

Cerebral Oximetry and Cardiopulmonary Resuscitation

Clifton W. Callaway, MD, PhD

The article by Ibrahim et al in this issue of *JAHA* describes how cerebral oximetry measured during cardiopulmonary resuscitation (CPR) is associated with restoration of pulses and survival.¹ The authors consider whether this technology, which is portable, noninvasive, and easy to apply, could be used to guide resuscitation. They wisely provide tempered enthusiasm for this technology, and their data add to a literature about physiological monitoring during CPR.

Measuring the quality of performance of CPR during resuscitation is a high priority. Long pauses in chest compressions, inadequate depth of compressions, or incorrect rates of compressions can reduce survival.² Consequently, devices to provide feedback to providers about depth, rate, leaning, and continuity of chest compressions have been deployed in clinical practice. Unfortunately, none of these devices measure physiological effects of CPR that are most important to promote patient survival.

Intriguing evidence about the importance of physiological feedback for improving CPR comes from several laboratory studies. In swine, when providers titrated chest compressions to an arterial blood pressure tracing during CPR, they achieved better survival,³ and this improvement was associated with improved cerebral perfusion.⁴ This fact is very important for CPR that occurs in the intensive care unit or operating room, where such monitors might be in place. Arterial monitors have rarely been placed in out-of-hospital cardiac arrest, aside from a few research studies.^{5,6} An easily and rapidly deployed monitor that could guide CPR is a priority for improving out-of-hospital resuscitation.

The current article explored cerebral oximetry specifically to address the need for monitoring during CPR. Cerebral

oximetry passes light of various wavelengths through tissue of the head and measures absorbance at wavelengths corresponding to oxyhemoglobin and deoxyhemoglobin. The calculated saturation thus corresponds to a mixture of venous ($\approx 2/3$ of blood in the region) and arterial blood ($\approx 1/3$ of blood in the region) saturation.⁷ Presumably, when oxygen delivery is impaired, oxygen extraction will increase, and venous oxygen saturation will fall. Thus, the oximeter will detect changes in the balance of oxygen delivery and oxygen utilization. Several factors may dissociate oximetry from actual oxygen delivery including venous congestion (that changes ratio of venous to arterial blood), edema, and shunting.

The central conclusion of this present study is that higher cerebral oximetry during resuscitation is associated with better outcomes. While this finding suggests that this instrument might be used to monitor CPR delivery, this article did not test whether oximetry values vary when providers adjust their interventions. An important next study should test whether providers can actually use the cerebral oximetry results to guide resuscitation.

Correlations of cerebral oxygenation, measured using the same and other perfusion monitors, with outcomes in human CPR have been reported in a number of other studies.^{8–11} Taken together, several conclusions appear to be well established: (1) cerebral oxygenation is very low during CPR, (2) cerebral oxygen measurements rise after restoration of pulses, and (3) the absence of recovery of cerebral oxygen to near-normal levels portends a bad outcome. This study also confirmed the observation that absolute values of cerebral oxygenation after return of pulses are very difficult to interpret.¹²

Probably one of the greatest concerns about cerebral oximetry is whether the light path actually reaches the brain. Elegant studies have shown that the sensors detect a significant amount of light from shallower paths through the scalp.^{7,13} To some extent, this technical uncertainty does not matter. While the brain may be the most interesting organ in which to study perfusion during resuscitation, in most shock states, oxygen delivery to superficial compartments will probably correlate with oxygen delivery to the brain. As long as the measurements provided by the devices are related to the outcomes of resuscitation, the measurements may be useful to guide clinical care.

The opinions expressed in this article are not necessarily those of the editors or of the American Heart Association.

From the Department of Emergency Medicine, University of Pittsburgh, PA.

Correspondence to: Clifton W. Callaway, MD, PhD, Department of Emergency Medicine, University of Pittsburgh, Iroquois 400A, 3600 Forbes Ave, Pittsburgh, PA 15260. E-mail: callawaycw@upmc.edu

J Am Heart Assoc. 2015;4:e002373 doi: 10.1161/JAHA.115.002373.

© 2015 The Authors. Published on behalf of the American Heart Association, Inc., by Wiley Blackwell. This is an open access article under the terms of the Creative Commons Attribution-NonCommercial License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes.

Nevertheless, we should be honest that the probe may be a global perfusion monitor rather than a specific brain monitor. Available commercial cerebral oximetry devices use a variety of proprietary innovations to reduce noise and improve tissue penetration.^{7,13} Technology will continue to advance. Future trials should explicitly assess what tissue is being measured. For example, a control experiment might be to place oximeter probes both on the head and on another part of the body. Near infrared devices easily measure regional perfusion when placed on the arm or abdomen.^{14,15} Compartments will either differ or vary together. Attention to these technical issues is important when commenting on organ-specific physiology.

In summary, this article provides additional observational data about a potential physiological monitor that could help guide CPR. Regardless of whether the device used measures brain perfusion or other tissue perfusion, a monitor that provides data correlated with outcome that can be easily deployed in an emergency is sorely needed. Because many groups have now replicated similar observations with similar instruments, perhaps we do not need additional observational data. Perhaps it is time to test whether using these monitors in real-time to adjust CPR performance, drug administration, or other features of resuscitation improves outcome.

Disclosures

None.

References

- Ibrahim AW, Trammell AR, Austin H, Barbour K, Onuorah E, House D, Miller HL, Tutt C, Combs D, Phillips R, Dickert NW, Zafari AM. Cerebral oximetry as a real time monitoring tool to assess quality of in-hospital cardiopulmonary resuscitation and post-cardiac arrest care. *J Am Heart Assoc*. 2015;4:e001859 doi: 10.1161/JAHA.115.001859.
- Meaney PA, Bobrow BJ, Mancini ME, Christenson J, deCaen AR, Bhanji F, Abella BS, Kleinman ME, Edelson DP, Berg RA, Aufderheide TP, Menon V, Leary M; CPR Quality Summit Investigators, the American Heart Association Emergency Cardiovascular Care Committee, and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Cardiopulmonary resuscitation quality: improving cardiac resuscitation outcomes both inside and outside the hospital: a consensus statement from the American Heart Association. *Circulation*. 2013;128:417–435.
- Friess SH, Sutton RM, French B, Bhalala U, Maltese MR, Naim MY, Bratinov G, Arciniegas Rodriguez S, Weiland TR, Garuccio M, Nadkarni VM, Becker LB, Berg RA. Hemodynamic directed CPR improves cerebral perfusion pressure and brain tissue oxygenation. *Resuscitation*. 2014;85:1298–1303.
- Friess SH, Sutton RM, Bhalala U, Maltese MR, Naim MY, Bratinov G, Weiland TR III, Garuccio M, Nadkarni VM, Becker LB, Berg RA. Hemodynamic directed cardiopulmonary resuscitation improves short-term survival from ventricular fibrillation cardiac arrest. *Crit Care Med*. 2013;41:2698–2704.
- Wildner G, Pauker N, Archan S, Gemes G, Rigaud M, Pocivalnik M, Prause G. Arterial line in prehospital emergency settings—a feasibility study in four physician-staffed emergency medical systems. *Resuscitation*. 2011;82:1198–1201.
- Manning JE. Feasibility of blind aortic catheter placement in the prehospital environment to guide resuscitation in cardiac arrest. *J Trauma Acute Care Surg*. 2013;75(2 suppl 2):S173–S177.
- Bickler PE, Feiner JR, Rollins MD. Factors affecting the performance of 5 cerebral oximeters during hypoxia in healthy volunteers. *Anesth Analg*. 2013;117:813–823.
- Parnia S, Nasir A, Ahn A, Malik H, Yang J, Zhu J, Dorazi F, Richman P. A feasibility study of cerebral oximetry during in-hospital mechanical and manual cardiopulmonary resuscitation. *Crit Care Med*. 2014;42:930–933.
- Parnia S, Nasir A, Shah C, Patel R, Mani A, Richman P. A feasibility study evaluating the role of cerebral oximetry in predicting return of spontaneous circulation in cardiac arrest. *Resuscitation*. 2012;83:982–985.
- Sanfilippo F, Serena G, Corredor C, Benedetto U, Maybauer MO, Al-Subaie N, Madden B, Oddo M, Cecconi M. Cerebral oximetry and return of spontaneous circulation after cardiac arrest: a systematic review and meta-analysis. *Resuscitation*. 2015;94:67–72.
- Ito N, Nishiyama K, Callaway CW, Orita T, Hayashida K, Arimoto H, Abe M, Endo T, Murai A, Ishikura K, Yamada N, Mizobuchi M, Anan H, Okuchi K, Yasuda H, Mochizuki T, Tsujimura Y, Nakayama T, Hatanaka T, Nagao K; J-POP Registry Investigators. Noninvasive regional cerebral oxygen saturation for neurological prognostication of patients with out-of-hospital cardiac arrest: a prospective multicenter observational study. *Resuscitation*. 2014;85:778–784.
- Storm C, Leithner C, Krannich A, Wutzler A, Ploner CJ, Trenkmann L, von Rheinbarben S, Schroeder T, Luckenbach F, Nee J. Regional cerebral oxygen saturation after cardiac arrest in 60 patients—a prospective outcome study. *Resuscitation*. 2014;85:1037–1041.
- Davie SN, Grocott HP. Impact of extracranial contamination on regional cerebral oxygen saturation: a comparison of three cerebral oximetry technologies. *Anesthesiology*. 2012;116:834–840.
- Kalkan A, Bilir O, Ersunan G, Ozel D, Tas M, Memetoglu ME. Abdominal oxygen saturation for monitoring return of spontaneous circulation in out-of-hospital cardiac arrest using near infrared spectrophotometry. *Am J Emerg Med*. 2015;33:344–348.
- Neto AS, Pereira VG, Manetta JA, Espósito DC, Schultz MJ. Association between static and dynamic thenar near-infrared spectroscopy and mortality in patients with sepsis: a systematic review and meta-analysis. *J Trauma Acute Care Surg*. 2014;76:226–233.

Key Words: Editorials • cerebral blood flow • sudden cardiac arrest • sudden death