2.0%)	
Discharge status			
Alive	3 (27.3%)	18 (36.7%)	0.693
Deceased	8 (72.7%)	31 (63.3%)	
CNS sequelae			
No	3 (75.0%)	13 (68.4%)	0.795
Yes	1 (25.0%)	6 (31.6%)	

CPR: cardiopulmonary resuscitation; CNS: central nervous system; IHCA: in-hospital cardiac arrest; IQR: interquartile range; OHCA: out-of-hospital arrest; Min: minimum; Max: maximum. A p value < 0.05 was accepted as significant.

4. Discussion

This single-center retrospective study, which encompasses a diverse patient cohort, was conducted in a city with significant socioeconomical weakness. It was to be expected that patients who had received post-resuscitative care from the same PICU specialist, those with OHCA would have poorer outcomes than those who had IHCA. The outcomes for patients with OHCA, patients whose initial treatments were unsuccessful or who required prolonged resuscitation, and patients whose CNS examinations were pathological at the time of admission to the PICU were also found to be poor. To obtain more precise data, it would be beneficial to conduct multi-center studies that encompass the same patient groups. There are local and national programs for IHCA; however, there is no such national program for the OHCA group. Consequently, there is a necessity for the establishment of rapid alarm systems to facilitate early diagnosis and intervention. Furthermore, community training should be provided and automatic external defibrillators should be made widely available.

Cardiopulmonary arrest due to a primary cardiac cause is rare in children and usually develops slowly as a result of respiratory failure [13, 14]. Our hospital was the only one, in our city, having a PICU specialist during the study period with an average admission of 1400 patients per year of which 60 (10%) were age 51.21 $\pm$ 56.29 months and hospitalized after ROSC. In the USA, 8.04 per 100,000 pediatric patients are reported to have OHCA annually, which is equivalent to approximately more than 5000 cases per year. It is estimated that of 1800 children, approximately 36% achieve ROSC and reach post-resuscitation care [18]. In a study conducted in Australia, the epidemiology of OHCA and the factors associated with ROSC at the time of hospital arrival were investigated. The study reported that one in four of the 1612 patients had ROSC at the time of hospital arrival [19, 20]. The influence of both environmental and medical factors at the time of OHCA and IHCA on ROSC, neurological outcome, and mortality is well documented. In our study, we also examined the analyses, comparisons and influencing factors of patients across both groups.

In various studies conducted in the USA from 2005–2013, the survival rate of all pediatric cardiac arrest patients was reported as 6.4–10.2% [21, 22]. Discharge without neurological sequelae has been reported with a rate of 77% in OHCA [19]. In a 2011 study in which the follow-up of multi-center pediatric cardiac arrests in PICU was examined, a 38% survival rate was reported [10]. In our study, we observed an average length of hospital stay of 25.55 $\pm$ 41.96 days, with a corresponding survival rate of 35%. The slightly lower mortality rate in the study of high-income countries is associated with early diagnosis and treatment, and advanced technological opportunities. As such, Moler *et al*. [10] reported mortality and sequelae rates in their multi-center study that are more similar to ours, which supports our hypothesis that the effectiveness of current guidelines are effectively implemented despite insufficient facilities.

The 2015 guidelines on pediatric ROSC published by the American Heart Association (AHA) are based on the growing recognition of the prevalence of PCAS. From this data, it was determined that all resuscitations from cardiac arrest result in predictable sequelae in the days to weeks following the arrest. These sequalae include, but are not limited to, neurological insult, myocardial dysfunction, systemic ischemia, and persistent precipitating pathophysiology [23]. Consequently, for recirculation with sufficient oxygenation, a considerable number of advanced centers initiated a new procedure with the assistance of experienced pediatric extracorporeal cardiopulmonary resuscitation (ECPR) teams, particularly in the case of patients with IHCA. In a study that presents 3 years' worth of ECPR experiences from Türkiye, 15 patients were examined. ROSC was achieved in 10 (66.6%) patients, with five of these patients surviving (50%). In total, five patients were discharged from the hospital [24]. This situation demonstrates that ECPR applications represent a life-saving option and an effective method of increasing survival rates in advanced centers.

A healthy child experiencing sudden cardiac arrest with an initial rhythm of ventricular fibrillation or ventricular tachycardia is most likely to have an underlying genetic or congenital cardiac abnormality as the cause. The intoxication drugs or toxins, viral myocarditis, among others can cause acquired arrhythmic cardiac arrest. These acquired factors can cause sudden arrhythmias. If there is weak brain oxygenation, CPR or defibrillation can rapidly and effectively protect neurological functions [12]. Although the treatment procedures in our study were conducted in accordance with PALS and AHA guidelines, seven patients (30.4%) developed CNS sequelae.

In the multi-center study that evaluated pediatric IHCA, the duration of CPR was $<$15 min and $>$30 min for 41.9% of patients, and 15–30 minutes for 16.1% of patients. In addition, the dose of adrenaline was $>$4 doses for 47.4% of patients, whereas in this study, the reason for hospitalization was mostly cardiovascular diseases and 20.3% of patients had at least one defibrillation attempt. Moreover, cardiac arrest occurred on a weekday for 82.7% of patients and during daytime for 68.7% of patients. Cardiac arrest is reported to have occurred in an ICU for 61.4% of patients [19]. Similarly, in our study, our rate of performing short-term CPR was higher. Moreover, the mean number of adrenaline pushes during CPR was 2.42 $\pm$ 1.50 and bicarbonate was 0.89 $\pm$ 0.60, whereas defibrillation was only one (1.7%). As stated in the pediatric CPR 2020 update, it is appropriate to administer early adrenaline and administer bicarbonate in arrests of unknown duration [19]. In accordance with these practices, effective CPR was performed on all patients included in our study. In a 12-year multi-center study in which patients younger than 18 years underwent at least 2 min of CPR in 354 hospitals using AHA's CPR guidelines, survival after night and weekend IHCA was investigated. In the study, 12,404 children were evaluated of which 8568 (69.07%) CPRs occurred during daytime or evening hours and 3836 (30.92%) CPRs were at night. In addition, 8586 (69.07%) CPRs occurred on weekdays and 3818 (30.78%) on weekends. When investigating the places where all these arrests took place, 78.4% were in the PICU, 6.6% in the emergency department, 3.6% in the pediatric clinics and 11.4% in other places [25]. In our study of children with ROSC admitted to a tertiary center PICU, 49 (81.7%) arrests occurred during the day and 11 (18.3%) at night; and 42 (70%) arrests were on weekdays compared with 18 (30%) on weekends. On the contrary, considering the place where cardiac arrest occurred, 49 (81.7%) of our patients had OHCA and 11 (18.3%) had IHCA.

In a multi-center study involving mostly inpatients still in the PICU, 91.5% had intravenous access and 64.7% were intubated at arrest time [26]. Only 1.7% of the patients had intubation at the time of arrest and 31.7% had an intravenous line. Among the patients included in our study, CVC was not required in 15 (25%) patients and organ failure was not observed in 17 (28.3%) patients. However, dialysis was required in four (6.7%) patients (one (1.7%) CVVHDF and three (5%) PD). It is the severity of clinical conditions that affects the mortality and organ failure status of our patients.

After achieving recirculation, in children, seizures can occur in 10–50% [27]. The type of arrest or clinical variables might not be predictive of seizures. Seizures resulting from hypoxic–ischemic brain injury are a key determinant of the rate of neurological sequelae development. The goal of post-arrest PICU management is to protect the brain from hypoxic injury (including cerebral edema) [28]. There is a need to understand the etiology or interaction between post-CPR hypoxic seizures for which prospective and multi-center studies are required. Nowadays, responding to traumatic brain injury using hypertonic and mannitol for brain antiedema is controversial. Neuroimaging with brain computerized tomography (CT) and magnetic resonance imaging (MRI) should be used for diagnostic or prognostic aims and to predict clinical outcomes. A study comparing the neurological outcomes of patients under the age of 18 years, as assessed by CPC after cardiac arrest and with quantitative diffusion-weighted magnetic resonance neuroimaging, revealed that quantitative diffusion thresholds on MRI within 7 days after cardiac arrest were associated with an unfavorable outcome in children. The age-independent apparent diffusion coefficient threshold showed high specificity in predicting an unfavorable outcome [29]. In our study, seven (30.4%) patients developed CNS sequelae compared with their previous neurological status (both CPC score and MRI or CT findings).

In a prospective study of IHCA, the rate of survival was lower for night arrest than for daytime and evening arrests in children, which is similar to adult survival rates [30]. Additionally, in another pediatric study, patients with OHCA reported a lower rate of survival if the cardiac arrest occurred at night, although their CPR time was the same [31]. Contrary to the data in the literature, the mortality rate in our study was 23.07% in those who underwent CPR at night and was 76.92% in the daytime. This difference in daytime arrests was associated with the fact that 81.7% had OHCA and possibly due to the difficulties associated with the rural and emergency transport systems of the region where our hospital is located. This data for arrest time (day versus night) significantly affected the discharge status of the patients. When survival is examined from the moment of hospitalization to discharge after arrest, the absence of light reflex and having organ failure negatively affected the discharge status of the patients. Similar to our study, in a small size population (57 patients) prospective cohort study with hypoxic ischemic injury, 44 cardiac arrest were evaluated. A GCS <5 and the absence of spontaneous respiratory and pupil light reflexes (after 24 hours) were significantly associated with negative outcomes [32]. Although the patients resuscitated after CPR were treated in the same PICU by PALS recommendations, our study included a heterogeneous population. For this reason, since it is a study that includes many different effects (*e.g.*, seizure conditions, weekend and night hours or out-of-hospital arrests), studies with much larger populations are needed to reach clearer conclusions. Likewise, the treatment to prevent neurological sequelae (antiedema or antiepileptic) and radiological imaging applied were not significantly affected.

When examining the parameters affecting pre-arrest, arrest, and post-arrest period in patients with spontaneous circulation after CPR; the PRISM III score ($p < 0.001$, OR = 1.05), the presence of light reflex ($p = 0.001$, OR = 13.66), chest X-ray findings of infiltration ($p = 0.016$, OR = 6.18), multiple organ failure ($p = 0.003$, OR = 8.43), respiratory failure ($p = 0.021$, OR = 7.67), and the need for tracheostomy ($p = 0.040$, OR = 19.00) significantly affected the discharge status of the patients. In our study, prognosis was statistically affected in patients with high PRISM III scores and whose CNS sequelae developed after the arrest process, such as the absence of pupillary light reflex. Infiltration on chest radiography (not associated with CPR), which is a sign of respiratory disease, was also more evident in those who were deceased. In addition, the prognosis of patients with multiple organ failure and severe pulmonary findings after CPR was worse. A tracheostomy was performed on patients who could not maintain spontaneous breathing due to central involvement. This method (not at operation time) also affected mortality in patients who maintained their breathing.

In a study examining IHCA child arrests that were rapidly intervened with an alarm system (2017–2019) at a university located in the largest metropolitan city of Türkiye, CPR was applied to 27.1% patients and 84.2% of these patients who received CPR were discharged from the hospital [33]. However, in another training and research hospital study in the same city, the survival rate was 20.3% in alarm system data between 2011 and 2013 [34]. This data supports our hypothesis that effective practices, not the center or facilities, determine life chances. In the present era, in addition to the rapid and efficacious administration of CPR, the use of ECPR is also on the rise [35].

As the IHCA and OHCA data of our study were examined according to Utstein Data Identification Analysis, the mean age and interquartile range value of the patients with IHCA were statistically younger than the OHCA group ($p = 0.002$). Higher age criterion values in the OHCA group were associated with a higher incidence of environmental events (*e.g.*, accidents, traffic accidents, drowning, falls, *etc.*) in childhood and adolescence. Although there were numerically more daytime OHCA cases than others in our study, this situation was not statistically significant between day and night and OHCA and IHCA ($p = 0.087$). This finding could be because the children were outside the hospital during the day, a period when they usually be active. The location of CPR in OHCA cases was the emergency department of our hospital in 57.1% of cases, and this was statistically significant ($p < 0.001$). The first point of administering CPR for OHCA is in the EDs and it is also the first entry point of the health transport systems. Although there was no statistical difference between OHCA and IHCA in terms of the duration of CPR (p = 0.110), the number of patients who received CPR for >30 min was higher in OHCA cases. On the contrary, if IHCA develops, mortality is higher than for OHCA in our study (p = 0.693, 72.7%). Since it is not always clear when OHCA develops and the process of effective interventions is difficult, the development of CNS sequelae in IHCA cases was numerically higher, although not statistically significant, in our hospital where intervention was faster, and the code blue system was active (p = 0.795, 31.6%). Based on published literature, it is possible to achieve ROSC, regardless of the reason and whether it is IHCA or OHCA, with treatments that are rapid, effective, and in accordance with current guidelines. In the post-arrest period, patients should be treated with current recommendations [3]. Our study encompasses a heterogeneous population in the pediatric age group, and provides analogous data to the extant literature, once again demonstrating that effective treatments should be applied under all circumstances.

The limitation of our study was its retrospective, single-center design, which included the patients hospitalized after both out of and in-hospital arrest, and that the study included only 1 year (2021) worth of patients data, limiting the sample size and generalizability of study findings. The region where our hospital is located was rural, most people are of low socio-economic status, and there were physical difficulties in the emergency transportation systems, furthur compromising generalizability of findings. Nonetheless, in the center where this study was conducted, all surgical and medical examinations and treatments can be performed, except for extracorporeal membrane oxygenation. During the study period, it was the only health-care center in the province with a pediatric intensive care specialist. The average age of the people in the province is low, and the young population and fertility rate are quite high. For these reasons, our study is valuable because it includes many different disease groups at pediatric ages.

5. Conclusions

This study provides valuable insights into the clinical characteristics, interventions, and outcomes of pediatric patients with PCAS in a low-income region. The findings indicate that higher PRISM III scores, absence of light reflex, abnormal chest X-ray findings, multiple organ failure, respiratory failure and the need for tracheostomy were significantly associated with adverse discharge outcomes. Despite adherence to standardized resuscitation and intensive care protocols, the overall survival rate remained low at 35%, underscoring the need for improved post-resuscitation care strategies. Enhancing critical care resources, early identification of high-risk patients, and the development of targeted interventions might contribute to better neurological outcomes and overall survival in this at-risk population. Future research should focus on optimizing post-arrest management and identifying factors that might improve long-term prognosis.

AVAILABILITY OF DATA AND MATERIALS

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

AUTHOR CONTRIBUTIONS

HFA and ÜA—designed the study. HFA, TÇ, FE and ÜA—conducted the research. TÇ and FE—analyzed the data. HFA—wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the Harran University Ethical Committee for the number of 22/03/01 before the study began and in accordance with Helsinki Declarations. The requirement for informed consent was waived by the Harran University Ethical Committee. The clinical trial number is not applicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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