

Cerebral oxygen saturation monitoring in pediatric cardiopulmonary resuscitation patients in the emergency settings: A small descriptive study

Aykut Çağlar, Anıl Er, Emel Ulusoy, Fatma Akgül, Hale Çitlenbik, Durgül Yılmaz, Murat Duman

Division of Pediatric Emergency Medicine, Department of Pediatrics, Dokuz Eylul University Faculty of Medicine, İzmir, Turkey. E-mail: mduman@deu.edu.tr

Received: 27th February 2017, Accepted: 2nd April 2017

SUMMARY: Çağlar A, Er A, Ulusoy E, Akgül F, Çitlenbik H, Yılmaz D, Duman M. Cerebral oxygen saturation monitoring in pediatric cardiopulmonary resuscitation patients in the emergency settings: A small descriptive study. Turk J Pediatr 2017; 59: 642-647.

Near infrared spectroscopy (NIRS) is a new technology for monitoring cardiopulmonary resuscitation (CPR). The use of NIRS has advantages in monitoring cerebral oxygenation in cardiac arrest patients. The aim of this study was to describe cerebral regional oxygen saturation (CrSO₂) values in a small cohort of pediatric out-of-hospital cardiac arrest patients and to determine if there is an association with CrSO₂ and return of spontaneous circulation (ROSC).

All the out-of-hospital cardiac arrest patients admitted to our pediatric emergency department were included in this prospective study. All patients were monitored through NIRS in addition to standard monitoring during CPR. All cerebral rSO₂ measurements were obtained with an INVOS 5100C cerebral/somatic oximeter. Cardiopulmonary resuscitation was performed according to the Pediatric Advanced Life Support 2010 guidelines. The patients were classified as ROSC and non - ROSC. Ten patients were included in this study. The median age of patients was 40.0 (14.0-88.2) months. Three (30%) of the 10 patients achieved sustained ROSC. Abrupt increase in cerebral regional oxygen saturation (CrSO₂) was observed in all 3 of these patients. Minimum values of the CrSO₂ were significantly lower and the percentage of median time with CrSO₂ under 30% of CrSO₂ were significantly higher in the non - ROSC group (p=0.02). Our study indicated that the patients in the non - ROSC group have lower minimum CrSO₂ value. Additionally, abrupt increase of CrSO₂ during CPR could be an indicator for ROSC.

Key words: cerebral oximetry, pediatric, cardiac arrest, regional cerebral oxygen saturation, near infrared spectroscopy.

In cardiac arrest (CA) patients, the primary goal is to maintain normal brain activity after cardiopulmonary resuscitation (CPR). In past decades, many enhancements have been developed for high quality CPR to achieve better neurologic outcomes. Current guidelines suggest the use of end tidal CO₂ (ETCO₂) to determine return of spontaneous circulation (ROSC). Evidence concerning the use of capnography in pediatric CA patients

is inadequate in contrast to adults.^{1,2} The main disadvantage of the capnography is the necessity of an advanced airway with an effective tidal volume, and there are also some limitations in situations including the blockage of endotracheal intubation tube via secretion or blood.³ Additionally, in patients who have long CPR periods, ETCO₂ cannot be truly determinative due to pulmonary edema.⁴

The near infrared spectroscopy (NIRS) device is a monitor that can measure oxygenation of tissue with infrared technology similar to the pulse oximetry. Pulse oximeter measures only oxyhemoglobin in pulsatile tissue whereas NIRS can measure the difference between oxyhemoglobin and deoxyhemoglobin levels 2-3 cm below the sensor applied to the forehead region. This measurement reflects regional oxygenation of arterial, venous and capillary tissues in the frontal lobe of the brain. More importantly, NIRS does not required arterial pulsation in contrast to the pulse oximeter.⁵

This difference is an advantage for NIRS use in CA patients. The use of NIRS in CA patients has increased in the few years prior to this study. The reports about whether the use of NIRS can be an indicator or not for ROSC are dominating the studies in the adult population⁶, but there are few studies that aim to determinate a cut of value of CrSO₂ for futility of CPR.⁷⁻⁹ Pediatric studies about NIRS use in CA patients are limited to cardiac surgery patients.¹⁰ So we designed a descriptive study to investigate how useful monitoring CrSO₂ is during CPR as a method for determination of ROSC or futility of CPR in pediatric out – of – hospital cardiac arrest (OHCA) patients in the emergency department (ED).

Material and Methods

Setting and design

We enrolled 17 OHCA patients in this prospective study between March 2014 and March 2016. All patients younger than 18 years of age with CA were included in this study. This study excluded patients with chronic cyanotic cardiac disease, pulmonary disease, frontal head trauma or intracranial injury.

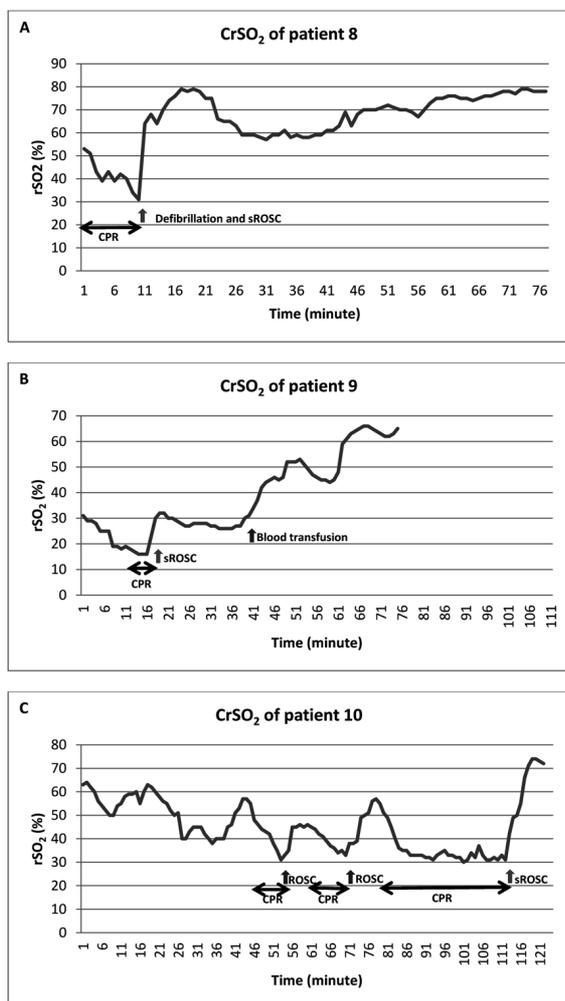


Fig.1. Abrupt increments of CrSO₂ were observed in 3 patients. (A) The CrSO₂ value of Patient 8 increased abruptly immediately after defibrillation. (B) Abrupt increments were observed in Patient 9 despite severe anemia. (C) In Patient 10, 3 CPR episodes were performed, but sustained ROSC was achieved with continued high levels of CrSO₂. ROSC: Return of spontaneous circulation, sROSC: Sustained ROSC

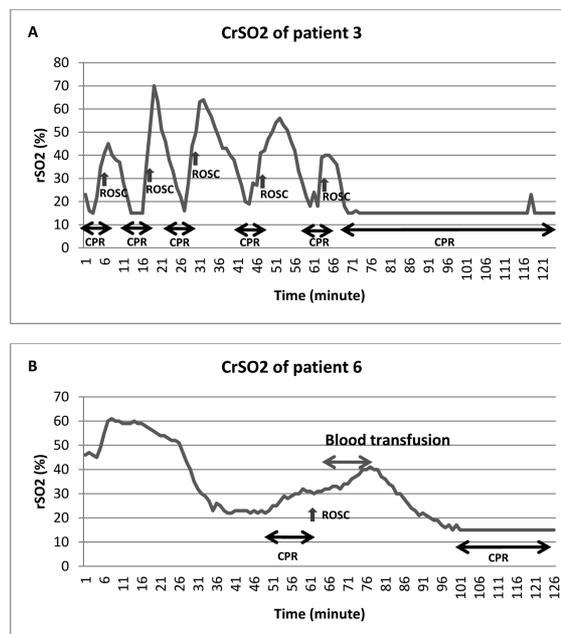


Fig. 2. Demonstration of sROSC is needed to continue high levels of CrSO₂. (A) Patient 3 had 5 ROSC episodes after 2 minutes of CPR episodes. (B) Patient 6 achieved ROSC, but the CrSO₂ value could not increase to higher levels even with a blood transfusion. ROSC: Return of spontaneous circulation, sROSC: Sustained ROSC

Table I. Patients' Characteristic Features and Prehospital Data.

Patient	Age (m)	Sex	Etiology	Body temp	Arrival time to ED from scene (min)	Total duration of CPR before ED (min)	Initial rhythm in the ED
1 ^{ab}	2	M	Heat stroke	32.5	120	80	Tachy
2 ^b	62	M	Head trauma	34.0	40	40	Asy
3 ^c	18	M	Septic shock	34.0	10	0	Tachy
4	14	F	Multiple trauma	34.2	8	8	Asy
5 ^{ab}	14	F	Septic shock	35.0	35	30	Tachy
6 ^{ab}	64	M	Drowning	34.0	120	80	Tachy
7 ^b	67	F	Asphyxia	36.0	75	75	Asy
8	152	F	VT	35.6	15	15	VT
9 ^a	17	M	Multiple trauma	35.0	15	10	Tachy
10 ^a	158	F	Unknown	34.8	10	2	Tachy

^a Five patients have achieved ROSC after CPR before admission to the ED.

^b These patients had recurrent CPR episodes before admission to the ED.

Table II. Patients' CPR Characteristics, and Cerebral rSO₂ Values in the ED.

Patient	Initial rhythm when CPR started	Duration of CPR in the ED (min)	CPR episodes in the ED	sROSC	Hospital discharge status	CrSO ₂ values				
						On admission to the ED	CrSO ₂ during CPR			
						Initial	Lowest	Highest	Avg	
1	Brady	45	1	No	Death	31	15	15	15	15.0
2	Asy	42	1	No	Death	33	33	29	51	41.0
3 ^a	Brady	57	6	No	Death	23	16	15	23	15.3
4	Asy	45	1	No	Death	31	31	25	42	28.4
5	Brady	30	1	No	Death	24	24	23	30	25.7
6 ^a	Brady	52	2	No	Death	22	17	15	15	15.0
7	Asy	45	1	No	Death	45	45	23	48	34.1
8	VT	35	1	Yes	Alive	37	37	31	53	41.5
9	Brady	4	1	Yes	Death	30	32	29	32	30.6
10 ^a	Brady	51	3	Yes	Death	46	48	30	57	38.4

ROSC: Return of spontaneous circulation, sROSC: Sustain ROSC, ED: Emergency department, CPR: Cardiopulmonary resuscitation, Tachy: Tachycardia, Asy: Asystole, VT: Ventricular tachycardia, CrSO₂: Cerebral regional oxygen saturation, Avg: Average.

^aThese patients had recurrent CPR episodes in the ED, the values shown in the table belong to the last episodes of the patients.

Consistent with the Pediatric Advanced Life Support 2010 guidelines, CPR was performed on all patients by pediatric emergency physicians and pediatric residents. All patients were monitored by nursing staff with a pulse oximeter and by electrocardiogram (ECG).

In addition, ETCO₂ monitoring was used for patients with an advanced airway. The characteristic features related to CPR were recorded as such: initial rhythm on admission to the ED and at the start of the CPR, elapsed time until admission to the ED, total duration

Table III. Patients' Laboratory Data.

Patient	Hb	pH	pCO ₂	HCO ₃	BE	Lactate
1	9.1	7.1	56.5	16.8	-8.1	13.8
3	12.0	6.8	66.6	7.7	-20.8	17.0
5	12.1	7.1	43.4	15.0	-11.2	0.8
6	5.3	6.6	58.7	5.1	-25.7	18.0
8	14.6	7.0	63.1	10.9	-14.4	7.2
9	2.7	6.9	51.5	8.6	-20.2	7.9
10	15.0	7.0	72.4	11.6	-12.2	7.2

Blood test can be obtained in 7 patients. The median (IQR) timing of drawing blood was 5.0 minutes from admission to the ED(5.0 – 7.0).

of CPR in the ED and before admission to the ED, ROSC and sustained ROSC if achieved. ROSC was defined as the presence of arterial pulsation after CPR. If ROSC continued longer than 20 minutes, a terminology of sustained ROSC was used.

Near-infrared spectroscopy probe was administered using adhesive strips to the right and left frontal area by a paramedic. All cerebral rSO₂ measurements were obtained with an INVOS 5100C cerebral/somatic oximeter (Covidien, Mansfield, MA, USA). Cerebral monitoring was continued until CPR was terminated or until patients who achieved sustained ROSC were transferred to the pediatric intensive care unit.

This study was approved by the Dokuz Eylul University Faculty of Medicine Clinical Research Ethics Committee. Financial assistance has not been received for this study

Statistical method

Statistical analysis was performed using SPSS Software 16.0. If the numerical data fit the normal distribution, mean ± standard deviation were calculated, if the numerical data did not fit a normal distribution median, the interquartile range (IQR) 25–75 percentile was calculated. The Mann–Whitney U test was used to compare the variables that did not fit normal distribution. The definitive chi-square test was used for the numerical variables. Statistical significance was accepted as $p < 0.05$ for all tests.

Results

Seventeen OHCA patients were originally included in this study. Seven patients were

excluded: 3 due to technical problems, 2 who had congenital cyanotic cardiac disease, and 2 who had frontal hematoma due to trauma. A total of 10 patients were included in the study. The median (IQR) age of patients was 40.0 (14.0–88.2) months. Five of the 10 patients were boys. The characteristics of the patients are summarized in Table I and II. Cardiopulmonary resuscitation was performed in 9 of the 10 patients by the physicians of the emergency medical transport services prior to arrival at the ED. In 5 of the 9 patients, ROSC was restored and they had tachycardia on admission and CPR was started again when their heart rates decreased under 60/min. The median time of the duration of CPR before the arrival to the ED and the elapsed time until admission to the ED were 22.5 (6.5–76.2) and 25.0 (10.0–86.2) minutes, respectively. The median duration of CPR in the ED was 45.0 (33.7–51.2) minutes. All patients were monitored with a pulse oximeter and ECG. ETCO₂ measurement was obtained in only 3 patients, as 3 patients had pulmonary hemorrhages. Four patients did not have an advanced airway for avoiding interruption of chest compression because ventilation via bag valve mask was provided effectively. Blood specimens were obtained in 7 of 10 the patients. Laboratory parameters of the patients are summarized in Table III. Three (30%) of 10 patients achieved sustained ROSC. Abrupt increases in cerebral regional oxygen saturation (CrSO₂) were observed in these 3 patients (Fig 1). After ROSC, the average CrSO₂ of the patients (patients 8, 9, and 10) were 69.3%, 44.6%, and 68.8%; respectively. Patient 9 had severe anemia due to splenic injury, his increments of CrSO₂ continued to

Table IV. Comparison of Groups with and without ROSC.

Parameters	ROSC		p ^b
	Yes (n=3)	No (n=7)	
Percentage of median time with CrSO ₂ under 30%	0.0 (0.0–25.0) ^b	100 (27–100)	0.02
CrSO ₂ values on admission	37.0 (30.0–46.0)	31.0 (23.0–33.0)	0.20
Initial CrSO ₂ during CPR	24.0 (16.0–33.0)	37.0 (32.0–48.0)	0.08
Median CrSO ₂ in the last 5 minutes	31.5 (29.5 – 31.5)	26.2 (15.0–30.3)	0.08
Minimum CrSO ₂ during CPR*	30.0 (±1.0)	20.7 (±5.7)	0.02
Maximum CrSO ₂ during CPR	53.0 (32.0– 57.0)	30.0 (15.0–48.0)	0.08
Average CrSO ₂ during CPR	38.4 (30.6–41.5)	25.7 (15.0–34.1)	0.08
Duration of resuscitation in the ED	35.0 (4.0–51.0)	45.0 (42.0–52.0)	0.29
Hemoglobin (g/dl)	14.6 (2.7–15.0)	10.5 (6.2–12.0)	0.48
Body Temperature (°C)*	35.1 (±0.41)	34.2 (±1.0)	0.16

Values are median (interquartile range)

*Values are mean (±SD)

^avalue is median (min – max)

^bMann-Whitney U test was used to compare the 2 groups.

increase markedly after transfusion of red blood cells. Comparisons between the patients with and without ROSC are summarized in Table IV. Minimum values of CrSO₂ were significantly higher and the percentage of median time with CrSO₂ under 30% of CrSO₂ were significantly lower in the ROSC group (p=0.02) Patients 9 and 10 died in the pediatric intensive care unit and patient 8 survived with mild neurologic deficits (cerebral performance category scale 1).

Informed consent was obtained from the patients' parents.

Discussion

In all pediatric OHCA patients, the primary goal is to maintain normal cerebral function after ROSC by high quality CPR. In the current study, we aimed to determine whether using NIRS is a useful method for monitoring CPR in ED settings. There are controversial studies in the literature about monitoring CPR with cerebral rSO₂. To our knowledge, this is the first prospective cohort study of pediatric OHCA patients in the literature. Although Newman et al.¹¹ found that CrSO₂ had no effect on CPR, some studies with opposing findings have been published recently.^{8,12-14} Newman et al.¹¹ reported that cerebral oxygenation is rarely detectable in OHCA patients and they concluded that this result is due to a longer time from the arrest event to the initial measurements. Another study enrolling 33

OHCA patients with a CrSO₂ value of 15% reported that all 33 patients died, and the authors indicated that the data might predict the futility of CPR. In our study, 2 patients with the longest CPR period before arrival to the ED had no change of CrSO₂ during CPR. This finding was consistent with previous studies.^{9,11}

There is no absolute threshold for CrSO₂ value to determine the futility of CPR. Fukuda et al.⁷ reported that lower CrSO₂ values may be a predictor for non-ROSC. Also, in another study, none of the patients with CrSO₂ below 30% achieved ROSC.⁸ In a large multicenter study with adult patients which was reported by Parnia et al.¹⁵, while negative predictive value for prediction of ROSC was found 100% in values of CrSO₂ greater than 25%, whereas positive predictive value was found 93% for the prediction of ROSC in values of CrSO₂ greater than 65%. In our study, 3 of 10 patients achieved sustained ROSC. We found that the lowest CrSO₂ and percentage of median time with CrSO₂ under 30% were statistically different in the ROSC group, consistent with previous reports.^{7,15} Although a few studies reported that higher mean or median CrSO₂ values might predict ROSC, we did not detect any difference for median and higher CrSO₂ values between the ROSC and non-ROSC groups. We attributed this result to the limited number of patients and the long CPR durations

of patients before arrival to the ED.

Abrupt increase of CrSO₂ after ROSC have been documented in recently published studies.¹¹⁻¹⁶ Parnia et al.¹² reported that higher CrSO₂ value in the last 5 minutes is more important than abrupt increase for prediction of sustained ROSC. Also in a large series study by the same author, the mean CrSO₂ value in the last 5 minutes was highlighted as a major predictive factor for ROSC¹⁵. In our study, ROSC occurred in 5 patients, 3 of whom had recurrent CPR episodes. We observed sustained ROSC only in 3 of 5 patients with continued high levels of CrSO₂ after ROSC. This data was consistent with our results. However, we found that there was not a statistically significant difference between groups for the median CrSO₂ value in the last 5 minutes but we thought that these result was related with our limited patient number. The major limitation of this study was the small number of patients sampled. In addition, all patients had different lengths of time between the performing time between cardiac arrest and the initiation of NIRS measurement. Further studies are warranted to clarify whether there is role of CrSO₂ in pediatric CPR.

In conclusion, the main result of this small descriptive study is that minimum CrSO₂ value is lower in the non – ROSC patient group. And also, abrupt increase of CrSO₂ during CPR can be an indicator for ROSC, but ongoing high levels of CrSO₂ values should be maintained for sustained ROSC. Further evaluation of NIRS during pediatric CPR may be helpful to reach more accurate results.

REFERENCES

1. Maconochie IK, de Caen AR, Aickin R, et al. Part 6: Pediatric basic life support and pediatric advanced life support: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. *Resuscitation* 2015; 95 :e147-e168.
2. Link MS, Berkow LC, Kudenchuk PJ, et al. Part 7: Adult Advanced Cardiovascular Life Support: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation* 2015; 132: S444-S464.
3. Kodali BS, Urman RD. Capnography during cardiopulmonary resuscitation: Current evidence and future directions. *J Emerg Trauma Shock* 2014; 7: 332-340.
4. Peberdy MA, Callaway CW, Neumar RW, et al. Part 9: Post-Cardiac Arrest Care: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation* 2010; 122: S768-S786.
5. Marin T, Moore J. Understanding near-infrared spectroscopy. *Advances in neonatal care : official journal of the National Association of Neonatal Nurses* 2011; 11: 382-388.
6. Sanfilippo F, Serena G, Corredor C, et al. Cerebral oximetry and return of spontaneous circulation after cardiac arrest: A systematic review and meta-analysis. *Resuscitation* 2015; 94: 67-72.
7. Fukuda T, Ohashi N, Nishida M, et al. Application of cerebral oxygen saturation to prediction of the futility of resuscitation for out-of-hospital cardiopulmonary arrest patients: a single-center, prospective, observational study: can cerebral regional oxygen saturation predict the futility of CPR? *Am J Emerg Med* 2014; 32: 747-751.
8. Ahn A, Nasir A, Malik H, D'Orazi F, Parnia S. A pilot study examining the role of regional cerebral oxygen saturation monitoring as a marker of return of spontaneous circulation in shockable (VF/VT) and non-shockable (PEA/Asystole) causes of cardiac arrest. *Resuscitation* 2013; 84: 1713-1716.
9. Ito N, Nanto S, Nagao K, Hatanaka T, Kai T. Regional cerebral oxygen saturation predicts poor neurological outcome in patients with out-of-hospital cardiac arrest. *Resuscitation* 2010; 81:1736-1737.
10. Abramo T, Aggarwal N, Kane I, Crossman K, Meredith M. Cerebral oximetry and cerebral blood flow monitoring in 2 pediatric survivors with out-of-hospital cardiac arrest. *Am J Emerg Med* 2014; 32: 394 e5- e10.
11. Newman DH, Callaway CW, Greenwald IB, Freed J. Cerebral oximetry in out-of-hospital cardiac arrest: standard CPR rarely provides detectable hemoglobin-oxygen saturation to the frontal cortex. *Resuscitation* 2004; 63: 189-194.
12. Parnia S, Nasir A, Shah C, et al. A feasibility study evaluating the role of cerebral oximetry in predicting return of spontaneous circulation in cardiac arrest. *Resuscitation* 2012; 83: 982-985.
13. Kamarainen A, Sainio M, Olkkola KT, et al. Quality controlled manual chest compressions and cerebral oxygenation during in-hospital cardiac arrest. *Resuscitation* 2012; 83: 138-142.
14. Schewe JC, Thudium MO, Kappler J, et al. Monitoring of cerebral oxygen saturation during resuscitation in out-of-hospital cardiac arrest: a feasibility study in a physician staffed emergency medical system. *Scand J Trauma Resusc Emerg Med* 2014; 22: 58.
15. Parnia S, Yang J, Nguyen R, et al. Cerebral oximetry during cardiac arrest: A multicenter study of neurologic outcomes and survival. *Crit Care Med* 2016; 44: 1663-1674.
16. Meex I, De Deyne C, Dens J, et al. Feasibility of absolute cerebral tissue oxygen saturation during cardiopulmonary resuscitation. *Crit Care* 2013; 17: R36.