Cardiopulmonary Resuscitation in Children With In-Hospital and Out-of-Hospital Cardiopulmonary Arrest

Multicenter Study From Turkey

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Objectives: The objectives of this study were to determine the causes, location of cardiopulmonary arrest (CPA) in children, and demographics of cardiopulmonary resuscitation (CPR) in Turkish pediatric emergency departments and pediatric intensive care units (PICUs) and to determine survival rates and morbidities for both in-hospital and out-of-hospital CPA.

Methods: This multicenter descriptive study was conducted prospectively between January 15 and July 15, 2011, at 18 centers (15 PICUs, 3 pediatric emergency departments) in Turkey.

Results: During the study period, 239 children had received CPR. Patients' average age was 42.4 (SD, 58.1) months. The most common cause of CPA was respiratory failure (119 patients [49.8%]). The location of CPA was the PICU in 168 (68.6%), hospital wards in 43 (18%), out-of-hospital in 24 (10%), and pediatric emergency department in 8 patients (3.3%). The CPR duration was 30.7 (SD, 23.6) minutes (range, 1–175 minutes) and return of spontaneous circulation was achieved in 107 patients (44.8%) after the first CPR. Finally, 58 patients (24.2%) were discharged from hospital; survival rates were 26% and 8% for in-hospital and out-of-hospital CPA, respectively ($P = 0.001$). Surviving patients' average length of hospital stay was 27.4 (SD, 39.2) days. In surviving patients, 19 (32.1%) had neurologic disability.

Conclusion: Pediatric CPA in both the in-hospital and out-of-hospital setting has a poor outcome.

Key Words: cardiopulmonary arrest, cardiopulmonary resuscitation, mortality

(*Pediatr Emer Care* 2015;31: 748–752)

Cardiopulmonary arrest (CPA) in childhood is a tragic event often resulting in death or poor neurologic outcome. In the United States, approximately 16,000 American children (8–20 in 100,000 children per year) suffer from CPA each year.[1] Cardiopulmonary arrest is often the end result of a progressive deterioration in the respiratory and circulatory systems.[1–5] Clinical factors that influence survival include the environment in which the arrest occurs, the comorbidities of the child, the duration of "no flow" (period of time when there is no pulsatile flow, and the patient is not undergoing cardiopulmonary resuscitation [CPR]) before resuscitation, the initial rhythm detected, and the quality of the basic and advanced life support interventions provided.[6–9]

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Disclosure: The authors declare no conflict of interest.

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ISSN: 0749-5161

Survival to hospital discharge is 2% to 28% after out-of-hospital CPR and 14% to 42% after in-hospital CPR.[1,9,10] Many survivors have severe neurologic disability. These poor outcomes are in part caused by prolonged periods of no flow, because many out-of-hospital cardiac arrests are not witnessed, and only 30% of children are provided with bystander CPR.[10–13]

To date, there are no multicenter data about CPR provision in children in Turkey. The aims of this study were to determine the causes and locations of CPA and provide information about CPR practices in pediatric emergency departments and pediatric intensive care units (PICUs) and also multicenter data about survival and morbidities for both in-hospital and out-of-hospital CPA in Turkey.

METHODS

Data

This multicenter descriptive study was conducted prospectively between January 15 and July 15, 2011, at 18 centers (15 PICUs, 3 pediatric emergency departments) in Turkey. Children aged 1 month to 18 years who received at least 1 minute of CPR were enrolled in the study. Patients with terminal disease, such as malignancy, were excluded from the study.

Study Setting

We determined demographic data, such as age, sex, comorbidities, and date of CPA. The causes of CPA were identified as respiratory failure (upper airway disease, pulmonary disease, hypoventilation), rhythm abnormalities, shock states (including septic, hypovolemic, cardiogenic, obstructive, etc), central nervous system disease, poisoning, and trauma.[14] The location of the CPA was noted as out-of-hospital or in-hospital (emergency unit, ward, PICU, operating room, or radiology unit). Furthermore, we identified the location where CPR was first applied as out-of-hospital or in-hospital (emergency unit, ward, PICU, operating room, or radiology unit). The number of health care personnel participating in CPR was asked, as well as which airway management was used (mouth-to-mouth breathing, balloon-mask, and intubation). Arrest rhythms were given as asystole, bradycardia, pulseless electrical activity (PEA), pulseless ventricular tachycardia, and ventricular fibrillation. The vascular access options were peripheral, intraosseous line, central venous catheter, and endotracheal tube during CPR. For resuscitation, the drugs given included epinephrine, amiodarone, lidocaine, sodium bicarbonate, atropine, calcium, and glucose, and their route of delivery was identified. During CPR, methods of monitoring included monitor (eletrocardiography, oxygen saturation, heart rate), debrillator, end-tidal carbon dioxide, and invasive arterial line.

TABLE 1. Etiology of CPA in Turkish Children

Causes of Cardiac Arrest	n	%
Respiratory failure	119	49.8
Shock states	73	30.5
CNS disease	35	14.7
Trauma	11	4.6
Poisoning	1	0.4

CNS indicates central nervous system.

We noted those patients who were treated with defibrillator and automatic external defibrillator. We noted CPR time and the outcome of CPR as return of spontaneous circulation (ROSC) or failed resuscitation.

In surviving patients, we described neurologic status as conscious or comatose; we also calculated the Glasgow Coma Scale (GCS) score within first 3 hours of the event for all patients. We checked arterial blood gases, lactate, whole blood count (white blood cell, hemoglobin, platelet count), bleeding profile (prothrombin time, activated partial thromboplastin time, fibrinogen, and D-dimer level), biochemical tests (glucose, liver enzymes, renal function tests, and others), and myocardial injury markers (troponin I, CK-MB). After CPR, we calculated the Pediatric Logistic Organ Dysfunction Score (PELOD)[15] and Pediatric Risk of Mortality III (PRISM III) score[16] for all survivors. Goldstein and colleagues'[17] multiorgan failure (MODS) criteria were used for MODS in the postarrest period. The PELOD score is used for evaluating organ failure severity, and it is calculated daily. The MODS criteria are used for how many organ failure developed. The PRISM III score is calculated at the 24th hour of PICU admission, and it is used for mortality probability. We categorized postarrest treatments as bolus fluid therapy or inotropes (dopamine, dobutamine, epinephrine, norepinephrine, milrinone, terlipressin); also, we documented the use of temperature-targeted management (TTM), hypertonic saline, mannitol, and steroid treatments for neuroprotection in comatose survivors in the post-CPA period.

We determined which methods of organ support (mechanical ventilation, renal replacement treatments [RRTs], plasma exchange [PE]) were used in patients with multiple organ failure. For outcomes, we documented survival and nonsurvival of patients, PICU length of stay, and neurologic outcome. We used the Pediatric Cerebral Performance Scale[18] at day 28 after CPA to describe short-term neurologic outcome. The Pediatric Cerebral Performance Scale is used for long-term neurologic disability after any neurologic insult such as trauma, CPA, and so on. It has 6 levels from normal (stage 1) to brain death (stage 6). If brain death developed in the patient within 28 days after CPA event, we determined organ donors. This study was approved by the local institutional review boards of all participating centers.

Statistical Analysis

The statistical analyses of the study were performed with SPSS 15.0 (SPSS Inc, Chicago, Ill). The differences in proportions between the group categories (CPA [CPR] and ROSC) and the place-of-CPA categories (in-hospital [PICU, hospital ward, pediatric emergency department], out-of-hospital) were compared by χ^2 test. Descriptive statistics were summarized in tables as counts and percentages for categorical variables and as mean (SD), minimum, and maximum for continuous variables. Data were collected from all centers, and statistical evaluation was performed in aggregate. None of the centers were evaluated separately. $P < 0.05$ was considered statistically significant.

RESULTS

Prevalence

During the study period, 239 children who received CPR were enrolled. Patients' mean age was 42.4 (SD, 58.1) months, and 130 (54.4%) were male. The most common cause of CPA was respiratory failure, with 119 (49.8%) patients; other causes included shock states, rhythm abnormalities, trauma, central nervous system disease, and poisoning (Table 1).

Patient Characteristics and Location

The location of CPA was PICU in 168 (68.6%), hospital ward in 43 (18%), out-of-hospital in 24 (10%), and emergency department in 8 cases (3.3%). Initial rhythms of CPA patients are bradycardia in 56%, asystole in 37%, ventricular tachycardia in 4% and ventricular fibrillation in 2%, and PEA in 1% patients. The CPR team consisted of 5 (SD, 1) health care providers. The leader of the team was a pediatrics resident in 118 (49.3%), pediatric intensivist in 63 (26.3%), pediatrician in 55 (23.0%), and pediatric emergency care doctors in 3 (1%). During CPR, vascular access was obtained by intraosseous line in 11 patients (5%). Vital signs monitor (VSM) in 183 (76.6%), VSM with defibrillator in 24 (10%), and VSM with end-tidal carbon dioxide in 10 (4.2%) were used in children with CPA. Defibrillator and automatic external defibrillator were applied in 16 (6.7%) and in 2 patients (0.8%), respectively.

The mean CPR duration was 30.7 (SD, 23.6) minutes (range, 1–175 minutes), and ROSC was obtained in 107 patients (44.8%) after the first CPA. The locations of CPA and their outcomes are given in Table 2. There was no statistically significant association between CPA location and likelihood of ROSC ($P = 0.539$).

Laboratory Data and Organ Dysfunction

Blood samples were obtained from surviving patients 38.1 (SD, 40.6) minutes after ROSC. Results of blood gases, lactate, whole blood count, coagulation parameters, and biochemistry are given in Table 3. After CPR, there was respiratory failure in 83 (77.6%), cardiovascular failure in 68 (63.6%), neurologic dysfunction in 60 (56.1%), renal injury in 34 (31.8%), hematologic dysfunction in 34 (31.8%), and liver injury in 18 (16.8%) patients. Patients' PELOD score was 25.3 (SD, 16.2), and PRISM III score was 24.1 (SD, 13.3). Mechanical ventilation was used in 96 (89.3%), RRT in 17 (16.4%), and PE in 5 (4.9%) of the patients with ROSC after first CPA. Medications given and their dosages are given in Table 4. Some patients had more than 1 CPA, and CPR was performed 2 times in 41, 3 times in 14, 4 times in 4, 5 times in 3, and 6 times in 1 patient.

TABLE 2. Location of CPA and Likelihood of ROSC

Place of CPA	Patients (n)	Patients (n) With ROSC After CPR	%	*P*
PICU	164	71	43.3	0.539*
Ward	43	18	41.9	
Pediatric emergency department	8	4	50	
Out-of-hospital	24	10	41	

*Significant if $P < 0.5$.

TABLE 3. Laboratory Data of Patients With ROSC After First CPR

Parameters	Patient, n	Value	Parameters	Patient, n	Value
pH	107	7.15 (0.2)	Fibrinogen, mg/dL	69	290 (354)
P_{CO_2}, mm Hg	107	55.9 (28.5)	D-Dimer, IU/L	69	3042 (3804)
P_{O_2}, mm Hg	107	104.7 (90.4)	Glucose, mg/dL	75	188 (129)
HCO_3, mEq/dL	107	19.4 (9.5)	BUN, mg/dL	75	27 (26)
S_{O_2}, %	107	84.3 (17.1)	Creatinine, mg/dL	75	0.8 (0.9)
Lactate (reference range, 0.2–2.2 mmol/dL), mmol/dL	88	6.8 (4.5)	Potassium, mg/dL	75	4.7 (1.4)
White blood cell count, /μL	75	13,500 (10,700)	AST, IU/L	75	331 (541)
Hemoglobin, g/dL	75	9.3 (1.9)	ALT, IU/L	75	144 (245)
Platelet count, /μL	75	244.000 (193.000)	Creatinine kinase, IU/L	75	1513 (4929)
Prothrombin time, s	72	18.9 (18.1)	Troponin I, ng/mL	58	2.9 (7.7)
aPTT, s	72	46.8 (28.7)	CK-MB, IU/L	58	183 (823)

aPTT indicates activated partial thromboplastin time; BUN, blood urea nitrogen; LDH, lactate dehydrogenase; AST, aspartate aminotransferase; ALT, alanine aminotransferase.

Following CPR, 60 (56.1%) of 107 surviving patients were comatose, and their mean GCS score was 6.4 (SD, 3.1). Neuroprotective therapies such as TTM were utilized in 22 patients (21%); hypertonic saline was given to 11 (10%) and mannitol to 5 patients (5%).

Outcome

Finally, 58 patients (24.2%) survived to hospital discharge, including 26% (56) of the in-hospital CPA group and 8%[2] of out-of-hospital CPA group ($P = 0.001$). In surviving patients, 19 (32.1%) had neurologic disability, and their mean Pediatric Cerebral Performance Scale score was 3.2 (SD, 1.4) on the 28th day after CPR. Seven patients became organ donors after a diagnosis of brain death was made. Surviving patients' mean length of stay in hospital was 27.4 (SD, 39.2) days.

DISCUSSION

Our study is the largest study of the utilization of CPR on children in Turkey. We found that CPR is generally performed in accordance with guidelines for children with in-hospital or out-of CPA. In our study, 44.8% of children achieved ROSC after CPA, but only 24.2% survived to hospital discharge. These results are within the range reported in previous studies.[7,10,13,19] Survival in other studies was 51.8% in Knudson and colleagues',[10] none in Olotu and colleagues',[7] 16.4% in Akçay and colleagues',[13] and 45% in Fink and colleagues'[19] studies. Recently, Knudson et al[10] reported the incidence and outcomes of pediatric in-hospital CPA in the United States. This study was based on the 2006 Kids' Inpatient Databases. In that report, 3739 hospital records (from 38 states) were screened for CPR within year 2006. In total, 5807 children had CPR performed, with an incidence of 0.77 per 1000 admissions.

Over the recent years, significant improvements in the managements have been made in the management of shock and respiratory failure. The creation and refinement of strategies aimed at preventing in-hospital cardiac arrest remain a priority.[10–13,20–29] In Turkey, both the Society of Pediatric Emergency and Intensive Care Medicine and the Ministry of Health are conducting advanced pediatric life support courses to teach early recognition and treatment of shock and respiratory failure. Furthermore, both pediatric emergency and pediatric intensive care medicine were recently given official subspecialty status within pediatrics, facilitating improved pediatric resident education in regard to shock, respiratory failure, airway management, basic life support, and advanced life support. On the other hand, the Ministry of Health also operates a well-organized prehospital emergency medical services system (so-called "112") including helicopter and fixed-wing air ambulance. The results of this multicenter study suggest to us that training, manpower, and technical infrastructure for provision of CPR are adequate in Turkey.

Pediatric out-of-hospital survival rate is lower than in-hospital CA.[10,28] Witnessed arrest was the most important determinant of survival. Ventricular fibrillation was an uncommon rhythm measured by pediatric emergency services. The majority of pediatric out-of-hospital CAs occurred at home. The rate of bystander CPR was low. Strategies to increase the rate of bystander CPR for children, especially by family members, are needed.[27,30–37] Foltin et al[27] reported on 147 children with out-of-hospital CA in New York City, United States, between 2002 and 2003. Sixty-nine percent of them had CPA at home. Bystander CPR was performed in 30% of children. Initial rhythm was determined as

TABLE 4. Medications and Their Doses After CPR in Patients With ROSC

Drug	Patients, n	Mean Dose	Minimum-Maximum Doses
Dopamine, μg/kg per min	71	12.1 (4.1)	3–24
Dobutamine, μg/kg per min	51	12.6 (4.8)	5–24
Epinephrine, μg/kg per min	48	0.7 (0.7)	0.1–4
Norepinephrine, μg/kg per min	14	0.3 (0.2)	0.1–1
Milrinone, μg/kg per min	2	0.4 (0.1)	0.3–0.5
Terlipressin,* μg/kg per dose	1	20	20

*Terlipressin dosage for bolus.

asystole in 50%, PEA in 9.5%, and VF in 2%. Survival was 4%, and they were all witnessed arrests. In our study, we reported 239 children with CA, and 24 (10%) of them were out-of-hospital CA. Finally, 58 patients (24.2%) were discharged from hospital; survival was 26% (56) for in-hospital and 8%[2] for out-of-hospital CA. But we could not determine bystander CPR for out-of-hospital CA.

Neuroprotective treatments are very important after both in-hospital and out-of-hospital CPA. Accepted brain protective treatments include the optimizing of circulation, hypothermia, sedation, and avoiding hyperventilation/hyperglycemia/hyperthermia. The American Heart Association 2010 Pediatric Advanced Life Support guidelines recommend the consideration of therapeutic hypothermia in children who are comatose after ROSC.[6] There are some pediatric studies addressing the use of neuroprotective treatments after ROSC.[18,28,34–41] Fink et al[19] published data on the use and feasibility of therapeutic hypothermia after pediatric CPA between 2000 and 2006. They reported 181pediatric patients who had CPA (40 of whom received post-ROSC TTM), and 52% of whom had an in-hospital CPA with an overall survival rate to hospital discharge of 45%. In this study, we collected performed therapies for neuroprotection and decreasing intracranial pressure. Sixty patients (56.1%) were comatose after CPA, and their mean GCS score was 6.4 (SD, 3.1).

We determined which performed organ support systems in children with ROSC after CPR. We performed mechanical ventilation in 96 (89.3%), RRT in 17 (16.4%), and PE in 5 patients (4.9%) with ROSC. In addition, inotropes were started in children with shock after ROSC. Indeed, we can perform most of organ support systems and administer drugs during and after ROSC in Turkey. Extracorporeal life support methods can be important during CPR especially in patients with high life expectancy such as after pediatric cardiac surgery. Extracorporeal life support, specifically extracorporeal membrane oxygenation, has become a useful therapeutic modality to care for neonates and children with progressive respiratory and cardiac failure that is refractory to conventional management.[9,42] Raymond et al[9] reported on 6288 pediatric CPA events, with extracorpereal cardiopulmonary resuscitation being performed in 199 (3.2%) and with 87 (43.7%) children surviving to hospital discharge. Although there is sporadic experience with extracorporeal life support and pediatric CPA in Turkey, extracorporeal membrane oxygenation is not routinely available in Turkey PICUs.

In conclusion, pediatric CPA is a serious event with a very poor prognosis, whether it occurs in the in-hospital or out-of-hospital setting. Preventive measures coupled with early recognition and management of respiratory failure and shock are crucial in preventing the occurrence and improving overall outcomes of children at risk for CPA. After ROSC, hemodynamics and ventilation should be optimized, and good general supportive care provided. Neuroprotective therapies should be optimized, including the avoidance of hyperventilation, hyperglycemia or hypoglycemia, and hyperthermia. The use of TTM should be considered and if used be applied carefully.

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