

# Cerebral Oximetry as a Real-Time Monitoring Tool to Assess Quality of In-Hospital Cardiopulmonary Resuscitation and Post Cardiac Arrest Care

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**Background**—Regional cerebral oxygen saturation (rSO<sub>2</sub>) as assessed by near infrared frontal cerebral spectroscopy decreases in circulatory arrest and increases with high-quality cardiopulmonary resuscitation. We hypothesized that higher rSO<sub>2</sub> during cardiopulmonary resuscitation and after return of spontaneous circulation (ROSC) would predict survival to discharge and neurological recovery.

**Methods and Results**—This prospective case series included patients experiencing in-hospital cardiac arrest. Cerebral oximetry was recorded continuously from initiation of resuscitation until ROSC and up to 48 hours post-arrest. Relationships between oximetry data during these time periods and outcomes of resuscitation survival and survival to discharge were analyzed. The cohort included 27 patients. Nineteen (70.3%) achieved ROSC, and 8 (29.6%) survived to discharge. Median arrest duration was 20.8 minutes (range=8 to 74). There was a significant difference in rSO<sub>2</sub> between resuscitation survivors and resuscitation nonsurvivors at initiation of the resuscitative efforts (35% versus 17.5%,  $P=0.03$ ) and during resuscitation (36% versus 15%,  $P=0.0008$ ). No significant association was observed between rSO<sub>2</sub> at ROSC or during the post-arrest period and survival to discharge. Among patients who survived to discharge, there was no association between cerebral performance category and rSO<sub>2</sub> at ROSC, during resuscitation, or post-arrest.

**Conclusions**—Higher rSO<sub>2</sub> levels at initiation of resuscitation and during resuscitation are associated with resuscitation survival and may reflect high-quality cardiopulmonary resuscitation. However, in this small series, rSO<sub>2</sub> was not predictive of good neurological outcome. Larger studies are needed to determine whether this monitoring modality can be used to improve clinical outcomes. (*J Am Heart Assoc.* 2015;4:e001859 doi: 10.1161/JAHA.115.001859)

**Key Words:** cardiac arrest • cerebral oximetry • research methods

Near infrared spectroscopy is a noninvasive optical monitoring technique that can be utilized to assess regional cerebral oxygen saturation (rSO<sub>2</sub>). This technique

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This manuscript is dedicated to Dr Austin's memory and in recognition of his scholarly achievements.

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has been used to assess rSO<sub>2</sub> in a variety of clinical conditions, including continuous assessment of cerebral oxygenation in patients with induced circulatory arrest<sup>1–3</sup> and healthy adult volunteers.<sup>4</sup> There has also been significant interest in the role of cerebral oximetry in cardiac arrest.

Although cerebral oximetry monitoring has not been established as a reliable method of detecting cerebral perfusion during a resuscitation attempt,<sup>5</sup> several small, single-center studies have suggested that cerebral oximetry may be beneficial either diagnostically or prognostically during resuscitation efforts for cardiac arrest and in the post-arrest period. During cardiac arrest, rSO<sub>2</sub> levels have been shown to increase with high-quality cardiopulmonary resuscitation (CPR), and several studies have demonstrated a correlation between rSO<sub>2</sub> levels during resuscitation and outcomes such as return of spontaneous circulation (ROSC) and survival.<sup>6–9</sup> The role of cerebral oximetry monitoring in the post-arrest period is less clear, but 1 study suggested that cerebral oximetry assessment in the

immediate post-arrest period may have prognostic value regarding survival to discharge.<sup>10</sup>

In this observational study, we evaluated the use of cerebral oximetry during resuscitation (intra-arrest) and during the post-arrest period as defined by the American Heart Association Consensus Statement.<sup>11</sup> We hypothesized that rSO<sub>2</sub> levels during both periods would predict survival to discharge and neurological recovery.

## Methods

### Study Population

Cerebral oximetry monitoring was performed on patients who experienced in-hospital cardiac arrest from May 1, 2011 to April 30, 2012 at the Atlanta Veterans Affairs Medical Center. Cardiac arrest was defined as the absence of spontaneous respirations, nonresponsiveness to stimuli, and lack of palpable pulse.<sup>12</sup> All patients underwent CPR according to Adult Cardiovascular Life Support guidelines.<sup>13</sup> Clinical data, including baseline characteristics and in-hospital clinical information, were abstracted from the electronic medical record and charts. Continuous rSO<sub>2</sub> monitoring was performed in 27 patients.

### Study Intervention

The Invos 5100 C near infrared spectroscopy device (Invos Somanetics, Troy, USA) was utilized. A disposable sensor was applied to the patient's forehead.<sup>14</sup> Light emitted from the diodes is used to calculate the frontal cortical hemoglobin concentration; resulting values represent cerebral arteriovenous saturation (normal range 60% to 80%).<sup>15</sup>

The near infrared spectroscopy device did not interfere with CPR efforts or post-arrest interventions and was not used by medical staff to alter management. The forehead sensor was placed as soon as possible after onset of resuscitation efforts (2 minutes or less in all patients), and monitoring was continued up to 48 hours post-arrest unless removed for clinical reasons or patient death. Cerebral oximetry values were available at 30-s intervals for analysis, and rSO<sub>2</sub> values are reported at onset of compressions (initial rSO<sub>2</sub>), during resuscitation (intra-arrest rSO<sub>2</sub>), at ROSC (end of compressions), and during the post-arrest monitoring period. Mean (average) rSO<sub>2</sub> was calculated during resuscitation and during the post-arrest period for each patient.

### Study End Points

The primary outcome measures were resuscitation survival and survival to discharge. Resuscitation survival was defined as ROSC lasting more than 20 minutes. A secondary outcome

was neurological status on discharge, as categorized by Glasgow–Pittsburgh Cerebral Performance Categories. Cerebral performance category (CPC) levels were defined as follows: CPC 1 (good performance) and CPC 2 (moderate disability), CPC 3 (severe disability), CPC 4 (vegetative state), and CPC 5 (brain death or death).<sup>12,16</sup> All outcome measures, including CPC scores, were assessed through chart review.

### Statistical Analysis

Descriptive analysis was performed for all major study variables. Continuous baseline characteristics and rSO<sub>2</sub> assessments are expressed as either mean±SD or median with interquartile range for non-normally distributed variables. Recorded values of “0” from the Invos data stream were excluded as these values likely represent detection failure. The Wilcoxon Rank-Sum test was used to analyze associations between rSO<sub>2</sub> assessments and outcome measures of resuscitation survival and survival to discharge. A 2-tailed value of *P*<0.05 was considered statistically significant. The Wilcoxon Rank-Sum test was also utilized to compare rSO<sub>2</sub> assessments, and outcomes between survivors and nonsurvivors. All analyses were performed using Statistical Analysis Software (SAS) software version 9.3 (SAS Institute Inc, Cary, NC).

### Ethical Considerations

The use of cerebral oximetry did not interfere with resuscitation protocols, and oximetry data were not used to alter resuscitation, to determine when to terminate resuscitation efforts, or to guide post-arrest care. Prospective informed consent was not considered practical, and the study was considered to represent no more than minimal risk. The Emory University School of Medicine Institutional Review Board and the Atlanta Veterans Medical Center Research and Development Committee approved the study under a waiver of informed consent.

### Results

Patient characteristics, including arrest location and survival outcomes, are presented in Table 1. The initial rhythm was pulseless electrical activity (PEA) in 20 patients, ventricular fibrillation in 4 patients, and asystole in 3 patients. Eight patients survived to discharge. The 2 survivors of ventricular fibrillation were treated with therapeutic hypothermia, and early coronary angiography with coronary revascularization was performed in 1 of these patients. They were both discharged with a CPC score of 1. The remaining 6 survivors to discharge had pulseless electrical activity as a presenting rhythm and were all discharged with a CPC score of 3 or 4. Patient characteristics by resuscitation survival status are presented in Table 2.

**Table 1.** Demographic, Clinical, and In-Hospital CPR Event Characteristics

Baseline Characteristics		
Mean age	65.6±12.3 years	
Mean duration	20.8±12.4 minutes	
Gender	Male 26 (96.3%)	Female 1 (3.7%)
Race	Black 15 (55.6%)	White 12 (44.4%)
Arrest location	Intensive care unit	14 (51.8%)
	General wards	10 (37.04%)
	Radiology	1 (3.7%)
	Other	2 (7.41%)
Survival to discharge	Yes	No
ROSC	8 (29.6%)	11 (40.7%)
No ROSC		8 (29.6%)

CPR indicates cardiopulmonary resuscitation; ROSC, return of spontaneous circulation.

Resuscitation survivors, compared to resuscitation non-survivors, had higher  $rSO_2$  at initiation of resuscitation (35% versus 17.5%,  $P=0.03$ ) (Table 3). This difference persisted throughout resuscitation; resuscitation survivors also had higher average  $rSO_2$  during resuscitation compared to resuscitation nonsurvivors (36% versus 15%,  $P=0.0008$ ). The median  $rSO_2$  for resuscitation survivors at ROSC (at the time

**Table 2.** Demographic, Clinical, and Resuscitation Event Characteristic Comparisons Between Resuscitation Survivors and Nonsurvivors

Characteristics of Resuscitation Survivors and Nonsurvivors		
	Resuscitation Survivors (n=19)	Resuscitation Nonsurvivors (n=8)
Sex	Male 18/19 (95%)	Male 8/8 (100%)
Race		
Black	8/19 (42%)	7/8 (88%)
White	11/19 (58%)	1/8 (13%)
Presenting rhythm		
Pulseless electrical activity	14/19 (74%)	6/8 (75%)
Ventricular fibrillation	2/19 (10%)	2/8 (25%)
Asystole	3/19 (16%)	0/8 (0%)
Resuscitation duration, mean	19 minutes	23 minutes
Age, mean	60.4 years	65.5 years
Mean Charlson Comorbidity Index <sup>17</sup>	4.5	4.8

of CPR termination) and 48 hours into the post-arrest period were 41% and 42%, respectively. Comparing resuscitation survivors who survived to discharge with those who did not, no significant differences were observed in  $rSO_2$  at ROSC (median 42% versus 41%,  $P=0.64$ ) or during the post-arrest period (43.5% versus 40.0%,  $P=0.45$ , Table 4). Finally, among the patients who survived to discharge, there was no association between CPC score and  $rSO_2$  at ROSC, during resuscitation, or post-arrest (Table 5).

## Discussion

This prospective case series investigated the use of real-time cerebral oximetry monitoring during resuscitation and during the post-arrest period in patients with in-hospital cardiac arrest. Prior studies involving out-of-hospital cardiac arrest patients have noted that low  $rSO_2$  levels during resuscitation predict a lower chance of resuscitation survival.<sup>6,18,19</sup> We observed a similar association for in-hospital cardiac arrest patients. This study thus supports the hypothesis that very low  $rSO_2$  levels at resuscitation initiation and during resuscitation may predict failure to achieve ROSC. However, we did not have data about the quality of CPR in each individual context, and providers did not use oximetry information to alter resuscitation efforts. As a result, this study does not address the question of whether low  $rSO_2$  levels during resuscitation identify individuals with an unalterably poor prognosis or individuals for whom resuscitative efforts could potentially be improved.

While these findings complement previously published evidence<sup>20</sup> that higher  $rSO_2$  during resuscitation may predict ROSC, they do not suggest a significant relationship between  $rSO_2$  during resuscitation and neurologic status at discharge. Specifically, the neurologic status at discharge of individuals with initial pulseless electrical activity arrest was markedly poor (all CPC 3 or 4) despite relatively acceptable  $rSO_2$  during resuscitation. Moreover,  $rSO_2$  values in that population were not different from those of the individuals with an initial shockable rhythm who did have a good neurologic outcome. This finding thus casts some doubt on whether oximetry-guided efforts to increase  $rSO_2$  during resuscitation will meaningfully impact neurologic outcomes. Though  $rSO_2$  levels have been shown to increase with the use of an automated compression device,<sup>8</sup> for instance, no data exist at this point to demonstrate that altering management based on oximetry data improves neurologic status.

This study also may temper enthusiasm for the use of cerebral oximetry as an early prognostic tool regarding likelihood of survival or good neurological outcome in the post-arrest period, an area in which very limited data exist.<sup>1,10,19</sup> In this study,  $rSO_2$  following ROSC (post-arrest  $rSO_2$ ) did not correlate meaningfully with either survival to

**Table 3.** Cerebral Oximetry Assessments

Cerebral Oximetry Assessments				
	All Patients (N=27)	Survivors (N=19)	Nonsurvivors (N=8)	P Value*
Median initial rSO <sub>2</sub> (compression onset)	26% (20 to 40)	35% (20 to 40)	17.5% (15 to 25.5)	0.03
Median average rSO <sub>2</sub> during resuscitation <sup>†</sup>	34% (21 to 39)	36% (31 to 41)	15% (13 to 23)	0.0008
Median rSO <sub>2</sub> at ROSC (end of compressions)	N/A	41% (39 to 49)	N/A	
Median average post-arrest rSO <sub>2</sub> <sup>†</sup>	N/A	42% (34 to 49)	N/A	

N/A indicates not applicable; ROSC, return of spontaneous circulation; rSO<sub>2</sub>, regional cerebral oxygen saturation.

\*The Wilcoxon Rank-Sum test comparing rSO<sub>2</sub> measurements between survivors and nonsurvivors. A 2-tailed value of  $P < 0.05$  was considered statistically significant.

<sup>†</sup>Median (within each group) of the calculated mean rSO<sub>2</sub> for each patient during this period.

**Table 4.** Comparison of Cerebral Oximetry Assessments Between Resuscitation Survivors Who Survived to Discharge and Those Who Did Not

	Resuscitation Survivors (n=19 Patients) Median and Interquartile Range		
	Survivors to Discharge (n=8)	In-Hospital Mortality (n=11)	P Value*
Median rSO <sub>2</sub> at ROSC	42.0% (40 to 47)	41.0% (34 to 50)	0.64
Median average post-arrest rSO <sub>2</sub> <sup>†</sup>	43.5% (34.2 to 53)	40% (33.5 to 48.3)	0.45

ROSC indicates return of spontaneous circulation; rSO<sub>2</sub>, regional cerebral oxygen saturation.

\*The Wilcoxon Rank-Sum test was utilized to test associations between rSO<sub>2</sub> assessments and survival to discharge among resuscitation survivors. A 2-tailed value of  $P < 0.05$  was considered statistically significant.

<sup>†</sup>Median of calculated mean rSO<sub>2</sub> values for each patient during this period.

discharge or neurological recovery. Among the 8 survivors to discharge in our study, for example, there was no significant relationship between the CPC score and the post-arrest rSO<sub>2</sub>. Importantly, this study was small in size and there was a low rate of survival with good neurological status. Moreover, it is possible that cerebral oximetry may be useful in the post-arrest period in other ways, such as to actively monitor for worsening perfusion and, potentially, direct therapeutic intervention. The potential utility of this modality for a range of uses warrants further assessment within larger populations.

**Table 5.** CPC Scores and rSO<sub>2</sub> Levels at ROSC and in the Post-arrest Period Among Survivors to Discharge

Survivors to Discharge (n=8)				
Presenting Rhythm	CPC Score	Median rSO <sub>2</sub> at ROSC (%)	Median Post-arrest rSO <sub>2</sub> (%)	Number of Patients
Ventricular fibrillation	1	44	38	2
Pulseless electrical activity	3	42	46	4
	4	42	46	2

CPC indicates cerebral performance category; ROSC, return of spontaneous circulation; rSO<sub>2</sub>, regional cerebral oxygen saturation.

The study has important limitations. First, it was small and observational. Larger prospective trials are needed to determine the potential clinical value of this assessment method. Second, we did not compare cerebral oximetry with other methods of assessing adequacy of resuscitation such as invasive arterial pressure, end-tidal CO<sub>2</sub>, or compression depth. However, this study helps to demonstrate that cerebral oximetry can be quickly initiated without interruption in resuscitation efforts. Third, there are differences, for example, in presenting rhythm, race, and age between patients who maintained ROSC and those who did not. There may also have been differences in response time or “down time” between groups that were reflected in differences in initial rSO<sub>2</sub>. These factors represent potential confounders as they may play important roles in predicting outcome; however, it is not expected that they would substantially obscure whether cerebral oximetry is a helpful assessment modality, particularly regarding neurologic status. Finally, we could not analyze the impact of post-arrest interventions such as extracorporeal membrane oxygenation–assisted resuscitation (E-CPR), therapeutic hypothermia, and urgent coronary revascularization on rSO<sub>2</sub> levels as only 2 patients received the latter 2 treatments and none received E-CPR. Notably, 1 patient showed a rise in rSO<sub>2</sub> levels following the initiation of therapeutic hypothermia post-arrest that remained stable during the rewarming phase.



## Conclusions

This study further supports the association between higher rSO<sub>2</sub> levels during resuscitation and improved resuscitation survival. Important questions remain, however, about the role of this monitoring modality during resuscitation. Further studies are essential to establish whether oximetry monitoring effectively identifies correctable deficiencies in resuscitation and whether improvement of rSO<sub>2</sub> during resuscitation meaningfully impacts neurologic outcomes and not just resuscitation survival or survival to discharge. Larger studies may also clarify whether there is any prognostic role for post-arrest oximetry monitoring.

## Disclosures

None.

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