RESEARCH PAPER

Impact of System Factors and Modifiable ICU Interventions on the Outcome of Cardio-pulmonary Resuscitation in PICU

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Received: December 19, 2013; Initial review: January 21, 2014; Accepted: March 10, 2015.

Objectives: To assess the impact of system factors and modifiable interventions on outcome of cardiac arrest in a pediatric intensive care unit.

Design: Retrospective medical record review.

Setting: Pediatric intensive care unit of a hospital in China.

Participants: Children (age<14 yrs) who had cardiac arrest within our PICU over a period of two years.

Results: Sixty-one of the 94 cardiac arrest events were successfully resuscitated. There was no significant association between personal and unit factors with immediate outcomes in our unit. The rate of unsuccessful resuscitation in sedated patients and those without sedation was 26% and 50%, respectively. Unsuccessful resuscitation occurred in 19% of patients who were on positive pressure ventilation as compared with 74% for those without positive pressure ventilation. Arrests which had resuscitation attempts that lasted more than 30 min had 135-fold higher odds of unsuccessful outcome. 78% of patients who received base supplement at the time of arrest had unsuccessful resuscitation compared with 21% for those without base supplement.

Conclusions: Our data shows no impact of system factors on the outcome of cardio-pulmonary resuscitation in our PICU. Pre-arrest sedation in pediatric critical ill patients might be beneficial to the outcome of cardiac arrests.

Keywords: *Mortality, Outcome, Predictors, Resusci-tation.*

Cardiac arrest occurs in 2%-6% of children admitted to a Pediatric intensive care (PICU) unit [1,2]. Successful resuscitation (return of spontaneous circulation) after in-hospital cardiac arrest has been reported in 70% to 80% of pediatric patients, while survival to hospital discharge was seen in only about half of those successfully resuscitated [3,4]. Identification of modifiable risk factors for cardiac arrest might help to improve resuscitation outcomes.

Previous studies evaluating the occurrence of and outcome after cardiac arrest in pediatric critical care environments have focused primarily on patient-specific and perioperative factors, features of the arrest, and the resuscitation interventions [5-7]. Investigations focused on system factors of pediatric cardiac arrest are scarce [8-10]. We assessed the impact of system factors (timing and date of cardiac arrest, nursing experience, staffing of the unit) and modifiable intensive care unit (ICU) interventions (sedation, analgesia, central venous access) on outcome from cardiac arrest in a Pediatric intensive care unit.

METHODS

We performed a retrospective chart review of every documented cardiac arrest from April 1, 2011 to April 30, 2013, that occurred within the PICU at the First Affiliated Hospital of Sun Yat-sen University, China. The study was approved by Institutional review board.

The PICU of this hospital is a dedicated 8-bed unit with two pediatricians on round-the-clock duty (a resident and a fellow). Additionally, 4-5 doctors are present in the unit from Monday to Friday during the day time. There are 3-4 nurses at daytime and 2-3 nurses at night. All nurses and physicians are trained in Pediatric Advanced Life Support. All patients undergo cardiopulmonary monitoring in PICU. Every bed is equipped with an emergency cart providing items and medicines for resuscitation.

Sedation, analgesia and central venous access were listed as modifiable pre-arrest interventions. Sedation and analgesia were used more often in patients who had surgical interventions, seizures, mechanical ventilation, or prolonged hospital stay. Agents for sedation and analgesia in our PICU included Fentanyl, Morphine and Midazolam. The incremental increase or decrease in the amount of medication administered is based on the use of formal sedation scores, along with the nurse's assessment of the patient's vital signs.

Children (<14 y of age) who received active chest compressions during cardiopulmonary resuscitation for in-

hospital cardiac arrest were included. Cardiac arrest was defined as event requiring active chest compression for any duration. Only the first cardiac arrest during a patient's hospitalization was included in analysis. Patients' demographic and clinical data (age, gender, pre-existing disorder) were collected from the medical records. Details of the resuscitation (mechanical ventilation, central venous access, positive pressure ventilation, chest compressions, tracheal intubation, and duration of resuscitation) were extracted from the nursing record, which was completed by the bedside nurse. Information of medications (sedation, analgesia, epinephrine, antiarrhythmics, and vasoactive support) used in the resuscitation was collected from the physician's order sheet. Relevant investigation reports were collected from the inspection sheets.

The time of arrest since PICU admission was categorized into: <24 hrs or ≥24 hrs. The timing of arrest was categorized into one of four categories: weekday day (8 AM to 6 PM, Monday-Friday), weekday night (6 PM to 8 AM, Monday-Friday), weekend day (8 AM to 6 PM, Saturday and Sunday), weekend night (6 PM to 8 AM, Saturday and Sunday). The experience of the bedside nurse was categorized based on the number of years in our PICU: <1yr or ≥1yr.

The endpoint was successful resuscitation (return of spontaneous circulation) during cardiac arrest. Return of spontaneous circulation was defined as the restoration of a pulse for at least 20 minutes during the cardiac arrest.

The associations with arrest outcome were evaluated using Fisher's exact test. System Variables, modifiable clinic interventions and variables with $P<0.1$ were entered into a multivariable logistic model to determine their independent contributions to the outcome. A forward-selection procedure was used for entry of variables into the multivariate model, and a variable inclusion criterion was set at $P\leq0.05$. Statistical significance was set at probability value ≤0.05. All analysis was performed using SPSS version13.0.

RESULTS

We retrieved records of 94 patients who had cardiac arrest at our PICU from April 2011 to April 2013. Sixty-one (65%) of the 94 arrest events were successfully resuscitated. Overall survival (to discharge from hospital) for patients having an arrest was 34%. Patients' pre-existing disorders are shown in ***Table* I**.

The results of univariate analyses are shown in ***Table* II**. For multivariate analysis, system variables (time of arrest since PICU admission, timing of cardiac arrest, experience of bedside nurse), modifiable clinic interventions (sedation, analgesia, central venous access) and variables with $P<0.1$ (positive pressure ventilation, base supplement, duration of resuscitation, tracheal intubation) were used to construct a multivariable model. Sedation, positive pressure ventilation, base supplement

TABLE I CHARACTERISTICS OF PATIENTS (*N=94*)

Characteristic	*No.* (%)
Age ≤1 y	46 (49%)
Male gender	56 (60%)
Pre-existing disorders	24 (26%)
Renal insufficiency	32 (34%)
Hepatic insufficiency	38 (41%)
Cardiac insufficiency	76 (81%)
Pneumonia or respiratory failure	14 (15%)
Neurologic disease	38 (40%)
Hypotension or hypertension	23 (24%)
Immunodeficiency	28 (30%)
Malignant disease	66 (70%)
Septicemia	38 (40%)
Post-surgical electrolyte disturbance	23 (24%)

TABLE II FACTORS ASSOCIATED WITH UNSUCCESSFUL RESUSCITATION (*N=33*)

	Unsuccessful resuscitation No. (%)	*P value*
System variables		
Duration since admission <24 h	9 (60%)	0.047
Timing of arrest (8:00-18:00)	15 (36%)	1.000
Date of arrest: Weekday	8 (11%)	0.451
Experience of bedside nurse <1 y	11 (23%)	0.388
Pre-arrest interventions		
Mechanical ventilation	27 (33%)	0.764
Vasoactive support	25 (39%)	0.259
Sedation	16 (26%)	0.027
Analgesia	4 (23%)	0.401
Central venous access	12 (25%)	0.130
Interventions at the time of arrest		
Positive pressure ventilation	13 (19%)	0.001
Tracheal intubation	9 (21%)	0.029
Epinephrine	32 (37%)	0.253
Antiarrhythmics	15 (45%)	0.174
Base supplement	18 (78%)	0.001
Calcium supplement	3 (60%)	0.340
Duration of resuscitation <30min	4 (8%)	0.001

WHAT IS ALREADY KNOWN?

- Successful resuscitation after cardiac arrest is common in in-patient children in intensive care setting.

WHAT THIS STUDY ADDS?

- Successful resuscitation is more common in children who receive sedation.
- Arrests where resuscitation continue for >30 min, and those associated with acid-base disturbances, have lesser odds of successful resuscitation.

and duration of resuscitation remained significantly associated with outcome. Arrests in sedated patients had lower odds of unsuccessful resuscitation relative to those in patients who were not on sedation (26% *vs*. 50%, OR 0.07 95% CI 0.01-0.43). Patients who were on positive pressure ventilation at the time of arrest were more likely for have unsuccessful resuscitation as compared to those without positive pressure ventilation (OR 0.01, 95% CI 0.001-0.101). Arrests where resuscitation attempts lasted more than 30 min had markedly higher odds of unsuccessful outcome (74% *vs.* 8%, OR 135, 95% CI 10-1806). Patients who received base supplement at the time of arrest were more likely to be unsuccessfully resuscitated than those without base supplement (78% *vs.* 21%; OR 17.7, 95% CI 2.1-120.0).

DISCUSSION

In the present study, sedation, positive pressure ventilation and duration of resuscitation were significantly associated with immediate outcome of resuscitation in PICU patients.

There are several limitations to this study. The data were collected retrospectively from a single center which may affect its generalizability. As we collected data from medical records, subjectivity may be a problem. However, we made efforts to ensure that all variables in analyses were collected from objective data. In addition, the small sample size limited our ability to further assess the pre-arrest clinical status, which may be an important factor influencing resuscitation outcome. Outcomes over long-term were also not evaluated in our study.

There was no significant association between system factor variables (time of arrest since PICU admission, timing and date of cardiac arrest nursing experience) and unsuccessful resuscitation in our unit. This result is different from a recent study [8] which reported that less experience of the primary nurse caring for a patient, and weekend timing of an arrest event may increase the likelihood of failure to resuscitate cardiac arrest in a dedicated pediatric cardiac ICU [8]. Other reports also suggest that nurses are greater experience are more likely to provide rapid diagnosis of cardiac arrest and pre-arrest intervention to prevent arrest in pediatric patients [11-14]. In our PICU, the nursing staff are usually arranged in pairs to ensure that every shift includes an experienced nurse. In addition, two doctors on duty always stay in the unit round-the-clock, both during weekdays and weekends. This staffing model might have been responsible for different results in our study. Our study results suggested that sedation may benefit pediatric critically ill patients. Sedation could facilitate mechanical ventilation, create anxiolysis, analgesia, amnesia, decrease oxygen consumption and reduce dyspnea, thus to increase tolerance to hypoxia, and lead to improved successful resuscitation. However, patients with more severe conditions, such as coma, did not receive sedation in our study. Positive pressure ventilation was also associated with better outcome of successful resuscitation in our study. Positive pressure ventilation provided immediate respiratory support and therefore was beneficial for children with cardiac arrest, who mainly develop arrest secondary to respiratory factors [15,16].

No impact of system factors and central venous access on the outcome of cardio-pulmonary resuscitation in our PICU might be relevant to appropriate staffing models. We conclude that pre-arrest sedation in pediatric critical ill patients might be beneficial to the outcome of cardiac arrests. Arrests which have resuscitation attempts >30 min and arrests caused by acid-base disturbance predict a poor prognosis.

Acknowledgments: Hong Chen and Xi Chen for language editing. An-Bin Hu for valuable advice in the design of the study. Yi Cao for his help in the statistical analysis.

Contributors: WT: conceived and designed the study and revised the manuscript for important intellectual content. He will act as guarantor of the study; HMH, YJL, XQH, LLX, LDZ: collected data, drafted the paper, analyzed the data and helped in manuscript writing. The final manuscript was approved by all authors.

Funding: National Clinical Priority Specialty Construction Project and Sun Yat-sen University Research Project 5010; Number 2007015; *Competing interests*: None stated.

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