

Postoperative cardiac arrest in children with congenital heart abnormalities

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Original Article

Abstract

BACKGROUND: The exact survival rates and markers of survival after postoperative cardiac arrest in children with congenital heart abnormalities are unknown.

METHODS: In this one-year study, we identified children younger than seven years of age with postoperative cardiac arrest in our pediatric cardiac intensive care unit database. Parameters from perioperative, pre-arrest, and resuscitation periods were analyzed for these patients. Comparisons were made between survivors and non-survivors after cardiopulmonary resuscitation (CPR). Fisher's exact, Student's t, and chi-square tests were used to analyze data.

RESULTS: Of 529 evaluated children who underwent corrective heart surgery, 59 (11%) sustained a documented cardiac arrest. Of these, 22 (37%) survived and regained their vital signs. Perioperative parameters (age, weight, and duration of cardiopulmonary bypass pumping), ventricular physiology, oxygen saturation, and bicarbonate concentration did not influence the outcome of CPR. Greater use of inotropic agents was not associated with higher mortality. A significant relationship was seen between having history of cardiac arrest and CPR success ($P < 0.001$).

CONCLUSION: CPR had undesirable outcomes in patients with hemodynamic dysfunction (i.e. low mean arterial blood pressure). Patients with univentricular physiology or history of cardiac arrest are not prone to a higher risk of mortality following arrest.

Keywords: Cardiac arrest, Congenital, Cardiopulmonary resuscitation, Pediatrics, Operation

Date of submission: 26 Sep 2012, *Date of acceptance:* 09 Nov 2012

Introduction

The rate of cardiac arrest in the U.S. is approximately 150000 cases per year. While about 10000 of these individuals die, 90000 cases have to continue their lives with cardiac complications. Children with known cardiac diseases, e.g. hypertrophic cardiomyopathy, anomalous coronary arteries, and severe aortic stenosis, may experience cardiac arrest during exercise.¹⁻⁴

Cardiac arrest in admitted children is one of the uncommon yet worrying events. Owing to advancements in cardiopulmonary resuscitation (CPR) and experienced treatment teams, many patients with cardiac arrest, even in the most fatal cases, have survived and returned to life. After surgery, children with congenital heart diseases spend a critical period of time in pediatric cardiac intensive care unit in order for their hemodynamic status to be stabilized. Early prevention and treatment of cardiac arrest during this period are of very high importance. Identifying cardiac arrest

markers and CPR success can lead to reduced mortality among these patients.

In developed countries, the prevalence of cardiac arrest and CPR among patients admitted in PCICUs have varied between 1.5 and 6% during the last 15 years.⁵⁻⁷ Survival rate of these patients has been 8.8-31% according to general reports.⁵⁻⁷ Survival rates of patients following cardiac arrest and respiratory arrest have been reported as 7% and 33%, respectively.⁷ There is inadequate data about the outcomes of cardiac arrest in patients after cardiac surgery in PCICUs. Moreover, survival markers are not well-identified. However, a previous study suggested long-term use of cardiopulmonary bypass pump (CBP) and high levels of serum lactate after surgery as major markers of cardiac arrest in children.⁸ Another research on patients in PCICUs indicated that cardiac arrest had better outcomes in infants compared to older children. In addition, infants with more severe hemodynamic dysfunction, lower blood pressure, and higher support of high-

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dose inotropic agents had lower survival rates. The present study aimed to identify the outcomes and related factors of cardiac arrest following CPR in pre-school aged children.

Materials and Methods

This descriptive-analytical study was conducted during 2001-02. All children younger than seven years of age who had been admitted in the PCICU of Shahid Rajaie Hospital (Tehran, Iran) after cardiac surgery were evaluated. All cases of cardiac arrest in PCICU were included through census sampling. Patients were divided into survivors (who responded to CPR and regained vital signs particularly palpable spontaneous pulse) and non-survivors (who died after CPR).

Using patient records, cardiac catheterization, vital signs of patients in the PCICU, arterial blood gas test results, disease course, physician's order, and the report of the nurse in charge were extracted. The crude data was recorded in a questionnaire and then analyzed using SPSS for Windows 10.0 (SPSS Inc., Chicago, IL, USA). Various indices (including median, mean, and ratio) and tests (Fisher's exact, Student's t, and chi-square tests) were used to analyze data. P values less than 0.05 were considered statistically significant.

Results

During the one-year period of study, 529 children under seven years old were admitted to the PCICU. Overall, 59 cases (11%) of cardiac arrest were detected and CPR was carried out for them. CPR success rate was 37%. The mean age of survivors and non-survivors was 17.8 and 15.9 months, respectively

(Table 1). While 91.5% of the patients had biventricular physiology, 8.5% had univentricular physiology.

Diagnosis and type of congenital heart disease are summarized in table 2. The most prevalent congenital heart disease was ventricular septal defect (VSD). Cyanotic heart diseases were more common among patients with cardiac arrest. The mean heart rate before the cardiac arrest was 109.0 ± 40.8 beats per minute (bpm) in survivors and 93.0 ± 42.9 bpm in non-survivors. A significant difference was observed in mean arterial blood pressure of survivors and non-survivors (43.8 ± 11.3 vs. 37.8 ± 15.2 mmHg). Therefore, successful CPR was associated with higher mean arterial blood pressure. In addition, CPR success rate in patients with systolic blood pressure lower and greater than 60 mmHg was 31.8% and 68.2%, respectively ($P < 0.05$). On the other hand, CPR was successful in 22.7% of patients with diastolic blood pressure below 30 mmHg and in 77.3% of those with diastolic blood pressure above 30 mmHg ($P = 0.02$).

The mean pH in survivors and non-survivors was 7.20 ± 0.20 and 7.12 ± 0.30 , respectively ($P > 0.05$). There were no significant differences between survivors and non-survivors in mean rate of arterial oxygen saturation ($73.8 \pm 25.1\%$ vs. $66.7 \pm 28.9\%$) or mean bicarbonate concentration (73.8 ± 8.2 vs. 17.2 ± 6.4 mEq/L) (Table 3).

Among 80% of patients with cardiac arrest who had received inotropic agents, 30% had been prescribed with one inotropic agent and 70% had been prescribed with more than one agent. CPR success rates in the mentioned patients were 35.7% and 42.4%, respectively. No significant relationship was seen between increased number of inotropic agents and CPR success rate.

Table 1. Age, weight, duration of cardiopulmonary bypass pump (CBP) and aortic clamping in patients who survived cardiopulmonary resuscitation (survivors) and those who died (non-survivors)

Parameter		Survivors (n = 22)	Non-survivors (n = 37)	P
Age (months)	Mean \pm SD	17.8 \pm 21.1	15.9 \pm 20.6	0.70
	Median (min-max)	6.5 (1.0-60.0)	7 (0.6-72.0)	
Weight (kg)	Mean \pm SD	7.2 \pm 4.2	0.4 \pm 3.5	0.40
	Median (min-max)	5.3 (2.7-16.0)	5.4 (2.7-14.0)	
Duration of CBP use* (min)	Mean \pm SD	93.3 \pm 51.1	79.9 \pm 19.9	0.44
	Median (min-max)	70.0 (15.0-160.0)	83.0 (39.0-110.0)	
Duration of aortic clamping* (min)	Mean \pm SD	55.1 \pm 35.9	37.1 \pm 17.9	0.16
	Median (min-max)	38.0 (4.0-116.0)	40.0 (14.0-72.0)	

* CBP and aortic clamping were used in 11 survivors and 11 non-survivors.

Table 2. Diagnosis and type of congenital heart disease in the study subjects

Diagnosis	N (%)
Ventricular septal defect	10 (16)
Transposition of great arteries	9 (15)
Tetralogy of fallot	8 (13)
Atrioventricular septal defect	10 (6)
Total anomalous pulmonary venous connection	10 (6)
Ventricular septal defect and pulmonary atresia	6 (4)
Tricuspid atresia	6 (4)
Coarctation of aorta	6 (4)
Aortic valve stenosis	5 (3)
Pulmonary atresia	3 (2)
Ventricular septal defect and pulmonary stenosis	3 (2)
Single ventricle	1 (1)

Table 3. Heart rate, mean arterial blood pressure, and laboratory findings for arterial blood gases before cardiac arrest in patients who survived cardiopulmonary resuscitation (survivors) and those who died (non-survivors)

Parameter		Survivors (n = 22)	Non-survivors (n = 37)	P
Heart rate (bpm)	Mean \pm SD	109.2 \pm 40.8	93.2 \pm 12.9	0.08
	Median (min-max)	109.0 (30.0-168.0)	100.0 (23.0-167.0)	
Oxygen partial pressure (mmHg)	Mean \pm SD	81.3 \pm 97.6	60.4 \pm 32.2	0.25
	Median (min-max)	50.0 (12.0-387.0)	54.0 (12.0-138.0)	
Oxygen saturation (%)	Mean \pm SD	66.7 \pm 28.9	73.8 \pm 25.1	0.35
	Median (min-max)	82.0 (18.0-100.0)	67.0 (11.0-99.0)	
Carbon dioxide partial pressure (mmHg)	Mean \pm SD	46.6 \pm 28.3	53.2 \pm 26.6	0.46
	Median (min-max)	40.0 (14.0-152.0)	47.0 (13.0-119.0)	
Bicarbonate concentration (mEq/L)	Mean \pm SD	18.4 \pm 8.3	17.2 \pm 6.4	0.50
	Median (min-max)	17.0 (4.0-39.0)	18.0 (5.0-29.0)	
pH	Mean \pm SD	7.20 \pm 0.20	7.12 \pm 0.30	0.29
	Median (min-max)	7.26 (6.80-7.50)	7.15 (6.00-7.60)	
Mean arterial blood pressure (mmHg)	Mean \pm SD	43.8 \pm 113.0	37.8 \pm 15.2	0.04

Table 4. Parameters related to cardiopulmonary resuscitation (CPR) in survivors and non-survivors

Parameter		Survivors (n = 22)	Non-survivors (n = 37)	P
Period between cardiac arrest and surgery (hours)	Mean \pm SD	110.1 \pm 188.4	240.2 \pm 62.4	0.34
	Median (min-max)	25 (2-840)	31 (1-3600)	
Lowest pH during CPR	Mean \pm SD	7.07 \pm 0.20	6.99 \pm 0.24	0.22
	Median (min-max)	6.99 (6.63-6.79)	6.94 (7.49-6.50)	
CPR duration (min)	Mean \pm SD	36.6 \pm 22.1	41.5 \pm 20.7	0.39
	Median (min-max)	30 (15-120)	30 (20-135)	

CBP was used for 21 patients. The duration of CBP use was less than 90 minutes in 62% of the cases. Maximum duration of CBP use was 150 minutes. The mean duration of CBP use in survivors and non-survivors was 93.9 ± 19.9 and 79 ± 19.9 minutes, respectively ($P > 0.05$) (Table 3). CPR success rate in patients with and without history of cardiac arrest was 67.8% and 10%, respectively ($P < 0.001$). The mean lowest pH during CPR was 7.07 ± 0.20 for survivors and 6.99 ± 0.24 for non-survivors. However, the difference between the two groups was not statistically significant (Table 4).

Discussion

In this study, among 529 children younger than seven years of age in PCICU, 59 cases (11%) of cardiac arrest were observed and CPR success rate was 37%. Previous studies have reported the in-hospital survival rate and long term survival rate after CPR as 13-52% and 5-27%, respectively.^{9,10} In a 15-year long study, Slonim et al. found that 1.5-6% of children admitted to pediatric intensive care unit suffered from cardiac arrest and required CPR.⁵ In a study by Rhodes et al., cardiac arrest and thus the need for CPR was detected in 6% of infants after cardiac surgery.¹¹

The rates of cardiac arrest in our center and other parts of the hospital were not considerably different (11% vs. 13%). However, the rate was higher in our patients compared to those admitted in intensive care unit (ICU).⁹ The difference might have been caused by advanced facilities and greater experience, awareness, and coordination of the staff in ICU.

There was not a significant difference in mean age between survivors and non-survivors in the current study. Similarly, Rhodes et al. suggested that age was not effective on the success of CPR.¹¹

Although CPR success rate was higher in patients with univentricular physiology compared to those with biventricular physiology, there was no significant relationship between the CPR success rate and the physiology of cardiac patients. Likewise, Rhodes et al. reported that univentricular physiology was not an important risk factor for mortality.¹¹ Moreover, mean heart rate and success of CPR were not significantly related since about 83% of survivors and 70% of non-survivors had a heart rate more than 60 bpm. In agreement with our findings, Rhodes et al. indicated that heart rate before cardiac arrest and CPR success rate were not significantly correlated.¹¹

We detected a statistically significant difference in mean arterial blood pressure between survivors and non-survivors. CPR success rate has been previously reported to be positively associated with higher mean arterial blood pressure.¹¹ On the other hand, CPR success rate was significantly higher in patients with systolic blood pressure greater than 60 mmHg and those with diastolic blood pressure greater than 30 mmHg. The reason for this association can be better hemodynamic stability of patients and maintaining blood supply to regain vital signs in vital organs. Rhodes et al. found a similar significant relationship between mean arterial blood pressure and success of CPR.¹¹

In the current study, there were no significant differences in mean pH, oxygen saturation, bicarbonate concentration, or the lowest pH during CPR between survivors and non-survivors. In their study on infants, Rhodes et al. did not find significant correlations between CPR success rate and any of the abovementioned parameters except the lowest pH during CPR.¹¹

We failed to find a significant relationship between increased number of inotropic agents and improved CPR success rate. Rhodes et al. allocated higher scores to increased number of inotropic agents. Similar to our findings, they showed no

significant relationship between CPR success rate and increased number of inotropic agents.¹¹ In addition, in agreement with the findings of Rhodes et al. in infants,¹¹ there was no significant difference in mean duration of CBP use between survivors and non-survivors in the present study.

History of cardiac arrest was significantly related with increased CPR success rate. The possible reason might have been higher attention and support of the staff of PCICU to patients with history of cardiac arrest. They could also regain vital signs due to their hemodynamic status and underlying heart disease. However, this parameter has not been investigated in other studies.

Conclusion

Postoperative cardiac arrest in children is a major concern PCICU. Undesirable CPR outcomes are expected in cases with hemodynamic dysfunction (lower mean arterial blood pressure). Patients with univentricular physiology and/or history of cardiac arrest are not more prone to post-arrest mortality risk.

Acknowledgments

The authors appreciate the staff of pediatric intensive care unit of Shahid Rajaie Hospital (Tehran, Iran) for their kind cooperation and Mr. Hassanzadeh for statistical analyses of data.

Conflict of Interests

Authors have no conflict of interests.

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How to cite this article: Ahmadi AR, Aarabi MY. **Postoperative cardiac arrest in children with congenital heart abnormalities.** *ARYA Atheroscler* 2013; 9(2): 145-9.