ORIGINAL ARTICLE

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The Monitorization of the Return of Spontaneous Circulation Using Peripheric Oxygen Saturation with Near Infrared Spectroscopy in Out-of-Hospital Cardiac Arrest

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Abstract

Objective: Near-infrared spectroscopy (NIRS) is frequently used to predict the return of spontaneous circulation (ROSC) and evaluate the oxygenation of organs. The aim of this study was to predict ROSC by assessing extremity oxygenation during cardiopulmonary resuscitation (CPR).

Methods: This prospective observational study was conducted between March 2019 and March 2020 at the emergency department (ED). The extremity and brain oxygen saturation data of patients with out-of-hospital cardiac arrest (OHCA) were collected from 66 patients aged >18 years who were transported to the ED by ambulance or by relatives due to non-traumatic OHCA. After excluding 40 patients, analysis was performed for the data of 26 patients who met the study inclusion criteria.

Results: The 26 patients included in the study comprised 11 males and 15 females with an average age of 65.27±12.44 years. ROSC was achieved in 15 patients. No statistically significant difference was found between the initial and final NIRS scores of patients without ROSC ($p>0.05$). A statistically significant difference was found between the initial and final NIRS scores at all measurement points in patients with ROSC ($p<0.05$). The initial and final NIRS values at all measurement points were significantly higher in patients with ROSC than in those without ROSC ($p<0.05$).

Conclusion: The return rate of spontaneous circulation was higher in patients with better extremity oxygenation and increased extremity oxygenation during CPR. Evaluating extremity oxygenation with NIRS during resuscitation can help predict ROSC in patients with OHCA.

Keywords: Near-infrared spectroscopy, cardiopulmonary resuscitation, return of spontaneous circulation

INTRODUCTION

Although new guidelines on resuscitation techniques are published every 5 years and techniques are continuously improved, the survival rates of cases of out-of-hospital cardiac arrest (OHCA) are still low (1). The success of resuscitation is not only related to the return of spontaneous circulation but also to proper oxygenation of vital organs. In recent guidelines, the importance of this issue has been emphasized (2,3). Oxygenation of extremities is as important as vital organs in patients with arrest. Recently, the use of near-infrared spectroscopy (NIRS) to evaluate the oxygenation of the brain and other organs has increased. NIRS is frequently used both for the prediction of the return of spontaneous circulation and for the evaluation of organ oxygenation (4-7). NIRS, previously used for oxygenation monitoring in cardiovascular surgery, is now used to evaluate organ oxygenation in many diseases (8-10). NIRS measures the total oxygen saturation in a specific tissue volume by approximately evaluating the hemoglobin oxygen saturation in

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the terminal vascular network of the tissues (11). This technology, which can be used to evaluate extremity oxygenation during cardiopulmonary resuscitation (CPR) and after CPR, can provide important therapeutic information by evaluating extremity perfusion or continuous monitoring. Extremities that remain hypoxic for a long time might be evidence that peripheral oxygenation is insufficient. Good oxygenation of peripheral tissues is evidence of efficient cardiopulmonary resuscitation and return of spontaneous circulation. By evaluating extremity oxygenation during CPR, the necessary precautions can be taken both during and after CPR.

The aim of this study was to predict return of spontaneous circulation (ROSC) by assessing extremity oxygenation using NIRS during CPR.

Oximeters and INVOS-5100c (INVOS 5100c Covidien, Boulder, CO, USA):

The INVOS-5100c used in this study uses continuous wave application and evaluates the scattering components of light attenuation using a light source and two detectors that are spaced close to each other. Thus, measuring the oxy and deoxy hemoglobin values can provide an absolute assessment of the ratio of total hemoglobin expressed as a percentage of tissue oxygen saturation (12-16).

The regional oxygen saturation (rSO2) value gives the percentage of oxygen saturation defined as the total oxygenation index by INVOS 5100 (Somanetics / Covidien, Mansfield, USA). NIRS monitoring also allows for the evaluation of fractional tissue oxygen extraction, which gives a measure of the amount of oxygen removed by tissue and predicts the balance between local oxygen delivery and consumption (17,18). This value represents saturation and is expressed as a percentage. In addition to personal differences, in some studies, tissue oxygenation decreases by 25% from baseline measurements are known as hypoxia indicators (19). In the current study, NIRS measurements were continuously recorded during CPR, and these measurements were evaluated in patients who did or did not obtain ROSC.

METHODS

Study Design and Setting

In this prospective observational study, data on extremity and brain oxygen saturation were collected from patients with OHCA. Brain and extremity oxygenation data were collected by emergency medicine specialists and were not used in any treatment protocols or therapeutic decisions. The study was conducted in University of Health Sciences Turkey, Prof. Dr. Cemil Taşcıoğlu City Hospital Emergency Medicine Department between March 2019 and March 2020. Approval for the study was granted by the local ethics committee before the start of the study (approval number: 48670771-514.10, date: 02.04.2019). Written consent was obtained from the legal representative of each patient included in the study. All CA cases were managed according to the 2015 American Heart Association advanced life support (ALS) guidelines.

Participants

The study included patients aged >18 years who were transported to the emergency department (ED) by ambulance due to non-traumatic OHCA were included in the study. Patients were excluded from the study if they had a history of vascular disease (aortic aneurysm rupture, peripheral artery disease) or received an emergency diagnosis that could affect peripheral circulation, had a lesion occupying space in the brain (tumor, hemorrhage etc.), had a cerebrovascular event, a traumatic CA, if they had a pulse on first presentation, hyperthermia or hypothermia, or if they were pregnant.

CPR was started or continued immediately after patient arrival at the ED. ALS was provided to all patients by a CPR team consisting of 4 nurses and 1 emergency medicine resident led by an emergency medicine specialist. The CPR of all patients was managed by the same emergency medicine specialist. CPR was performed on the patients until ROSC or termination of resuscitation. Patients with no return of spontaneous circulation after thirty minutes were accepted as exitus. No type of mechanical compression devices were used in any of the patients in this study. The time from the estimated arrest until reaching the hospital was recorded. Patients with an estimated arrest duration of <10 minutes were coded as 1, and those with >10 minutes were coded as 2.

NIRS Measurements

Immediately after starting CPR in the ED, NIRS monitoring was started using the INVOS 5100C device. Thirty seconds is sufficient to establish NIRS measurements at all points. Resuscitation was not interrupted during monitoring. NIRS measurements were continued until ROSC or termination of CPR. Brain oxygenation was measured by selecting the frontal region, upper extremity right and left forearm flexor region radial and ulnar artery trace, and for the lower extremity, by selecting the dorsal side of both feet dorsalis pedis artery trace. Brain and extremity oxygenation was performed using the first INVOS 5100C device, and the extremity oxygenation was performed with a second device. One probe was attached to each area after proper field cleaning and continuous measurements were performed. The obtained data were recorded.

Statistical Analysis

Data obtained in the study were analyzed statistically using SPSS vn.18.00 software (SPSS, Chicago, IL, USA). Descriptive statistics were presented as frequency, percentage, mean ± standard deviation (SD) and median, minimum, and maximum values. The Mann-Whitney U test was used to analyze differences between the measurement values of the two groups. Receiver operating characteristic (ROC) analysis was performed to calculate the sensitivity, specificity, and area under curve (AUC) values of specific variables in discriminating between ROSC and non-ROSC patients. NIRS value differences between the start and end of the CPR were calculated with this formula; [(final value - initial value)/initial value]. NIRS measurements are independent variables, and ANCOVA analysis was applied to determine factors influencing the NIRS measurements. Effect sizes were calculated using partial eta squared (ηp^2) (0.01: small, 0.10: medium, 0.25: large) (20). A value of $p<0.05$ was regarded as statistically significant (20).

RESULTS

A total of 66 patients were initially included in the study, and 40 were excluded for various reasons: 23 had hypothermia or hyperthermia, 8 were diagnosed with a cerebrovascular event, 4 were detected to have aortic dissection, and 5 were found to have metastatic brain tumor. Thus, an evaluation was made of 26 patients with OHCA, including 11 males and 15 females, with a mean age of 65.27±12.44 years. Diabetes mellitus, hypertension, and ischemic heart disease were detected in 9 patients. The initial rhythms on admission to ED were determined as asystole in 14 (53.8%), Pulseless electrical activity in 4 (15.4%), and ventricular fibrillation in 8 (30.8%) patients. ROSC was achieved in 15 patients (Table 1).

Pre-hospital arrest duration was statistically significantly shorter, and the pH levels were significantly higher in patients with ROSC than in those without ROSC. No statistically significant differences were detected between patients with and without ROSC in terms of age, CPR duration, and laboratory values, such as glucose, urea, creatinine, sodium, potassium, ALT, AST, PO_2, PCO_2, lactate, and hemoglobin values (Table 2).

In patients without ROSC, no significant difference was observed between the initial and final NIRS scores at all measurement points (p>0.05) (Table 3). In patients without ROSC, the mean rSO_2 value in the right brain at the beginning of CPR was 17.18±5.34% (Q1-Q3 =15-15) and 18.82±8.68% (Q1-Q3 =18.82-8.68) at the end. There was no statistical relationship between these values. The mean initial rSO_2 value in the left brain was 16.55 ± 4.5% (Q1-Q3 =15-15) and the final value was 18.09±6.93% (Q1-Q3 =18.09-6.93) (p>0.05). The rSO_2 values at the beginning of the right upper extremity was 18.82±8.61% and 21.36±10.41% at the end, and there was no statistically significant difference between the values (p>0.05). The rSO_2 value at the beginning of the left upper extremity was 18.18±7.83% and at the end was 20.36±9.46%, and there was no statistically significant difference (p>0.05). The rSO_2 values at the beginning of the right lower extremity was 22.09±8.42% and 22.82±9.47% at the end, and there was no statistically significant difference (p>0.05). The rSO_2 values at the beginning of the left lower extremity was 22.36±8.98% and 22.18±8.76% at the end of the experiment, and there was no statistically significant difference (p>0.05).

In patients with ROSC, a statistically significant difference was found in the initial and final NIRS scores at all measurement points (p=0.000) (Table 4). In patients with ROSC, the rSO_2 value in the right brain at the beginning of CPR was 20.73±8.59%, and the rSO_2 value at the end was 53.4±11.44%. There was a statistically significant difference between these values. The left brain rSO_2 value at the beginning was 21±8.91% and the final value was 54.33±12.31%. (p=0.000). The rSO_2 values at the beginning of the right upper extremity was 23.2±14.14% and 48.8±13.03% at the end of the study period, and the difference was statistically significant (p=0.000). The rSO_2 values at the beginning of the left upper extremity was 22.4±13.98% and 46.2±11.12% at the end , with a statistically significant difference (p=0.000). The rSO_2 values at the beginning of the right lower extremity was 23.6±13.53% and 45.87±12.05% at the end of the study period, and the difference was statistically significant (p=0.000). The rSO_2 values at the beginning of the left lower extremity was 23.4±13.21% and 48.2±11.73% at the end of the study period, and the difference was statistically significant (p=0.000).

Table 1. Patient characteristics		
	n	%
Age (Mean + SD)	65.27±12.44	
Male gender	15/26	57.70
Initial rhythm		
Asystole	14/26	53.8
Pulseless electrical activity	4/26	15.4
Ventricular fibrillation	8/26	30.8
Diabetes mellitus	9/26	34.6
Hypertension	9/26	34.6
Coronary artery disease	9/26	34.6
Return of spontaneous circulation (+)	15/26	57.7

SD: Standard deviation

Table 2. Laboratory parameters and others

Variables		All patients	ROSC (+)	ROSC (-)	p
		Mean ± SD	Mean ± SD	Mean ± SD	
Glucose	mg/dL	272.04±151.85	237.27±151.06	319.45±146.32	0.178
Urea	mg/dL	72.46±45.07	65.67±40.63	81.73±51.03	0.483
Creatinine	mg/dL	1.71±1.48	1.77±1.87	1.63±0.74	0.378
Sodium	mmol/L	138.92±11.36	139.53±14.38	138.09±5.65	0.639
Potassium	mmol/L	5.60±1.42	5.53±1.46	5.69±1.43	0.783
Alanine aminotransferase	U/L	99.58±144.08	89.07±161.72	113.91±122.01	0.337
Aspartate aminotransferase	U/L	172.96±246.26	160.07±255.52	190.55±244.17	0.836
PO_2	mmHg	80.82±81.81	105.14±95.47	47.65±43.30	0.092
PCO_2	mmHg	49.32±18.86	45.96±16.01	53.91±22.14	0.364
pH		7.05±0.16	7.10±0.16	6.97±0.14	**0.043**
Lactate	mmol/L	9.47±3.61	9.32±3.26	9.69±4.19	0.803
Hemoglobin	g/L	10.77±3.47	10.77±3.88	10.76±3.01	0.659
Prehospital arrest duration	code	1.54±0.51	1.33±0.49	1.82±0.40	**0.016**
Age	year	65.27±13.40	63.53±14.23	67.64±12.44	0.452
CPR duration	min.	28.65±11.10	25.67±13.07	32.73±6.07	0.151

ROSC: Return of spontaneous circulation, PO_2: Partial oxygen pressure, PCO_2: Partial carbon dioxide pressure, CPR: Cardiopulmonary resuscitation, pH: Power of hydrogen, Min: Minutes, SD: Standard deviation

Table 3. NIRS values in patients without ROSC

	Patients without ROSC				
	Values at the start of CPR		Values at the end of CPR		p
	Mean ± SD	Median (Q1-Q3)	Mean ± SD	Median (Q1-Q3)	
Right brain (%)	17.18±5.34	15 (15-15)	18.82±8.68	15 (18.82-8.68)	0.317
Left brain (%)	16.55±4.5	15 (15-15)	18.09±6.93	15 (18.09-6.93)	0.18
Right upper extremity (%)	18.82±8.61	15 (15-16)	21.36±10.41	16 (21.36-10.41)	0.068
Left upper extremity (%)	18.18±7.83	15 (15-15)	20.36± 9.46	15 (20.36-9.46)	0.109
Right lower extremity (%)	22.09±8.42	15 (15-31)	22.82±9.47	31 (22.82-9.47)	0.2
Left lower extremity (%)	22.36±8.98	15 (15-30)	22.18±8.76	30 (22.18-8.76)	0.581

NIRS: Near-infrared spectroscopy, CPR: Cardiopulmonary resuscitation, ROSC: Return of spontaneous circulation, SD: Standard deviation

Table 4. NIRS values in patients with ROSC

	Patients with ROSC				
	Values at the start of CPR		Values at the end of CPR		p
	Mean ± SD	Median (Q1-Q3)	Mean ± SD	Median (Q1-Q3)	
Right brain (%)	20.73±8.59	15 (15-25)	53.4±11.44	53 (46-62)	**0.001**
Left brain (%)	21±8.91	15 (15-28)	54.33±12.31	53 (44-60)	**0.001**
Right upper extremity (%)	23.2±14.14	15 (15-24)	48.8±13.03	48 (40-59)	**0.001**
Left upper extremity (%)	22.4±13.98	15 (15-22)	46.2±11.12	47 (40-58)	**0.001**
Right lower extremity (%)	23.6±13.53	15 (15-31)	45.87±12.05	50 (37-54)	**0.001**
Left lower extremity (%)	23.4±13.21	15 (15-30)	48.2±11.73	51 (39-57)	**0.001**

CPR: Cardiopulmonary resuscitation, ROSC: Return of spontaneous circulation, SD: Standard deviation

In addition, the difference between the initial and final NIRS measurement values of patients with and without ROSC was determined at all measurement points. These differences were found to be statistically significantly higher in patients with ROSC than in those without ROSC (p=0.000) (Table 5). The possibility of ROSC was found to be increased when an increase of more than 13.3% was achieved in the left-brain region measurement values. (specificity 90.91%, sensitivity 100%, AUC=0.988). When the same situation was evaluated for the right brain, a 32% increase was sufficient to determine the ROSC (specificity: 90.91%, sensitivity: 93.33%, AUC: 0.988). The specificity was 90.91%, sensitivity was 86.67%, and AUC was 0.931 in determining ROSC in individuals with an increase of 26.6% in the measurement values in the right upper extremity. The specificity was 81.82%, sensitivity was 100%, and AUC was 0.952 for determining ROSC in those with an increase of 6.66% in the measurement values in the left upper extremity. The specificity was 100%, sensitivity was 73.33%, and the AUC was 0.936 for determining ROSC in those with an increase of 37% in the measurement values in the right lower extremity. The specificity was 100%, sensitivity was 100%, and the AUC was 1.000 for determining ROSC in those with an increase of 6.6% in the measurement values in the left lower extremity (Figure 1).

When the main effects explaining the final value of the left brain NIRS result were evaluated, the main effects of duration of arrest (F (1,21)=0.56, ns, ηp^2=0.026) and pH (F (1,21)=0.02, ns, ηp^2=0.001) was not statistically significant. When corrected for baseline left brain measurement, the correction factor was significant (F (1,21)=9.20, p=0.006, ηp^2=0.305) and the main effect of ROSC (F (1,21)=49.04, p<0.001, ηp^2=0.7) was found to be significant in the model.

When the main effects explaining the final value of the right brain NIRS result were evaluated, the main effects of duration of arrest (F (1,21)=1.19, ns, ηp^2=0.054) and pH (F (1,21)=0.24, ns, ηp^2=0.011) was not statistically significant. When corrected for baseline right brain measurement, the correction factor was significant (F (1,21)=9.20, p=0.006, ηp^2=0.305) and the main effect of ROSC (F (1,21)=49.04, p<0.001, ηp^2=0.7) was found to be significant in the model.

When the main effects explaining the final value of the left upper extremity NIRS result were evaluated, the main effects of duration of arrest (F (1,21)=1.49, ns, ηp^2=0.066) and pH (F (1,21)=0.13, ns, ηp^2=0.006) was not statistically significant. When corrected for baseline left upper extremity measurement, the correction factor was significant (F (1,21)=9.99, p=0.005, ηp^2=0.322) and the main effect of ROSC (F (1,21)=23.67, p<0.001, ηp^2=0.530) was found to be significant in the model.

When the main effects explaining the final value of the left lower extremity NIRS result were evaluated, the main effects of duration of arrest (F (1,21)=0.023, ns, ηp^2=0.001) and pH (F (1, 21) = 0.02, ns, ηp^2=0.012) was not statistically significant. When corrected for baseline left lower extremity measurement, the correction factor was significant (F (1,21)=9.19, p=0.006, ηp^2=0.304) and the main effect of ROSC (F (1,21)=26.11, p<0.001, ηp^2=0.554) was found to be significant in the model.

When the main effects explaining the final value of the right upper extremity NIRS result were evaluated, the main effects

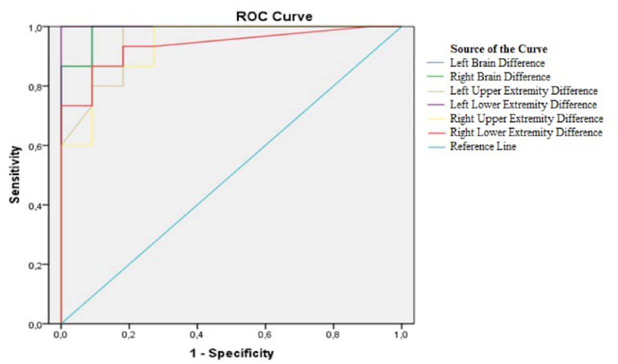

Figure 1. ROC analysis of the differences in the measurements of all regions
ROC: Receiver operating characteristic

Table 5. NIRS value differences in patients with and without ROSC

NIRS value differences	Patients without ROSC		Patients with ROSC		p
	Mean ± SD	Median (Q1-Q3)	Mean ± SD	Median (Q1-Q3)	
Left brain	0.08±0.23	0 (0-0)	1.84±0.84	1.93 (1.16-2.53)	**0.000**
Right brain	0.07±0.25	0 (0-0)	1.82±0.85	1.83 (1.07-2.53)	**0.000**
Right upper extremity	0.14±0.32	0 (0-0.19)	1.54±1.14	1.38 (0.59-2.6)	**0.000**
Left upper extremity	0.12±0.26	0 (0-0.07)	1.47±0.99	1.67 (0.68-2.2)	**0.000**
Right lower extremity	0.02±0.05	0	1.32±1.03	1.47 (0.13-2.53)	**0.000**
Left lower extremity	-0.01±0.04	0 (0-0)	1.45±1.05	1.47 (0.6-2.53)	**0.000**

NIRS: Near-infrared spectroscopy, CPR: Cardiopulmonary resuscitation, ROSC: Return of spontaneous circulation, SD: Standard deviation of duration of arrest (F (1,21)=2.273, ns, ηp^2=0.098) and pH (F (1,21)=0.11, ns, ηp^2=0.005) was not statistically significant. When corrected for baseline right upper extremity measurement, the correction factor was significant (F (1,21)=6.04, p=0.023, ηp^2=0.223) and the main effect of ROSC (F (1,21)=17.26, p<0.001, ηp^2=0.451) was found to be significant in the model.

When the main effects explaining the final value of the right lower extremity NIRS result were evaluated, the main effects of duration of arrest (F (1,21)=0.57, ns, ηp^2=0.026) and pH (F (1,21)=0.01, ns, ηp^2=0.000) was not statistically significant. When corrected for baseline right lower extremity measurement, the correction factor was significant (F (1,21)=5.97, p=0.024, ηp^2=0.221) and the main effect of ROSC (F (1,21)=15.57, p<0.001, ηp^2=0.426) was found to be significant in the model (Table 6).

DISCUSSION

The results of this study of patients with OHCA demonstrated that the ROSC rate was higher in patients with high extremity oxygenation than in patients with lower extremity oxygenation levels. Patients with lower extremity oxygenation cannot regain spontaneous circulation. A good correlation was also observed between extremity and cerebral saturation in patients with

Table 6. ANOVA analyzes to identify factors affecting NIRS measurements

		F	p	η^2	$\eta^2 p$
Final value of left brain	ROSC	49.0398	<0.001	0.614	0.700
	Initial value of left brain	9.2035	697.78	0.115	0.305
	Arrest time	0.5647	42.81	0.007	0.026
	pH	0.0170	1.29	0.000	0.001
	Residuals		75.82		
Final value of right brain	ROSC	40.354	<0.001	0.587	0.658
	Initial value of right brain	5.946	0.024	0.087	0.221
	Arrest time	1.191	0.288	0.017	0.054
	pH	0.244	0.627	0.004	0.011
	Residuals				
Final value of left upper extremity	ROSC	23.673	<0.001	0.421	0.530
	Initial value of left upper extremity	9.992	0.005	0.178	0.322
	Arrest time	1.495	0.235	0.027	0.066
	pH	0.130	0.722	0.002	0.006
	Residuals				
Final value of left lower extremity	ROSC	26.1102	<0.001	0.461	0.554
	Initial value of left lower extremity	9.1892	0.006	0.162	0.304
	Arrest time	0.0231	0.881	0.000	0.001
	pH	0.2575	0.617	0.005	0.012
	Residuals				
Final value of right upper extremity	ROSC	17.259	<0.001	0.370	0.451
	Initial value of right upper extremity	6.038	0.023	0.129	0.223
	Arrest time	2.273	0.147	0.049	0.098
	pH	0.109	0.745	0.002	0.005
	Residuals				
Final value of right lower extremity	ROSC	15.5670	<0.001	0.361	0.462
	Initial value of right lower extremity	5.9670	0.024	0.138	0.221
	Arrest time	0.5674	0.460	0.013	0.026
	pH	0.0104	0.920	0.000	0.000
	Residuals				

NIRS: Near-infrared spectroscopy, ROSC: Return of spontaneous circulation

OHCA with and without ROSC. Based on these results, extremity saturation measurements can be an indication of ROSC. This is the first study to evaluate extremity oxygenation during CPR using a non-invasive technique. There are studies in the literature that have frequently evaluated brain oxygenation during CPR, and only one study has evaluated abdominal oxygenation (11,16,21-26). Although there are studies evaluating extremity oxygenation with NIRS in various diseases, no studies have evaluated this during CPR (27-29).

In a study conducted in the intensive care unit, the relationship between peripheral oxygenation and mortality was evaluated in patients with multiple organ failure. Shapiro et al. (30) evaluated 3 groups in their studies. The first group included patients with septic shock with systolic blood pressure <90 mmHg despite adequate fluid resuscitation, the second group included patients who only had sepsis, and the third group included patients without infections who were checked in through the emergency room. In all patients, measurements were made using NIRS from the thenar region. The measurements were evaluated before and after the venous occlusion created using a tourniquet. It has been reported that patients with septic shock who have poor peripheral circulation and whose oxygen saturation does not increase rapidly after removal of venous occlusion mostly develop organ failure. As a result of that study, it was stated that patients with rapid reperfusion after ischemia have better organ perfusion. Thus, it was concluded that in critical patients, extremity oxygenation would be a good method for evaluating the perfusion of other organs (30). The results of the current study support these findings. Patients with high peripheral oxygenation on admission, which continued to rise during CPR, were more likely to return to spontaneous circulation. This finding can be attributed to the fact that patients with peripheral circulation will also have good oxygenation in the brain and other vital organs.

A study by Payen et al. (31) also supported the results of the current study. In that study, Payen et al. (31) compared the peripheral circulation of patients with septic shock with that of healthy individuals. In patients who underwent the venous occlusion test at the brachial artery level, macrohemodynamic (systolic blood pressure, cardiac output, pulmonary artery catheterization) and microhemodynamic (lactate, pH, and base deficit) parameters and peripheral tissue oxygenations assessed by NIRS were compared in the assessment of tissue oxygenation at a cellular level. According to the results of that study, relationships were found between NIRS measurements and all of these parameters. Specifically, peripheral oxygenation was detected to be lower in the NIRS group than in the healthy control group. The mortality of patients with poor reperfusion after the venous occlusion test was found to be higher. NIRS measurements were detected to be lower in patients with low blood pH and high lactate. It has been argued that using both micro and macrohemodynamic parameters with peripheral oxygen saturation monitoring would be beneficial for the prediction of patient mortality (31). In the current study, although no relationship was determined between macro and micro hemodynamic parameters and ROSC, a direct relationship with the arrest duration was found. ROSC rates were lower in patients who had more than 10 minutes of arrest duration. As the CA duration increases, there can be expected to be a variation in bioindicators such as serum pH and lactate, which are hypoxia indicators. Although this finding was not statistically significant, many of the current study patients who did not have ROSC had low blood pH and high blood lactate levels.

Many studies using NIRS to detect ROSC have focused on brain oxygenation. In a study previously conducted by the authors, abdominal oxygenation was also evaluated. These studies evaluated the oxygenation of vital organs. The results of these studies demonstrate that patients with increased brain and abdominal oxygen saturation have a better chance of ROSC. The current study considered that peripheral tissue oxygenation is at least as valuable as the oxygenation of the brain and abdominal organs. Similar to previous studies, the results illustrated that patients with increased peripheral tissue oxygenation achieved return of spontaneous circulation.

Study Limitations

The most important limitation of this study was the limited number of patients. Further studies with a broader patient population will most likely support these results. In this study, extremity oxygenation was measured during CPR, and the lowest values on admission and the highest measurement values at the endpoint of CPR were obtained. Long-term measurements were not performed after ROSC. Long-term extremity oxygenation monitoring in patients who were hospitalized in intensive care may also provide different information. These measurements were not compared with healthy individuals or methods proven to predict ROSC. Long-term measurements may be useful in predicting both mortality and ischemia in other vital organs in patients admitted to the intensive care unit. The lack of a mechanical compression device was another limitation of the study. Although CPR standardization was achieved by our team, studies using compression devices are necessary.

CONCLUSION

Evaluating extremity oxygenation with NIRS during resuscitation can help predict ROSC in patients with OHCA. The return rate of spontaneous circulation was higher in patients with initially better extremity oxygenation and an increase in extremity oxygenation during CPR.

Ethics

Ethics Committee Approval: The study was conducted in University of Health Sciences Turkey, Prof. Dr. Cemil Taşcıoğlu City Hospital Emergency Medicine Department between March 2019 and March 2020. Approval for the study was granted by the local ethics committee before the start of the study (approval number: 48670771-514.10, date: 02.04.2019).

Informed Consent: Written consent was obtained from the legal representative of each patient included in the study.

Footnotes

Authorship Contributions

Concept: H.K., A.K., Design: H.K., A.K., Data Collection or Processing: H.K., Ö.B., M.Ş., S.Ü., Analysis or Interpretation: H.A., Ş.E.A., Literature Search: H.K., A.K., B.M.A., A.D., Writing: H.K., A.K., Ö.B., S.Ü.

Conflict of Interest: Asım Kalkan, MD, is a Section Editor in the European Archives of Medical Research. He had no involvement in the peer-review of this article and had no access to information regarding its peer-review. Other authors have nothing to disclose.

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