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Emerging Evidence

Use of Near-Infrared Spectroscopy by Paramedics During Out-of-Hospital Cardiac Arrest: A Feasibility Study

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ABSTRACT

Near-infrared spectroscopy (NIRS) provides continuous real-time measurement of regional cerebral oxygen saturation (rSO_2) during resuscitation. We aimed to evaluate the feasibility of paramedics using NIRS during out-of-hospital cardiac arrest (OHCA) resuscitation. Paramedics were trained to record rSO_2 and mark events during resuscitation. Feasibility was defined as > 70% of cases with rSO_2 data and event markers. The monitor was applied on 23 patients with OHCA. Of these, 19 (83%) had rSO_2 data (median duration of 17.9 minutes; interquartile range, 9.7-28) and 17 (74%) had event markers (median 3 events per case; interquartile range, 1-4). It is feasible for paramedics to apply NIRS during OHCA resuscitation.

RÉSUMÉ

La spectroscopie proche infrarouge (NIRS, de l'anglais *near-infrared spectroscopy*) fournit une mesure continue en temps réel de la saturation cérébrale régionale en oxygène (rSO_2) pendant la réanimation. Notre but était d'évaluer la faisabilité de l'utilisation de la NIRS par le personnel paramédical au cours de la réanimation d'un arrêt cardiaque extrahospitalier. Des intervenants paramédicaux ont appris à enregistrer la rSO_2 et les marqueurs d'événements pendant une réanimation. La faisabilité a été définie comme l'obtention de données sur la rSO_2 et de marqueurs d'événements dans plus de 70 % des cas. Ces intervenants médicaux ont utilisé le moniteur chez 23 patients en arrêt cardiaque extrahospitalier. Ils ont recueilli des données sur la rSO_2 chez 19 (83 %) de ces patients (durée médiane de 17,9 minutes; écart interquartile : de 9,7 à 28) et des marqueurs d'événements chez 17 (74 %) (médiane de 3 événements par cas; écart interquartile : de 1 à 4). Il est faisable pour le personnel paramédical d'utiliser la NIRS au cours de la réanimation d'un arrêt cardiaque extrahospitalier.

Out-of-hospital cardiac arrest (OHCA) remains a leading cause of death globally.[1-3] Although there have been improvements in achieving return of spontaneous circulation (ROSC), long-term outcomes remain poor. In North America, the average survival rate for patients with OHCA treated by emergency medical services (EMS) is 7.9%, ranging from 3.0% to 16.3%.[1] Because of high metabolic demand, the brain sustains significant damage during cardiac arrest from both prolonged ischemia and subsequent reperfusion post-ROSC.[4] Among patients with OHCA who survive to hospital admission, approximately two-thirds die before discharge as a result of neurological injuries, and of those discharged, one-third may have irreversible cognitive disabilities.[4] These neurological sequelae range from memory and motor deficits to persistent vegetative state.

As resuscitation science has advanced, the focus has shifted from restarting the heart to improving neurological recovery. There is currently no tool available in the prehospital setting that provides a direct measure of cerebral oxygenation and perfusion. Prehospital clinicians rely on indirect measures, such as end-tidal carbon dioxide ($ETCO_2$) values or cardiopulmonary resuscitation quality metrics, to indicate adequate cardiac output and presumably cerebral perfusion. It is not known whether these indirect measures translate to improved cerebral perfusion or oxygenation. There is a need for an easy, real-time monitor of brain perfusion and oxygenation during resuscitation, particularly in the out-of-hospital setting.

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Ethics Statement: The study was approved by the St Michael's Hospital and Lakeridge Health Research Ethics Boards.

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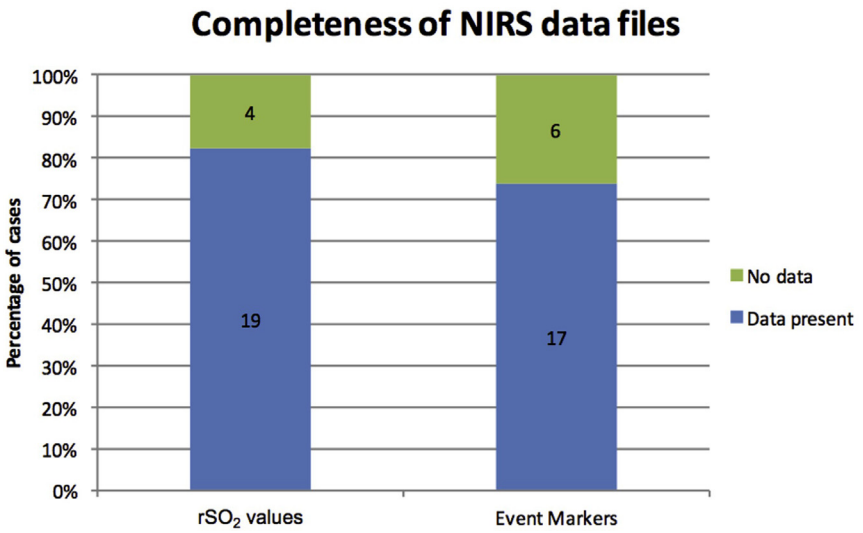

Figure 1. Completeness of data capture using a near-infrared spectroscopy (NIRS) device. rSO_2, regional cerebral oxygen saturation.

Near-infrared spectroscopy (NIRS) is a noninvasive optical imaging technology that provides continuous, real-time detection of regional cerebral oxygenation.[5,6] NIRS uses optodes placed on a patient's forehead that emit specific wavelengths of infrared light into the cerebral cortex, absorbed by chromophores (eg, oxygenated hemoglobin). The residual light scatter can be detected and interpreted, providing a measure of regional cerebral oxygen saturation (rSO_2).

NIRS has been studied in healthy patients and in low-flow states,[7,8] including cardiac surgery,[9] trauma resuscitation,[10] and during venoarterial-extracorporeal membrane oxygenation in the intensive care unit.[11] This technology has also been used during in-hospital cardiac arrest demonstrating associations between higher rSO_2 values and better patient outcomes.[12] Given that the majority of cardiac arrests occur out of hospital and patient outcomes are largely determined before hospital arrival,[13] NIRS may prove a more powerful tool when applied in the prehospital setting. However, the utility of NIRS in the field by paramedics is not known. To date, there are a limited number of small studies examining the use of NIRS during OHCA,[14-20] with only one study involving paramedics,[19] and this study did not involve the paramedics performing resuscitation. The objective of this study was to assess the feasibility of the use of NIRS by paramedics during OHCA resuscitation.

Methods

Setting and study design

We conducted this study from August 2016 to April 2017 within the Regional Municipality of York, which has a geographical area of 1762 km^2 and is home to more than 1.1 million people. In York Region, calls for cardiac arrest are responded to by the nearest ambulance, whether basic life support or advanced life support (ALS) staffed. If a basic life support paramedic crew were the closest ambulance, then the closest ALS crew would also attend the call for support. In addition to this standard care, there are 3 nontransporting Special Response Unit (SRU) ambulances, each staffed by a single ALS trained paramedic. The SRU paramedics historically respond to the most cardiac arrest calls (> 25 each per year) and were therefore selected for this trial.

SRU paramedics were trained in application of the NIRS monitor (Equanox 7600, Nonin, Plymouth, MI) through a "train-the-trainer" model. Paramedics were instructed to place the device on the patient as early as possible during the resuscitation and to leave the device on until arrival at the hospital or termination of resuscitation in the field. The noninvasive optode was placed on the patient's forehead on either side of the midline, between the eyebrows and hairline as per manufacturer instructions. Paramedics were asked to press an "event marker" when an intervention was performed (defibrillation, medication administration, intubation) but not to alter the resuscitation or use the rSO_2 recordings to guide patient care.

Population

We collected data on patients with OHCA who were attended to by the SRU paramedics. We included patients aged more than 18 years with OHCA of presumed cardiac origin. Patients had to be treated by SRU paramedics with a NIRS monitor.

We excluded cardiac arrests secondary to obvious noncardiac cause, patients with "do not resuscitate" orders, and patients who met criteria for obvious death.

Data collection and analysis

After the completion of each cardiac arrest resuscitation, monitor recordings were downloaded by a member of the research team onto a secure, password-protected computer. Recordings were then examined for completeness of both rSO_2 readings (duration of oximetry recording) and for recording of event markers (count variable). A priori, we defined our feasibility criteria as > 70% of patient recordings with rSO_2 data and > 70% of patient recordings with event markers indicated.

This study was approved by the Research Ethics Boards at St. Michael's Hospital and Lakeridge Health, the Base

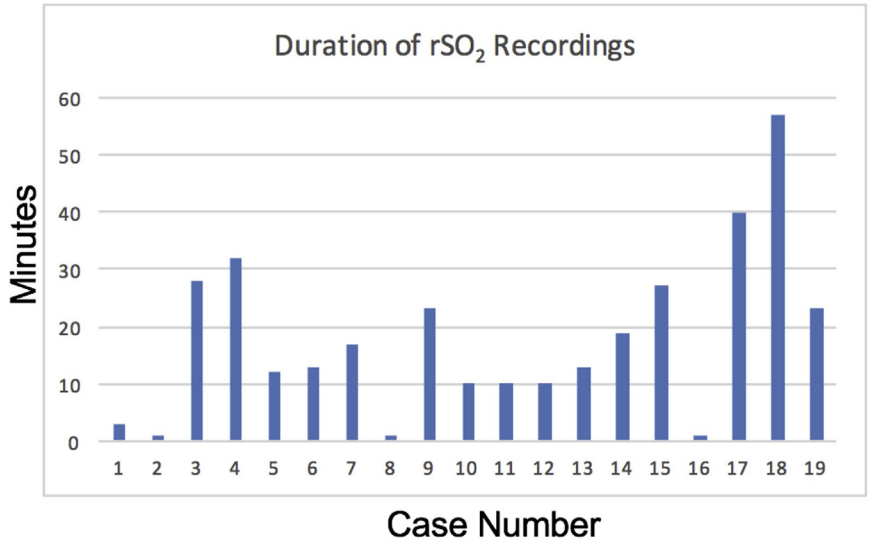

Figure 2. Duration of cerebral oximetry recordings. rSO_2, regional cerebral oxygen saturation.

Hospital for York Region Paramedic Services. Because the patients involved in this study were in cardiac arrest and could not provide consent, enrollment was performed under waiver of consent outlined in Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans, 2nd edition (TCPS 2) article 3.7. A notification letter was sent to all patients or family members with known addresses to inform of patient enrollment and study information, and allow for study withdrawal.

Results

We collected data from 23 cases of OHCA during the study period. Of the 23 cases, 19 (83%) contained rSO_2 recordings and 17 (74%) contained event markers recorded by the paramedics during resuscitation (Fig. 1). The median duration of recordings for the 19 cases was 17.9 minutes (interquartile range [IQR], 9.7-28.0 minutes) (Fig. 2). The median (IQR) value of rSO_2 readings for each case ranged from a low of 12 (10-15) to a high of 68 (66-70). The median number of event markers per case was 3 (IQR, 1-4) (Fig. 3).

Discussion

We found that the use of NIRS by paramedics was feasible during OHCA resuscitation. Paramedics demonstrated that they were able to reliably record and collect rSO_2 data and record trigger events in the prehospital setting. Paramedics were willing and able to collect NIRS data as part of their resuscitation efforts during OHCA.

Our study results align with previously published studies, which also found it feasible to obtain rSO_2 recordings during

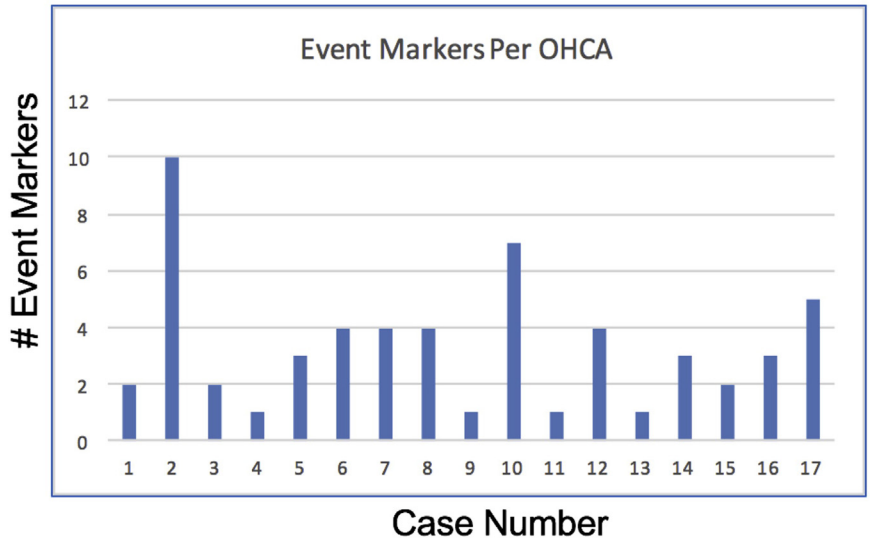

Figure 3. Number of event markers per case. OHCA, out-of-hospital cardiac arrest.

cardiac arrest in the prehospital setting.[15,16,19,21,22] These studies demonstrated feasibility in physician-based EMS systems or when used by study investigators to gather NIRS data from the field. In our study, we demonstrated the feasibility of NIRS monitoring during OHCA by the treating paramedics in a North American EMS system where out-of-hospital care is provided solely by paramedics.

Paramedics are currently limited in their patient monitoring capabilities during cardiac resuscitation. $ETCO_2$ monitoring has emerged as one of the most commonly used modalities to monitor physiological responses to resuscitation care. However, $ETCO_2$ is a surrogate marker of whole body perfusion and is not specific to the brain. Furthermore, accurate quantitative $ETCO_2$ readings rely on the use of advanced airways, specifically endotracheal intubation; however, current recommendations de-emphasize the use of advanced airways, which may lead to fewer patients being intubated in the prehospital setting. NIRS monitoring has the potential to become an important tool in treating OHCA. It is portable, noninvasive, and easy to apply, making it ideal for use in the prehospital setting. Clinicians are able to monitor cerebral oxygenation in real time to see the effect of treatment interventions and potentially prognosticate patient outcomes. Previous studies have shown that rSO_2 values are associated with clinical outcomes.[12,16,21,23-25] Patients who achieve ROSC have higher rSO_2 values during resuscitation compared with patients who cannot be resuscitated.[26] There are several small studies showing an association between higher rSO_2 values and survival and neurological outcome at hospital discharge.[12,22,26,27] However, it is not yet known what rSO_2 cutoffs are prognostic for ROSC, survival, and favourable neurological outcomes or how to best integrate rSO_2 information into clinical practice. Further research is required to determine how to optimize resuscitation efforts using NIRS monitoring.

Limitations

Our study has several limitations. This study did not mandate the use of the NIRS monitor for every cardiac arrest attended by the SRU paramedics, and there may have been some selection bias as to which patients were included in the study. However, the main objective of the study was to determine whether paramedics could use NIRS monitoring, and patient selection would not have affected our results. Second, the number of patients included was small, which limited our ability to analyze any associations between rSO_2 values and patient interventions (eg, cardiopulmonary resuscitation quality) or outcomes. The small number of patients was related to having only a single NIRS device, and the SRU paramedic did not attend all consecutive cardiac arrests because of geographical limitations. This can be overcome in future work by including multiple devices in ambulances that are able to attend a larger number of cardiac arrests. Last, we were unable to gather data from defibrillator files or patient care records, or to compare rSO_2 recordings, events, and patient outcomes.

Future direction

It is feasible for paramedics to use NIRS technology during OHCA; however, it is important to examine the impact of this technology on OHCA management and outcomes. The next phase of this study is to collect NIRS data from a larger number of OHCA cases and to align rSO_2 recordings with prehospital patient care records and defibrillator data. This will allow us to correlate rSO_2 data with prehospital treatment and examine for associations with clinical outcomes. An important aspect of our future work is to correlate NIRS recordings with the initiation of resuscitation, which will be important in establishing baseline NIRS readings, and to monitor the proportion of NIRS readings compared with the entire duration of resuscitation.

Conclusion

It is feasible for paramedics to use NIRS monitoring during OHCA resuscitation. NIRS has the potential to improve cardiac arrest resuscitation by optimizing brain oxygenation. Further research is required to evaluate regional oxygen saturation cutoffs to optimize cardiac arrest resuscitation.

Disclosures

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