Original article

In-hospital Pediatric Cardiac Arrest in Spain

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A B S T R A C T

Introduction and objectives: The objective was to analyze the characteristics and prognostic factors of in-hospital pediatric cardiac arrest in Spain.
Methods: A prospective observational study was performed to examine in-hospital pediatric cardiac arrest. Two hundred children were studied, aged between 1 month and 18 years, with in-hospital cardiac arrest. Univariate and multivariate logistic regression analyses were performed to assess the influence of each factor on survival to hospital discharge.
Results: Return of spontaneous circulation was achieved in 74% of the patients and 41% survived to hospital discharge. The survival rate was significantly higher than that reported in a previous Spanish study 10 years earlier (25.9%). In the univariate analysis, the factors related to mortality were body weight higher than 10 kg; continuous infusion of vasoactive drugs prior to cardiac arrest; sepsis and neurological disorders as causes of cardiac arrest, the need for treatment with adrenaline, bicarbonate, and volume expansion, and prolonged cardiopulmonary resuscitation. In the multivariate analysis, the factors related to mortality were hematologic/oncologic diseases, continuous infusion of vasoactive drugs prior to cardiac arrest, cardiopulmonary resuscitation for more than 20 min, and treatment with bicarbonate and volume expansion.
Conclusions: Survival after in-hospital cardiac arrest in children has significantly improved in recent years. The factors related to in-hospital mortality were hematologic/oncologic diseases, continuous infusion of vasoactive drugs prior to cardiac arrest, the duration of cardiopulmonary resuscitation, and treatment with bicarbonate and volume expansion.

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Parada cardiaca pediátrica intrahospitalaria en España

R E S U M E N

Introducción y objetivos: Analizar las características y los factores pronósticos de la parada cardiaca intrahospitalaria en España.
Métodos: Se realizó un estudio prospectivo observacional en el que se incluyó a 200 niños, de edades entre 1 mes y 18 años, con parada cardiaca intrahospitalaria. Se realizó un estudio univariable y multivariable para analizar la influencia de los factores en la supervivencia al alta del hospital.
Resultados: En un 74% de los pacientes se logró la recuperación de la circulación espontánea y el 41% sobrevivía al alta del hospital. La supervivencia fue mayor que la del estudio realizado 10 años antes (25,9%). En el estudio univariable, los factores relacionados con la mortalidad fueron el peso superior a 10 kg, el tratamiento con fármacos vasoactivos en perfusión continua antes de la parada, la sepsis y la enfermedad neurológica como causas de la parada cardiaca, la necesidad de tratamiento con adrenalina, bicarbonato y expansión de volumen, y un tiempo de reanimación cardiopulmonar largo. En el estudio multivariable, los antecedentes hematooncológicos, el tratamiento previo con fármacos vasoactivos, la duración de la reanimación cardiopulmonar superior a 20 min, el tratamiento con bicarbonato y la expansión de fluidos fueron los factores relacionados con la mortalidad.
Conclusiones: La supervivencia a la parada cardiaca intrahospitalaria en la infancia ha mejorado significativamente en los últimos años. Las enfermedades hematooncológicas, el tratamiento previo con fármacos vasoactivos, la duración de la reanimación cardiopulmonar y el tratamiento con bicarbonato y expansión de líquidos son los factores asociados con la mortalidad al alta hospitalaria.

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◇ A list of the researchers participating in the Spanish Study Group for Cardiopulmonary Arrest in Children is provided in the Appendix.

INTRODUCTION

In-hospital cardiac arrest (CA) is an important cause of death in children.[1–14] Every 5 years, the International Liaison Committee on Resuscitation updates the recommendations for cardiopulmonary resuscitation (CPR), but the effect of this technique on survival has not been clearly demonstrated.[15–17] A number of studies have analyzed the causes and prognostic factors of in-hospital CA in children and have found that survival after CA varies depending on where the event took place, the underlying disease, the initial electrocardiographic rhythm, and the duration of CPR.[18] However, there are few prospective studies that include a sufficiently large number of patients and have been carried out following the guidelines for Utstein style reporting,[5–11] and there are no studies that analyze the changes in survival after CA in children in a single country.

The main objective of this study was to analyze the prognostic factors that influence mortality associated with in-hospital CA in children in Spain and evaluate the outcomes of CPR since the application of the 2005 recommendations, comparing them with those of a Spanish study carried out 10 years earlier.

METHODS

We performed an observational multicenter study based on an international prospective registry of in-hospital CA in children.[19]

The study was approved by the local ethics and research committee, and the data were collected according to the international guidelines for Utstein style reporting.[20,21] The study population included children ranging in age from 1 month to 18 years who had experienced a CA during a hospital stay between December 2007 and December 2009 in 24 hospitals in 11 Spanish autonomous communities. CA was defined as the absence of a response to stimuli, apnea, the absence of signs of circulation and of palpable central pulse, or bradycardia (heart rate less than 60 bpm) accompanied by poor perfusion in infants that required external cardiac massage and ventilation.

The following variables were recorded: age, sex, body weight, cause of CA, previous history of CA, personal and family history, previous neurological status according to the pediatric cerebral performance category (PCPC), previous functional status according to the Pediatric Overall Performance Category, type of CA, area of the hospital in which the CA took place, variables monitored, assisted ventilation, vasoactive drugs, time to initiation of CPR, initial electrocardiographic rhythm, CPR maneuvers applied, duration of CPR, and in-hospital course. The variables were defined in accordance the guidelines for Utstein style reporting.[20,21]

The findings were compared with those for in-hospital CA from the database of a previous Spanish study performed 10 years earlier.[3]

The statistical analysis was carried out using version 18.1 of the SPSS software package (SPSS Inc.; Chicago, Illinois, United States) and Stata. Comparisons of the results between different groups of patients and of the findings in the present study with those of the previous report were performed using the chi-square test or Fisher's exact test. Univariate logistic regression analysis was carried out and, to evaluate the influence of each factor on hospital mortality, we built a multivariate logistic regression model that included all the variables that reached statistical significance ($P<.15$) in the univariate analysis. A P value less than .05 was considered to indicate statistical significance.

RESULTS

We studied 200 patients with in-hospital CA (54% boys). Return of spontaneous circulation was achieved in 74% of the patients; in another 7 patients (3.5%) without restoration of spontaneous circulation, recovery was achieved with extracorporeal membrane oxygenation. In all, 41% of the patients survived to hospital discharge; 5 of the 7 patients resuscitated by means of extracorporeal membrane oxygenation survived to discharge, although 3 subsequently died. Overall, 77.9% of the survivors had a good neurological outcome (PCPC of 1 or 2). The Figure illustrates the course and outcomes in this patient population.

Patient Characteristics and Clinical Status Prior to Cardiac Arrest

Table 1 shows the patient characteristics and the results of univariate survival analysis.

The mean age was 47.5 months (range, 1-207 months) and the mean body weight, 16.2 kg (range, 2-93 kg). There were no differences in mortality related to age or sex. The mortality rate was lower among children weighing less than 10 kg than among those whose weight was 10 kg or over.

In all, 79.5% of the patients had underlying diseases. The mortality rate was lower in children with a history of heart disease and was higher in those with oncological diseases.

In 76.5% of the patients, the available data included functional and neurological status prior to CA, assessed using the pediatric overall performance category and PCPC scores, and 94.8% of them had good neurological status (PCPC score of 1 or 2). Mortality in the 8 patients with severe neurological disorders (previous PCPC greater than 2) was 100%, significantly higher than that of the remainder of the patient population.

In all, 11% of the patients had experienced CA previously. The mortality rate among these children was somewhat higher than that among the patients who had not, but this difference was not significant.

At the time of CA, 94.3% of the patients were being monitored, 92.9% required mechanical ventilation, and 64.6% were receiving vasoactive drugs. The mortality rate was significantly higher among the children receiving vasoactive agents.

Characteristics of Cardiac Arrest and Cardiopulmonary Resuscitation

Table 2 summarizes the univariate analysis of the relationship between the characteristics of CA and CPR and mortality.

Cardiac and respiratory diseases were the main causes of CA. However, the mortality rate was significantly higher among the patients with neurological disorders and sepsis.

The majority of CA episodes took place in the pediatric intensive care unit. The mortality rate associated with CA that occurred in the emergency department was higher than that recorded for any other area of the hospital, although the differences were not statistically significant.

There were no differences in mortality between episodes that began as respiratory arrests and those presenting as CA.
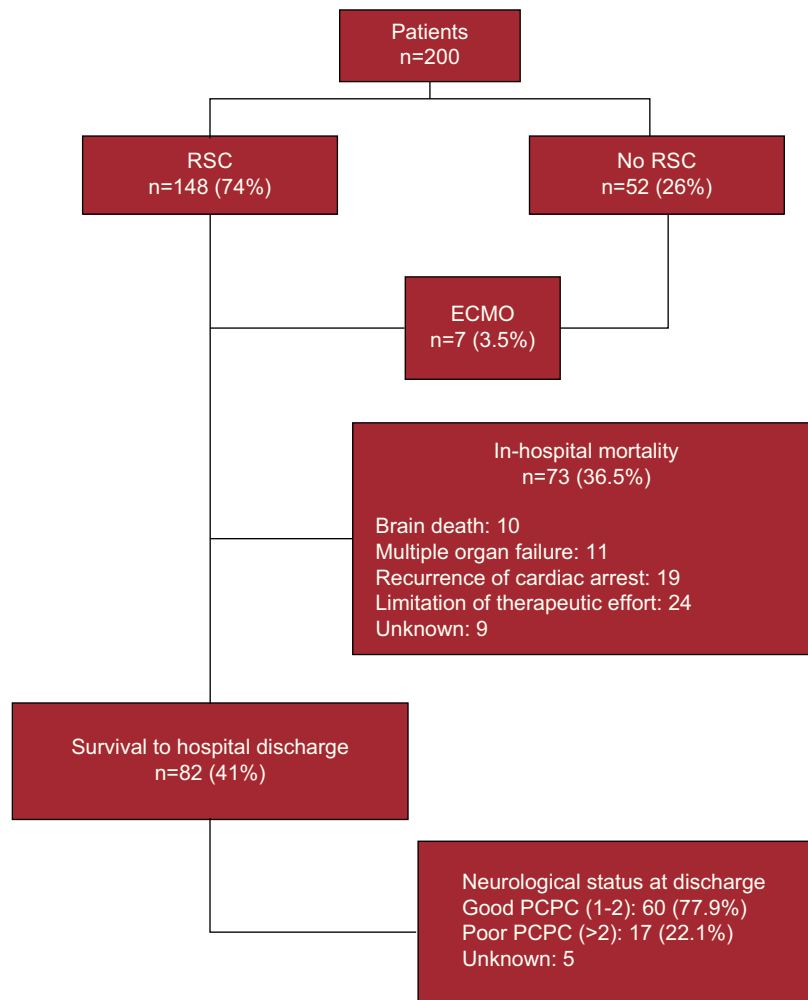
Figure. Course of in-hospital cardiac arrest (algorithm following the Utstein style). ECMO, extracorporeal membrane oxygenation; PCPC, pediatric cerebral performance category; RSC, return of spontaneous circulation.

Bradycardia was the most common electrocardiographic rhythm. Only 6.8% of the patients had shockable rhythms (ventricular fibrillation or pulseless ventricular tachycardia). The mortality rate among children with shockable rhythms was lower (36.4%), but the differences were not statistically significant. In 89.7% of the patient population, CPR was initiated less than 1 min after the diagnosis of CA.

Mortality was significantly higher among the patients who required adrenaline, bicarbonate, and volume expansion (at least 10 mL/kg during CPR). The mortality rate increased in relation to the duration of CA.

The multivariate logistic regression analysis (Table 3) revealed that hematologic/oncologic diseases, administration of continuous infusion of vasoactive drugs prior to the arrest, the need for bicarbonate administration, volume expansion during CPR, and CPR duration greater than 20 min were risk factors associated with mortality.

Comparison With the Previous Spanish Study

The study performed previously in Spain involved 283 patients with CA and/or respiratory arrest occurring both in hospital and out of hospital.[3] One hundred thirty-five children had in-hospital CA (71.1% of them in the pediatric intensive care unit). Survival was 25.9%, with a statistically significant difference (P<.001) between both studies. Duration of CPR greater than 20 min was the factor most strongly associated with mortality.[3]

DISCUSSION

Our study confirms that, although in-hospital CA in children is associated with a high mortality rate, survival (41%) has significantly improved in recent years.

In a previous study carried out in Spain, survival to discharge after in-hospital CA was 25.9%. This difference may be due to a number of factors. Over the past decade, there has been a considerable effort to provide training in pediatric CPR, coordinated by the Spanish Pediatric Cardiopulmonary Resuscitation Group, with the development of a number of courses on basic and advanced pediatric CPR.[22,23] The implementation of the 2005 international recommendations may also have played a role in the improvement in survival. Although most of the participating hospitals were the same in both the first and second studies, other factors such as the organization of hospital care may have influenced these results.

The patient characteristics and the factors related to mortality in the 2 studies were very similar. In both studies, the factors most closely related to mortality were the duration of CPR and the need

Table 1

Univariate Logistic Regression Analysis of the Factors Prior to Cardiac Arrest Associated With Mortality (n=200)

	Patients, %	Mortality, %	OR (95%CI)	P
Age				
>8 years	16.5	66.7	1	
1-12 months	45.5	57.1	0.67 (0.29-1.54)	.341
1-8 years	38.0	57.9	0.69 (0.29-1.62)	.390
Sex				
Male	54.5	55.6	1	
Female	45.5	62.2	1.34 (0.74-2.33)	.343
Body weight				
>10 kg	46.0	67.0	1	
<10 kg	54.0	52.8	0.55 (0.31-0.98)	.042
Previous diseases				
No	20.5	75.6	1	
Yes	79.5	54.7	0.39 (0.18-0.85)	.018
Cardiac	43.5	48.3	0.45 (0.26-0.81)	.007
Hematologic/oncologic	10.5	83.3	4.74 (1.35-16.67)	.015
Preterm birth	11.0	68.2	1.56 (0.61-4.01)	.356
Respiratory	14.0	46.4	0.55 (0.25-1.23)	.148
Neurological	10.0	55.0	0.83 (0.33-2.11)	.702
Gastrointestinal	8.5	70.6	1.74 (0.59-5.15)	.315
Multiple malformation syndrome	8.5	52.9	0.76 (0.28-2.07)	.595
Renal	5.0	30.0	0.28 (0.70-1.11)	.071
Malnutrition	12.5	64.0	1.27 (0.53-3.04)	.587
PCPC score				.017
1-2	94.8	57.2	—	
>2	5.2	100.0	—	
Previous CA				
No	88.8	56.9	1	
Yes	11.2	77.3	1.42 (0.41-4.87)	.579
Previous treatment				
Monitoring				
No	4.7	69.2	1	
Yes	94.3	57.7	0.61 (0.18-2.04)	.420
Mechanical ventilation				
No	7.1	44.0	1	
Yes	92.9	63.3	2.10 (0.67-6.64)	.204
Vasoactive drugs				
No	35.4	48.1	1	
Yes	64.6	64.9	1.99 (1.10-3.61)	.022

95%CI, 95% confidence interval; CA, cardiac arrest; OR, odds ratio; PCPC, pediatric cerebral performance category.

for measures such as adrenaline or bicarbonate administration and volume expansion.

Patient Characteristics and Clinical Status Prior to Cardiac Arrest

The mortality rate was lower among the children weighing less than 10 kg compared with that in those weighing more. Other authors have found that the survival rate was higher among younger children than in older patients.[10]

Previous neurological status was normal in most patients. Although mortality was 100% among the children with a previous neurological disorder (PCPC greater than 2), the small number of patients makes their inclusion in statistical comparisons unviable.

In addition, the mortality among patients who received vasoactive drugs was significantly higher. This circumstance probably only reflects the fact that they were more seriously ill, an observation reported in the previous Spanish study[3] and by other authors.[8,11]

Characteristics of Cardiac Arrest

The mortality rate was higher among patients with hematologic/oncologic diseases, a finding that had been reported in other studies.[9,11]

The most common causes of CA were respiratory and cardiac diseases. However, as observed in other studies, the causes most strongly associated with mortality were sepsis and neurological

Table 2

Univariate Logistic Regression Analysis of the Factors Related to Cardiac Arrest and Cardiopulmonary Resuscitation Associated With Mortality

	Patients, %	Mortality, %	OR (95%CI)	P
Cause of CA				
Cardiac	39.7	51.9	1	
Respiratory	30.2	47.5	0.84 (0.43-1.65)	.606
Sepsis	12.1	83.3	4.63 (1.45-14.8)	.010
Neurological	6.0	91.7	10.20 (1.26-82.8)	.030
Traumatic	1.5	66.7	1.85 (0.16-21.3)	.620
Others	10.6	66.7	1.85 (0.68-5.08)	.231
Site of CA				
PICU	73.7	59.3	1	
Emergency department	6.3	75.0	2.06 (0.53-7.94)	.294
Ward	5.8	36.4	0.39 (0.11-1.40)	.150
Operating room	7.4	50.0	0.69 (0.23-2.06)	.503
Other hospital areas	6.8	61.5	1.10 (0.34-3.53)	.874
Type of arrest				
Cardiac	69.7	60.5	1	
Respiratory	30.3	54.5	0.78 (0.43-1.43)	.429
Time to initiation of CPR				
<1 min	89.7	58.3		
≥1 min	10.3	52.9	0.79 (0.31-2.06)	.634
Initial ECG rhythm				
Asystole	34.6	65.2		
Bradycardia	40.6	55.1	0.65 (0.34-1.28)	.214
PEA	16.2	70.4	1.01 (0.41-2.52)	.977
VF/VT	6.8	36.4	0.31 (0.08-1.15)	.079
CPR measures				
Intubation				
No	60.0	60.0	1	
Yes	40.0	55.8	0.84 (0.47-1.50)	.560
Adrenaline				
No	7.6	20.0	1	
Yes	92.4	62.1	6.06 (1.78-24.10)	.005
Bicarbonate				
No	34.9	32.8	1	
Yes	65.1	71.0	5.01 (2.63-9.54)	<.001
Atropine				
No	81.4	59.7	1	
Yes	18.6	55.0	0.82 (0.41-1.66)	.588
Volume expansion				
No	45.4	41.8	1	
Yes	54.6	73.1	3.78 (2.07-6.91)	<.001
Total CPR time				
<5 min	40.0	35.6	1	
6-10 min	15.0	50.0	1.81 (0.78-4.20)	.168
11-20 min	11.3	50.0	1.81 (0.69-4.74)	.228
21-30 min	11.7	90.9	18.10 (3.91-83.5)	<.001
>30 min	22.1	91.7	19.90 (6.42-61.6)	<.001

95%CI, 95% confidence interval; CA, cardiac arrest; CPR, cardiopulmonary resuscitation; ECG, electrocardiographic; OR, odds ratio; PEA, pulseless electrical activity; PICU, pediatric intensive care unit; VF/VT, ventricular fibrillation or pulseless ventricular tachycardia.

disorders. This finding highlights the importance of establishing measures for the early diagnosis and treatment of sepsis.[21]

Most of the episodes of CA occurred in the pediatric intensive care unit. The mortality associated with CA that took place in the emergency department was higher than the rates corresponding to all other areas of the hospital, although the differences were not statistically significant. For this reason, it is important that a

program be developed for the prevention and treatment of CA throughout the entire hospital.[24] A number of studies have demonstrated the usefulness of creating rapid response teams to improve the prevention and treatment of CA in children.[25,26]

Bradycardia was the most frequently recorded electrocardiographic rhythm (82.2%), coinciding with the findings reported in other studies.[7,12,27] This is one of the most important differences

with respect to the previous Spanish study, in which bradycardia was the initial rhythm in only 38% of patients with CA, whereas asystole was the most frequently detected rhythm.[3] This finding is very important and is probably due to the fact that CA is diagnosed earlier and, thus, CPR is initiated sooner, a measure that increases the possibilities of recovery.

The percentage of children with shockable rhythms was low, a finding reported in other studies in children. For this reason, although early defibrillation improves survival, in cases of CA in children, the algorithms and management strategies should take into account mainly the treatment of nonshockable rhythms.

Characteristics of Cardiopulmonary Resuscitation

In out-of-hospital CA, the time to initiation of CPR is one of the most important prognostic factors. In contrast, in in-hospital CA, especially that occurring in the pediatric intensive care unit, CPR is begun immediately. Thus, this factor is not a highly important prognostic variable, a finding observed in our study.

The mortality rate was higher among patients who required adrenaline, bicarbonate and volume expansion, as reported in other studies.[1–3,10,11,28] In recent years, some authors have pointed out that agents such as adrenaline and bicarbonate may not be useful and may even increase mortality among CA patients.[29] However, there is insufficient evidence to support this hypothesis. It is unsurprising that the mortality rates among patients who require a greater number of doses of adrenaline or bicarbonate, which are only administered in situations of prolonged or refractory CA, are higher than in those who recover rapidly with massage and ventilation.

Comparative studies carried out in adults with out-of-hospital CA have found that adrenaline initially increases survival, although it has no effect on survival to hospital discharge.[30,31]

With respect to bicarbonate, some studies have reported a slight improvement in survival, whereas others have found no difference.[32,33]

The most consistent prognostic factor in our studies and in those of other authors is the relationship between the duration of CA and mortality,[3] a finding that indicates that any maneuvers and treatments should be undertaken as soon as possible.

In all, 7 patients with refractory CA were resuscitated by means of extracorporeal membrane oxygenation. Other studies have demonstrated that this technique can be an effective rescue treatment in children with in-hospital CA refractory to CPR, but that the availability of a multidisciplinary team, specifically trained and with the necessary material prepared for immediate use, is indispensable. This framework exists in few hospitals, mainly in those with a considerable volume of cardiac surgery.[34]

Limitations

Our study has several limitations. Although it included a large number of hospitals from nearly every region of Spain, randomized sampling was not employed. Thus, our data cannot be extrapolated to the Spanish population as a whole. The comparison with the previous Spanish study should be analyzed with caution because there may be uncontrolled factors that could have influenced the results.

CONCLUSIONS

Survival after in-hospital CA in children has improved significantly in recent years. Training in CPR and the early diagnosis of patients before they reach asystole are probably major factors that explain this improvement. Hematologic/oncologic diseases, receiving continuous infusion of vasoactive drugs at the time of CA, the duration of CPR, and treatment with bicarbonate and volume expansion are the factors associated with mortality before hospital discharge. Comparative studies involving prospective analysis of the effect of these treatments on survival are needed.

CONFLICTS OF INTEREST

None declared.

APPENDIX. RESEARCHERS PARTICIPATING IN THE SPANISH STUDY GROUP OF CARDIOPULMONARY ARREST IN CHILDREN

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Table 3

Multivariate Logistic Regression Analysis Including the Factors That Influenced Mortality

	OR (95%CI)	*P*
History of hematologic/oncologic disease	3.11 (0.86-11.30)	.085
History of heart disease	0.39 (0.17-0.91)	.030
Vasoactive drugs prior arrest	2.24 (1.02-4.94)	.045
Bicarbonate administration	2.15 (0.99-4.68)	.052
Volume expansion	2.01 (0.98-4.44)	.055
Total CPR time ($\geq$20 min)	10.10 (3.82-26.50)	<.001

95%CI, 95% confidence interval; CPR, cardiopulmonary resuscitation; OR, odds ratio. Variables introduced into the model: adrenaline, bicarbonate, volume expansion, cardiopulmonary resuscitation time (>20 min), body weight (<10 kg), history of heart disease, history of hematologic/oncologic disease, history of respiratory disease, history of renal disease, vasoactive drugs, cause of the arrest (cardiac, respiratory, sepsis, others).

(Hospital Germans Trias i Pujol, Badalona), María Elena May Llanas (Hospital Mútua de Terrassa, Terrassa), Abián Montesdeoca Melián (Hospital Universitario de Canarias, Tenerife), Alfredo Reparaz (Complexo Hospitalario Universitario de Vigo), Olivia Pérez Quevedo (Hospital Materno Infantil de Las Palmas, Las Palmas de Gran Canaria), Isabel Lucía Benítez Gómez (Hospital Virgen del Rocío, Seville)

REFERENCES

1. Slonim AD, Patel KM, Ruttimann UE, Pollack MM. Cardiopulmonary resuscitation in pediatric intensive care units. Crit Care Med. 1997;25:1951–5.
2. Suominen P, Olkkola KT, Voipio V, Korpela R, Palo R, Rasanan J. Utstein style reporting of in hospital paediatric cardiopulmonary resuscitation. Resuscitation. 2000;45:17–25.
3. López-Herce J, García C, Dominguez P, Carrillo A, Rodríguez-Núñez A, Calvo C, et al.; Spanish Study Group of Cardiopulmonary Arrest in Children. Characteristics and outcome of cardiorespiratory arrest in children. Resuscitation. 2004;63:311–20.
4. Reis AG, Nadkarni V, Perondi MB, Grisi S, Berg RA. A prospective investigation into the epidemiology of in-hospital pediatric cardiopulmonary resuscitation using the international Utstein reporting style. Pediatrics. 2002;109:200–9.
5. Guay J, Lortie L. An evaluation of pediatric in-hospital advanced life support interventions using the pediatric Utstein guidelines: a review of 203 cardiorespiratory arrests. Can J Anaesth. 2004;51:373–8.
6. Rodríguez-Núñez A, López-Herce J, García C, Carrillo A, Domínguez P, Calvo C, et al.; the Spanish Study Group of Cardiopulmonary Arrest in Children. Effectiveness and long-term outcome of cardiopulmonary resuscitation in paediatric intensive care units in Spain. Resuscitation. 2006;71:301–9.
7. Tibballs J, Kinney S. A prospective study of outcome of in-patient paediatric cardiopulmonary arrest. Resuscitation. 2006;71:310–8.
8. De Mos N, Van Litsenburg RR, McCrindle B, Bohn DJ, Parshuram CS. Pediatric in-intensive-care-unit cardiac arrest: incidence, survival, and predictive factors. Crit Care Med. 2006;34:1209–15.
9. Meert KL, Donaldson A, Nadkarni V, Tieves KS, Schleien CL, Brilli RJ, et al.; Pediatric Emergency Care Applied Research Network. Multicenter cohort study of in-hospital pediatric cardiac arrest. Pediatr Crit Care Med. 2009;10:544–53.
10. Meaney PA, Nadkarni VM, Cook EF, Testa M, Helfaer M, Kaye W, et al.; National Registry of Cardiopulmonary Resuscitation Investigators. Higher survival rates among younger patients after pediatric intensive care unit cardiac arrest. Pediatrics. 2006;118:2424–33.
11. Wu ET, Li MJ, Huang SC, Liu YP, Lu FL, Ko WJ, et al. Survey of outcome of CPR in pediatric in-hospital cardiac arrest in a medical center in Taiwan. Resuscitation. 2009;80:443–8.
12. Nadkarni VM, Larkin GL, Peberdy MA, Carey SM, Kaye W, Mancini ME, et al.; National Registry of Cardiopulmonary Resuscitation Investigators. First documented rhythm and clinical outcome from in-hospital cardiac arrest among children and adults. JAMA. 2006;295:96–8.
13. Olotu A, Ndiritu M, Ismael M, Mohammed S, Mithwani S, Maitland K, et al. Characteristics and outcome of cardiopulmonary resuscitation in hospitalised African children. Resuscitation. 2009;80:69–72.
14. Berens RJ, Cassidy LD, Matchey J, Campbell D, Colpaert KD, Welch T, et al. Probability of survival based on etiology of cardiopulmonary arrest in pediatric patients. Paediatr Anaesth. 2011;21:834–40.
15. International Liaison Committee on Resuscitation. 2005 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. Part 6: Paediatric basic and advanced life support. Resuscitation. 2005;67:271–91.
16. Biarent D, Bingham R, Eich C, López-Herce J, Maconochie I, Rodríguez-Núñez A, et al. European Resuscitation Council Guidelines for Resuscitation 2010 Section 6. Paediatric life support. Resuscitation. 2010;81:1364–88.
17. De Caen AR, Kleinman ME, Chameides L, Atkins DL, Berg RA, Berg MD, et al.; Paediatric Basic and Advanced Life Support Chapter Collaborators. Part 10: Paediatric basic and advanced life support: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. Resuscitation. 2010;81 Suppl 1:e213–59.
18. Donoghue AJ, Nadkarni VM, Elliott M, Durbin D; American Heart Association National Registry of Cardiopulmonary Resuscitation Investigators. Effect of hospital characteristics on outcomes from pediatric cardiopulmonary resuscitation: a report from the national registry of cardiopulmonary resuscitation. Pediatrics. 2006;118:995–1001.
19. López-Herce J, Del Castillo J, Matamoros M, Cañadas S, Rodriguez-Calvo A, Cecchetti C, et al.; Iberoamerican Pediatric Cardiac Arrest Study Network RIBEPCI. Factors associated with mortality in pediatric in-hospital cardiac arrest: a prospective multicenter multinational observational study. Intensive Care Med. 2013;39:309–18.
20. Cummins R, Chamberlain D, Hazinski MF, Nadkarni V, Kloek W, Kramer E. Recommended guidelines for reviewing, reporting, and conducting research on in hospital resuscitation: the in-hospital "Utstein style". Resuscitation. 1997;34:151–83.
21. Jacobs I, Nadkarni V, Bahr J, Berg RA, Billi JE, Bossaert L, et al.; International Liaison Committee on Resuscitation; American Heart Association; European Resuscitation Council; Australian Resuscitation Council; New Zealand Resuscitation Council; Heart and Stroke Foundation of Canada; InterAmerican Heart Foundation; Resuscitation Councils of Southern Africa; ILCOR Task Force on Cardiac Arrest and Cardiopulmonary Resuscitation Outcomes. Cardiac arrest and cardiopulmonary resuscitation outcomes reports: update and simplification of the Utstein templates for resuscitation registries: A statement for healthcare professionals from a task force of the international liaison committee on resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Councils of Southern Africa). Circulation. 2004;110:3385–97.
22. López-Herce J, Carrillo A; Iberoamerican Network for Study of Cardiorespiratory Arrest in Childhood. A survey on training in pediatric cardiopulmonary resuscitation in Latin America, Spain, and Portugal. Pediatr Crit Care Med. 2011;12:e200–4.
23. Carrillo Álvarez A, López-Herce Cid J, Moral Torrero R, Sancho Pérez L, Vigil Escribano D. Evaluación de los cursos de reanimación cardiopulmonar básica y avanzada en pediatría. An Esp Pediatr. 2000;53:125–34.
24. Morrison LJ, Neumar RW, Zimmerman JL, Link MS, Newby LK, McMullan PW, et al. Strategies for improving survival after in-hospital cardiac arrest in the United States: 2013 consensus recommendations: a consensus statement from the American Heart Association. Circulation. 2013;127:1538–63.
25. Sharek PJ, Parast LM, Leong K, Coombs J, Earnest K, Sullivan J, et al. Effect of a rapid response team on hospital-wide mortality and code rates outside the ICU in a children's hospital. JAMA. 2007;298:2267–74.
26. Tibballs J, Kinney S. Reduction of hospital mortality and of preventable cardiac arrest and death on introduction of a pediatric medical emergency team. Pediatr Crit Care Med. 2009;10:306–12.
27. Moler FW, Meert K, Donaldson AE, Nadkarni V, Brilli RJ, Dalton HJ, et al.; Pediatric Emergency Care Applied Research Network. In-hospital versus out-of-hospital pediatric cardiac arrest: a multicenter cohort study. Crit Care Med. 2009;37:2259–67.
28. Smith GB. In-hospital cardiac arrest: is it time for an in-hospital 'chain of prevention'? Resuscitation. 2010;81:1209–11.
29. Nolan JP, Perkins GD. Is there a role for adrenaline during cardiopulmonary resuscitation? Curr Opin Crit Care. 2013;19:169–74.
30. Jacobs IG, Finn JC, Jelinek GA, Oxer HF, Thompson PL. Effect of adrenaline on survival in out-of-hospital cardiac arrest: a randomised double-blind placebo-controlled trial. Resuscitation. 2011;82:1138–43.
31. Olasveengen TM, Wik L, Sunde K, Steen PA. Outcome when adrenaline (epinephrine) was actually given vs. not given — post hoc analysis of a randomized clinical trial. Resuscitation. 2012;83:327–32.
32. Weng YM, Wu SH, Li WC, Kuo CW, Chen SY, Chen JC. The effects of sodium bicarbonate during prolonged cardiopulmonary resuscitation. Am J Emerg Med. 2013;31:562–5.
33. Vukmir RB, Katz L; Sodium Bicarbonate Study Group. Sodium bicarbonate improves outcome in prolonged prehospital cardiac arrest. Am J Emerg Med. 2006;24:156–61.
34. Huang SC, Wu ET, Wang CC, Chen YS, Chang CI, Chiu IS, et al. Eleven years of experience with extracorporeal cardiopulmonary resuscitation for paediatric patients with in-hospital cardiac arrest. Resuscitation. 2012;83:710–4.