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Editorial

Oxygen: NIRS and dear to our heart… and brain

Cardiopulmonary resuscitation (CPR) aims to restore blood flow and oxygen delivery to the brain and heart. Although the exact mechanisms through which compression of the thoracic cavity achieves this these goals remain controversial, it is clear that CPR efficacy varies depending on measurable process parameters (e.g. compression rate and depth), the underlying cause of arrest, and patients' anatomy and physiology [1]. Identification of physiological measures that quantify the adequacy of end organ oxygen delivery is appealing. Such signals could be used to personalize and optimize the ongoing process of CPR or identify cases where inadequate oxygen delivery is likely to preclude return of spontaneous circulation (ROSC) or functional recovery after ROSC. A variety of such signals have been explored for this purpose with promising results, ranging from continuous waveform capnography to quantitative electrocardiographic analysis [2,3].

In this issue of *Resuscitation*, [editor to add cite] Genbrugge, et al., describe the results of the Copernicus I observational cohort study. The major goal of this work was to test the hypothesis that an improvement in regional cerebral oxygen saturation (rSO_2) measured using near-infrared spectroscopy (NIRS) during CPR predicts ROSC during resuscitation of out-of-hospital cardiac arrest. To achieve this, the authors enrolled over 300 subjects across the catchment area of 6 hospitals over a 4-year period. Emergency medical service (EMS) providers applied the NIRS monitor on initial patient contact, and data were collected for the duration of CPR. The authors compared the evolution of these repeated measures data between patients with ROSC and those without. Not surprisingly, patients who went on to have ROSC were more likely to have had witnessed arrests, shockable rhythms, shorter EMS response times, and higher initial rSO_2 measures. Patients also experienced significant improvement in rSO_2 during CPR regardless of whether they would go on to achieve ROSC. However, those that went on to have ROSC had a significantly greater change from beginning to end of CPR with a median increase of 17% compared to 8% ($p < 0.001$). In adjusted analysis, an increase in $rSO_2 > 15\%$ during CPR was the strongest independent predictor of ROSC identified.

The authors are to be commended on the considerable effort required to complete this prospective, multicenter study. Similar results have been reported when NIRS was measured during in-hospital cardiac arrest, where higher rSO_2 predicted both ROSC and favorable functional recovery [4]. The logistics involved in deploying this type of monitoring in the more austere prehospital setting must not be overlooked. The rigor of their statistical analysis, including treatment of NIRS as a repeated measure with nonlinear evolution over time, is refreshing. Although change in rSO_2 did not predict neurological outcome at hospital discharge, that was not the aim of the study nor was the sample size chosen to allow detection of such a change.

NIRS monitoring of rSO_2 is appealing insofar as it directly measures cerebral oxygenation. Improved cerebral oxygenation during CPR is presumably correlated with improved myocardial oxygen delivery, which could reasonably be expected to increase the chance of ROSC. Similarly, it seems logical that less cerebral hypoxia during CPR might predict better neurological outcomes. In these applications, NIRS probably does not need to measure actual brain tissue oxygenation. Oxygenation of the dermis, subdermal tissues, and other extracerebral structures is also likely to be correlated with delivery to the brain and heart. Indeed, conventional pulse oximetry measured in the finger might also be responsive to CPR quality and be correlated with global oxygen delivery [5]. Thus, skeptics of the extent to which the infrared signal actually penetrates the brain tissue might be reassured that, regardless of this assumption, NIRS is still a useful measure intra-arrest.

Beyond its potential usefulness in predicting ROSC during cardiac arrest, the prospect of an easily deployed method of non-invasive monitoring of cerebral oxygenation is appealing in any setting where tissue hypoxia might result in preventable injury brain. If effective, such a technology could be used to personalize care based on an individual patient's physiology. To this end, NIRS has been tested for perioperative monitoring of cardiopulmonary bypass, other major cardiac or vascular surgical applications, and also orthopedic and abdominal surgery [6]. In the intensive care unit, it has been evaluated as a method to improve outcomes in preterm infants and in pediatric critical care [7,8]. Unfortunately, there is little consistent evidence supporting an outcome benefit in any of these settings [6–8]. This limited success may be because of poor penetration of some NIRS technology into actual brain tissue [9]. Unlike intra-arrest applications, where global oxygen delivery may be comparably impaired throughout a range of vascular beds, cerebrovascular and extracranial vascular physiology may differ sufficiently in longer term critical illness such that limited penetration into the skull is a critical limitation. Whether NIRS monitoring is useful after resuscitation from cardiac arrest as a target for titration of post-arrest care remains to be seen, but studies in other settings suggest optimism be tempered.

For now, NIRS appears to be a useful predictor of ROSC during both in- and out-of-hospital cardiac arrest. We look forward to future work directly comparing this physiological measure to other established measures like waveform capnography or indeed actual CPR performance, which was not considered in the present study. Ultimately, development of a measure or combination of measures that can be used to effectively optimize CPR and/or identify cases where resuscitation is futile, is a much-needed advance in resuscitation science.

Disclosures

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Conflict of interest

None.

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