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Original Contribution

Near infrared spectrophotometry (cerebral oximetry) in predicting the return of spontaneous circulation in out-of-hospital cardiac arrest

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ABSTRACT

Aim: We assessed out-of-hospital cardiac arrest patients' cerebral oxygenation during cardiopulmonary resuscitation (CPR) using near infrared spectrophotometry (NIRS). We evaluated the relation between a rise in patients' cerebral saturation values between the start and end of CPR and return of spontaneous circulation.
Materials and methods: Twenty-three patients with unwitnessed out-of-hospital cardiac arrest and brought to our emergency department by emergency ambulance were evaluated. Cerebral saturations from time of start of CPR were measured using NIRS. CPR was performed for a maximum of 30 min. The relation between cerebral saturations in patients with or without return of spontaneous circulation was then evaluated.
Results: Twenty-three patients, 12 (52.2%) female and 11 (47.8%) male, with a mean age of 64.09 ± 13.66 were included. A correlation was determined between a rise in cerebral saturation measured throughout CPR and the return of spontaneous circulation ($P < .001$).
Conclusion: Patients whose cerebral saturation values measured with NIRS rise during CPR have a higher post-resuscitation survival rate. Monitoring of patients during CPR with this non-invasive technique may be a good method for predicting return of spontaneous circulation.

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1. Introduction

Despite the development of successful resuscitation techniques, the survival rate among out-of-hospital cardiac arrest patients is still low [1]. Successful resuscitation means not only achieving spontaneous circulation, but also the oxygenation of vital organs. The most important cause of death in arrest patients is central nervous system injury [2]. The use of cerebral oximetry to assess brain oxygenation has risen in recent years. Near infrared spectrophotometry (NIRS) is particularly used to evaluate cerebral oxygenation in cardiovascular surgery [3]. NIRS measures total oxygen saturation in a specific volume of tissue by approximately evaluating the hemoglobin oxygen saturation fraction inside the terminal vascular network of the brain tissue bed. Low measurements or initial measurements decreasing indicate ischemia or hypoxia in the brain tissue [4].

This technology can be used to assess cerebral oxygenation during CPR and in follow-up. Constant monitoring of cerebral perfusion with this technique can elicit important therapeutic information. Prolonged hypoxia in brain tissue increases mortality in arrest patients. We think that low cerebral oxygenation measured using NIRS may indicate that patients have a low level of return of spontaneous circulation. It also suggests greater brain damage. The purpose of this study was to determine whether or not spontaneous circulation had returned by evaluating the cerebral saturation of patients with out-of-hospital cardiac arrest.

1.1. NIRS (cerebral oximetry)

Cerebral oximetry is a neurological monitoring technique developed for adult and pediatric surgery in the 1970s. The technology is still used today in areas such as non-cardiac surgery cardiology, resuscitation, and trauma [5]. The INVOS-5100c COx device utilizes NIRS technology to measure mixed venous–arterial (70/30) oxygen saturation in the frontal lobes of the cerebral cortex. This primarily venous oxygen saturation level is a function of local tissue oxygen consumption and therefore oxygen delivery, making the measurement a reliable reflection of perfusion. Each probe consists of an adhesive strip housing a single near-infrared light transmitter and 2 sensors, allowing penetration of the skin, skull, and cortical brain tissue. Using two sensors, light is scattered by the tissues in two parabolic curves measuring hemoglobin saturation of the blood from the skin and skull in one sensor, and from the skin, skull, and frontal cortex tissue in the other. Frontal cortex hemoglobin saturation is

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calculated by subtraction of the two signals. Limits of detection for the device include a hemoglobin-oxygen saturation of <15% or >95% and a cortical tissue depth of >2 cm [6].

Cerebral saturation (Sco_2) values in normal healthy individuals range between 55 and 75. When Sco_2 values rise more than 25% above basal values during monitoring with NIRS in cardiovascular surgery, cerebral ischemia is suspected and appropriate measures are taken [7].

2. Materials and methods

2.1. Study design and setting

This study was performed at the Recep Tayyip Erdogan University Medical Faculty Emergency Medicine Department, Turkey, between January and June, 2013. The local ethical committee approved the study protocol before commencement. Written consent forms were received from the relatives of all the patients included. Our hospital emergency department (ED) admits approximately 120,000 patients annually. Approximately 100 to 150 of these patients brought to the ED with cardiac arrest arrive by ambulance. Since the urban settlement area is small (~250 km^2), all cardiac arrests cases reach our ED quickly and in a short time (~10 minutes), with the provision of basic life support-advance life support as required in compliance with the European Resuscitation Council guidelines 2010.

2.2. Participants

Thirty patients with a mean age of 64.09 ± 13.66 (mean±SD) years (21-82 years) brought in by the emergency ambulance service after unwitnessed out-of-hospital arrest were included. Seven patients were subsequently excluded due to diagnosis of cerebrovascular event at post-traumatic autopsy. The emergency medical service team included a doctor and a paramedic. They provided CPR to the patients in accordance with European Resuscitation Council Guidelines 2010 on site and during transport as required prior to admission to the ED. No mechanical compression device was employed. Only patients without pulse, despite having received CPR prior to admission to hospital ED, were included in this study. Admitted patients lacking spontaneous circulation continued to receive CPR by the emergency staff. The duration of the cardiac arrest before resuscitation was not determined. Monitoring with cerebral oximetry was provided as soon as the CPR team started resuscitation. CPR in line with the advanced cardiac life support American Heart Association 2010 guideline was administered to all patients. Duration of CPR was determined as a maximum 30 minutes. Cerebral saturations were monitored until patients were declared dead or until spontaneous circulation returned.

2.3. Cerebral oximetry measurements

Advanced life support was provided for each patient with arrest. Circulation was absent from all the patients brought in. Patients were met by a 6-member resuscitation team in the ED. The team consisted of 2 doctors, 2 nurses, and 2 paramedics. One of the nurse task was to monitor and record cerebral saturation. Recording was performed with an INVOS 5100C cerebral/somatic oximeter (Covidien). The oximeter probes were attached appropriately above the muscles in the frontal region. Recording took place throughout resuscitation. NIRS was not applied before admission because of possible disconnection after unsuccessful CPR interventions.

2.4. Statistical analysis

Descriptive statistics are presented as frequency, percentage, mean, standard deviation and median, minimum and maximum values. Fisher exact test or the Pearson χ^2 test were used in the analysis of relations between categorical variables. The Mann-Whitney *U* test was used in the analysis of differences between the 2 groups' measurement values. Receiver operating characteristic (ROC) analysis was performed in the calculation of sensitivity, specificity and area under curve (AUC) values of specific variables in differentiating surviving or non-surviving patients. Odds ratios with a 95% confidence interval were set in comparing risk of death of groups determined on the basis of determined cut-off points. $P < .05$ were regarded as significant. Analyses were performed using SPSS 18.00 (SPSS, Chicago, IL).

Table 1
Patient characteristics and demographic data

Characteristics	Number (%)
Age (mean ± SD)	64.09 ± 13.66
Male	11/23 (47.8)
Initial rhythm VF	11/23(47.8)
Initial rhythm asystolic	9/23 (39,1)
Initial rhythm PEA	3/23 (13)
Full recovery	7/23 (30.4)

3. Results

Twenty-three out-of-hospital cardiac arrest patients with a mean age of 64.09 ± 13.66 (mean ± SD) were included in the study. Twelve patients (52.2%) were female and 11 (47.8%) male. CPR in line with American Heart Association resuscitation rules was administered to all patients. Spontaneous circulation was established in 7 (30.4%) patients, but not in the other 16 (69.6%). Pulseless electrical activity (PEA) (n = 3, 13%), ventricular fibrillation (n = 11, 47.8%), and asystolic rhythms (n = 9, 39.1%) were determined when the patients were brought to our ED (Table 1).

Together with restoration or otherwise of spontaneous circulation, mean Sco_2 and the levels of increase in these values were compared during CPR. Patients' cerebral oxygenations were measured from the right and left frontal regions. The median of the highest Sco_2 values of the patients in whom spontaneous circulation was established was 68.86 (min: 43 max: 93), while the median of the lowest Sco_2 values was 18 (range, 15-47). Median of the rise in Sco_2 values in the right frontal region in restoration of spontaneous circulation with CPR was 52 (range, 17-77), and the median left frontal region value was 50 (range, 11-74). Median of the highest Sco_2 values in the right frontal region in patients in whom circulation could not be established was 24.5 (range, 15-49), and that of the lowest values was 15 (range, 14-31). Mean increase in Sco_2 values after CPR was halted and death declared was 5 (range, 0-18) in the right frontal region and 3 (range, 0-20) in the left. The highest Sco_2 values and the increase in Sco_2 values in the right and left frontal lobes were significantly higher in the patients in whom spontaneous circulation was restored compared to the others ($P < .001$). No statistically significant difference was determined between the lowest right and left lobe Sco_2 values ($P > .05$) (Table 2). Spontaneous circulation was established in patients with a rise in Sco_2 values, but not in patients with no rise.

Table 2
NIRS data and levels of increase measured during CPR

Variable	Survival NO (% min-max)	Survival YES (% min-max)	*P*
Highest right Sco_2 (%)	24.5 (15-49)	68.86 (43-93)	<.001
Highest left Sco_2 (%)	22.5 (14-53)	68 (53-92)	<.001
Lowest right Sco_2 (%)	15 (14-31)	18 (15-47)	<.356
Lowest left Sco_2 (%)	17 (13-33)	18 (17-52)	<.268
Level of right frontal Sco_2 increase (%)	5 (0-18)	52 (17-52)	<.001
Level of left frontal Sco_2 increase (%)	3 (0-20)	50 (11-74)	<.001