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Clinical paper

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☆

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A B S T R A C T

Background: Non-invasive monitoring of cerebral perfusion and oxygen delivery during cardiac arrest is not routinely utilized during cardiac arrest resuscitation. The objective of this study was to investigate the feasibility of using cerebral oximetry during cardiac arrest and to determine the relationship between regional cerebral oxygen saturation (rSO2) with return of spontaneous circulation (ROSC) in shockable (VF/VT) and non-shockable (PEA/asystole) types of cardiac arrest.
Methods: Cerebral oximetry was applied to 50 in-hospital and out-of-hospital cardiac arrest patients.
Results: Overall, 52% ($n = 26$) achieved ROSC and 48% ($n = 24$) did not achieve ROSC. There was a significant difference in mean ± SD rSO2% in patients who achieved ROSC compared to those who did not (47.2 ± 10.7% vs. 31.7 ± 12.8%, $p < 0.0001$). This difference was observed during asystole (median rSO2 (IQR) ROSC versus no ROSC: 45.0% (35.1–48.8) vs. 24.9% (20.5–32.9), $p < 0.002$) and PEA (50.6% (46.7–57.5) vs. 31.6% (18.8–43.3), $p = 0.02$), but not in the VF/VT subgroup (43.7% (41.1–54.7) vs. 42.8% (34.9–45.0), $p = 0.63$). Furthermore, it was noted that no subjects with a mean rSO2 < 30% achieved ROSC.
Conclusions: Cerebral oximetry may have a role as a real-time, non-invasive predictor of ROSC during cardiac arrest. The main utility of rSO2 in determining ROSC appears to apply to asystole and PEA subgroups of cardiac arrest, rather than VF/VT. This observation may reflect the different physiological factors involved in recovery from PEA/asytole compared to VF/VT. Whereas in VF/VT, successful defibrillation is of prime importance, however in PEA and asytole achieving ROSC is more likely to be related to the quality of oxygen delivery. Furthermore, a persistently low rSO2 <30% in spite of optimal resuscitation methods may indicate futility of resuscitation efforts.

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1. Introduction

While the use of the partial pressure of end-tidal CO_2 ($PETCO_2$) as a marker of CPR quality and return of spontaneous circulation (ROSC) following cardiac arrest has been advocated,[1] $PETCO_2$ has inherent limitations, such as the presence of any pulmonary pathology that increases dead space ventilation, which may lead to reduced $PETCO_2$ levels independent of the state of the circulation.[2] Furthermore, $PETCO_2$ does not provide data regarding the quality of cerebral resuscitation. Cerebral oximetry using near-infrared spectroscopy (NIRS) is a non-invasive monitoring system that continually measures regional cerebral oxygen saturation (rSO2), and provides information regarding the real-time status of the balance between oxygen delivery and uptake in regional cerebral tissue.[3] While this technology has been utilized in various clinical settings,[3–5] its application in cardiac arrest has been limited.[6,7]

NIRS technology is based on the Beer Lambert law that states the absorbance of light through a medium is dependent on the concentration of chromophores, its extinction coefficient, and the distance traveled in the medium.[3] The main chromophores in the brain are oxyhemoglobin, deoxyhemoglobin and oxidized cytochrome aa_3.[8] Cerebral oximetry determines the ratio of oxyhemoglobin to deoxyhemoglobin, and provides a measure of overall rSO2 with normal values close to venous saturation (60–80%) since the measured areas of the brain comprise mostly venous blood[3]. Importantly, cerebral oximetry does not require pulsatile flow,[3] so it can be used in cardiac arrest.

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Table 1
Patient data.

	Patients with ROSC ($n=26$)	Patients without ROSC ($n=24$)	p
Age (mean ± SD)	63.8 ± 18.0	65.8 ± 13.3	=0.65
M/F	18/8	18/6	=0.76
IH/OH	20/6	16/8	=0.53
Duration of resuscitation (minutes)[a]	32 ± 26	37 ± 20	=0.38
Time of sensor placement (minutes)[b]	IH: 9 (6–10)	IH: 11 (8–14)	=0.07 (IH)
	OH: 37 (31–45)	OH: 45 (35–51)	=0.41 (OH)
Initial rSO2% (mean ± SD)	27.9 ± 15.1	22.5 ± 16.3	=0.27
Mean rSO2% (mean ± SD)	47.2 ± 10.7	31.7 ± 12.8	<0.0001

ROSC = return of spontaneous circulation; SD = standard deviation; M = male; F = female; IH = in-hospital arrests; OH = out-of-hospital arrests; rSO2 = regional cerebral oxygen saturation.

[a] Duration of resuscitation for out-of-hospital arrests have been calculated from the time of call to the emergency medical service; expressed as mean ± SD in minutes.

[b] Time of cerebral oximetry sensor placement was calculated for in-hospital arrests from the initiation of cardiac arrest, and for out-of-hospital arrests from the time of call to the emergency medical service; expressed as median (IQR) in minutes.

We had previously demonstrated that the mean rSO2 measured during cardiac arrest was significantly higher in those who achieved ROSC compared to those without.[9] The aim of this observational study was to investigate the relationship between rSO2 and ROSC in a convenience sample of patients undergoing CPR, as well as the relationship between rSO2 and ROSC in the three main subtypes of cardiac arrest (ventricular fibrillation (VF)/ventricular tachycardia (VT), asystole and pulseless electrical activity (PEA)).

2. Methods

The study was approved by the local institutional review board (IRB). Cerebral oximetry (Equanox 7600, Nonin Medical, Inc., Plymouth, MN, USA) has been incorporated as a non-invasive monitor of cerebral resuscitation during CPR at Stony Brook University Hospital. In the emergency department (ED), a cerebral oximeter was stationed in an emergency resuscitation room where all out-of-hospital cardiac arrest patients were treated. For all in-hospital cardiac arrests, a member of the medical intensive care unit took the cerebral oximeter to the site of cardiac arrest. The cerebral oximeter sensor, consisting of an adhesive strip with two near-infrared light sources and detectors, was placed on the forehead of each patient in cardiac arrest while resuscitative efforts were carried out in accordance with the latest American Heart association Advanced Cardiovascular Life Support (ACLS) recommendations published in 2010 that included quality chest compressions with minimal interruptions, advanced airway placement, and vasopressor drug therapy using epinephrine every 3–5 min.[1] Continuous rSO2 monitoring was started at the earliest point possible and carried out until either ROSC was achieved or CPR was terminated. Exclusion criteria included (1) patients under 18 years of age, (2) patients in whom ROSC had been achieved before the placement of cerebral oximetry. Data was downloaded in accordance with the manufacturer's instructions. For each patient, continuous rSO2 measurements were analyzed and expressed as the mean of the recordings taken during the entire period of resuscitation based on an a priori decision. The overall mean rSO2 in patients achieving ROSC and those without ROSC were compared using a Student's *t*-test. Due to the smaller numbers of patients in each of the three subgroups of cardiac arrest, the rSO2 values in these subgroups were expressed as median and interquartile range (IQR), and data were analyzed using the Mann–Whitney test. All statistical analyses were performed using GraphPad Prism (GraphPad Software, Inc., La Jolla, CA). The data were analyzed with the assistance of a statistician.

3. Results

A total of 50 cardiac arrest patients had cerebral oximetry monitoring carried out during a six-month period. During this time, 24% ($n=12$) had VF/VT, 44% ($n=22$) had asystole and 32% ($n=16$) had PEA. Overall, 52% ($n=26$) achieved ROSC, whereas 48% ($n=24$) did not. The age, gender, the duration of resuscitation, and the initial rSO2 level at the time of sensor placement were similar between the patients with ROSC and those without ROSC (Table 1). Patients with ROSC had a significantly higher mean ± standard deviation (SD) rSO2 than those without ROSC (47.2% ± 10.7 vs. 31.7% ± 12.8, $p<0.0001$) (Fig. 1). The median (IQR) rSO2 in patients achieving ROSC (47.8% (39.8–56.0)) and those without ROSC (32.9% (21.8–41.7)) was similar to the mean values. None of the patients with a mean rSO2 of <30% achieved ROSC. In patients with VF/VT, there was no significant difference in the median (IQR) rSO2 between patients achieving ROSC ($n=5$) and those without ROSC ($n=7$) (43.7% (41.1–54.7) vs. 42.8% (34.9–45.0), $p=0.63$) (Fig. 2a). However, in patients with asystole, the median (IQR) of the rSO2 in patients achieving ROSC ($n=11$) was significantly higher than those without ROSC ($n=11$) (45.0% (35.1–48.8) vs. 24.9% (20.5–32.9), $p<0.002$) (Fig. 2b). A significant difference in the median (IQR) was also observed in the PEA subgroup with ROSC ($n=10$) compared to those without ROSC ($n=6$) (50.6% (46.7–57.5) vs. 31.6% (18.8–43.3), $p=0.02$) (Fig. 2c).

4. Discussion

Our results indicate that cerebral oximetry during cardiac arrest may provide data regarding the quality of resuscitation as well as the timing of ROSC. Furthermore, a higher level of rSO2 may be required to achieve ROSC. This supports the results of previous studies.[6,7,9] To our knowledge, this is the first study to indicate that

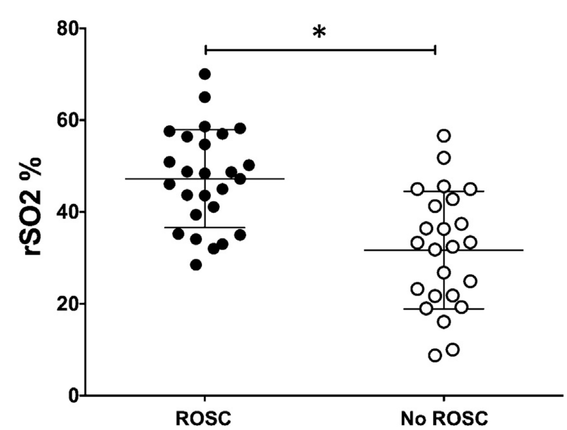

Fig. 1. The relationship between return of spontaneous circulation (ROSC) and mean regional cerebral saturation (rSO2) expressed as mean ± standard deviation (SD) during resuscitation in patients with ROSC ($n=26$) vs. no ROSC ($n=24$). *$p<0.0001$ using the Student's *t*-test.