The Value of NIRS and potential applications in V-A ECMO Patients

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Disclosure

- Research equipment and disposables provided by Nonin medical
Objectives

• What is a regional Oximetry device?

• Noritoshi et al (2014) Study

• SPH ECPR oximetry study

• Assessment of Cerebral autoregulation and post arrest ECMO management
Near Infrared Spectroscopy (NIRS)
Nonin Sensmart

- NIRS measures:
  - Oxygenated Hb
  - Deoxygenated Hb
  - Total tissue hemoglobin (Hb) density

- Cerebral oximetry = oxygenated Hb/ total Hb

- Provides an Absolute value
SPH ECPR Program

• Specifically for out of hospital cardiac arrests
• The first formal ECPR program in Canada with prehospital-hospital integration

• Patients arrive with the LUCAS mechanical CPR device
  – Difficult to assess efficacy of CPR for this demographic
Can Cerebral Oximetry be used to assess efficacy of conventional CPR?
Use of NIRS in ECPR

Noninvasive regional cerebral oxygen saturation for neurological prognostication of patients with out-of-hospital cardiac arrest: A prospective multicenter observational study☆,☆☆

- Noritoshi et al 2014
Noritoshi et al 2014

- Japan based multicenter Study
- n= 672
- EMS providers not permitted to stop CPR in the field
- All out of hospital Cardiac arrests are treated at hospitals with an ED
- Used the INVOS oximeter device
Noritoshi et al 2014

• Can Cerebral Oximetry values provide:
  – A reliable means to predict likelihood of good neurological outcome?

• What Oximetry values are reflective of adequate perfusion during conventional (LUCAS) CPR?
Noritoshi et al. 2014

- All cardiac arrest patients on arrival to the ED received rSO₂ monitoring within 3 minutes
- Monitoring commenced for 1 min
- Lowest rSO₂ reading was recorded
- Irrespective of rSO₂ values all patients received best therapy (ROSC or ECMO)
- Patients were categorized according to the Cerebral performance category (CPC) after 90 days
Cerebral Performance Categories Scale

CPC Scale

<table>
<thead>
<tr>
<th>Note: If patient is anesthetized, paralyzed, or intubated, use “as is” clinical condition to calculate scores.</th>
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<tbody>
<tr>
<td><strong>CPC 1.</strong> Good cerebral performance: conscious, alert, able to work, might have mild neurologic or psychologic deficit.</td>
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<tr>
<td><strong>CPC 2.</strong> Moderate cerebral disability: conscious, sufficient cerebral function for independent activities of daily life. Able to work in sheltered environment.</td>
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<tr>
<td><strong>CPC 3.</strong> Severe cerebral disability: conscious, dependent on others for daily support because of impaired brain function.Ranges from ambulatory state to severe dementia or paralysis.</td>
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<tr>
<td><strong>CPC 4.</strong> Coma or vegetative state: any degree of coma without the presence of all brain death criteria. Unawareness, even if appears awake (vegetative state) without interaction with environment; may have spontaneous eye opening and sleep/awake cycles. Cerebral unresponsiveness.</td>
</tr>
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<td><strong>CPC 5.</strong> Brain death: apnea, areflexia, EEG silence, etc.</td>
</tr>
</tbody>
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Results

Cerebral performance category (CPC)

94.3%

3.4%

N=672
Results

Cerebral performance category (CPC) 1

- $rSO_2 \leq 15\%$ (n = 449): 0.7% (3/449)
- $rSO_2 16-42\%$ (n = 167): 1.8% (3/167)
- $rSO_2 > 42\%$ (n = 56): 41% (23/56)

$p < 0.001$
Results

• rSO$_2$ value of $>42\%$ optimal value for predicting good neurological outcome after OHCA at 90 days

• Even with ROSC and detectable pulses:
  – very low chance (1%) of obtaining good neurological outcome unless rSO$_2$ $>42\%$ at hospital arrival
Study findings

• Data strongly implies the probability of good neurological outcomes with an rSO$_2$ <42% is 0.97% p=0.001
Limitations

• Neurological outcomes were not correlated with age/length of CPR and ECMO vs. non ECMO

• Length of time monitoring rSO$_2$ was limited

• rSO$_2$ measured by NIRS reflects only cerebral perfusion at the superficial layers in the limited frontal lobe areas

• Reliability/consistency of Oximetry device
rSO$_2$ As a means to assess ECPR candidacy

- SPH ECPR study:
  - Can we replicate the findings of Noritoshi et al 2014?
  - How can we improve the methodology?

- Were Noritoshi et al right to focus solely on Oximetry values???
SPH current inclusion criteria

without $r\text{SO}_2$

- Presumed Cardiac Etiology
- Age $< 65$ yrs
- Witnessed arrest
- Bystander CPR
- Or Hypothermia

Ideal Candidate!
Potential ECPR inclusion criteria with $rSO_2$

Ideal ECPR candidate profile

Cerebral Oximetry values below 42%

Ineligible for ECPR

Could this scenario become a reality at SPH?

Poor CPR/Peripheral vascular disease/dissection?

At SPH we will place all ECPR candidates on ECMO despite the $rSO_2$ value
ECPR Candidacy Dilemma

• Noritoshi et al (2014) acknowledge:
  – A small percentage (1%) of patients with an rSO$_2$ below 42% achieved good neurological outcome (CPC 1)
  – Adherence to a strict ECPR protocol becomes a moral and ethical dilemma for “ideal candidates” if using rSO$_2$ as a secondary means to assess candidacy for ECPR
SPH study

• Improve upon the Noritoshi study
  – Very specific patient population (ECPR ECMO patients only)
  – Correlate length of CPR-ECMO with neurological outcome

• Ultimate goal: Reliably predict good neurological outcome with 100% accuracy for ECPR candidates (Realistic??)

• Unlike the Noritoshi study:
  – Nonin device provides Absolute values as opposed to the INVOS which only provides a Trending Value = greater reliability
SPH Oximetry study

• What is Cerebral oximetry monitoring telling us about the Patient?
  – Could this improve/ direct post Cardiac arrest care?

• Can we use Cerebral oximetry and MAP to determine integrity of Cerebral autoregulation?
Assessment of Cerebral Autoregulation

• Loss of Cerebral autoregulation is "strongly associated with poor neurological outcomes"

Rangel-Castilla et al, Neurosurgical Focus 2008
Lower and Upper limits of Cerebral autoregulation

LLL = Lower limit of auto-regulation  ULA = Upper limit of autoregulation
Does ability to preserve Cerebral autoregulation determine survivability?

Rangel-Castilla et al, Neurosurgical Focus 2008
Autoregulation Index: ICP and Cerebral Blood Volume

Autoregulation

Cerebral Performance Category

rSO$_2$(%)

Loss of AR/Brain Death??

Integrity/wider plateau of AR??
Goal: To develop an autoregulation monitor that tells us *where* the patient is on the curve as blood pressure changes…

Should we target blood pressures that *optimize* autoregulation?
NIRS and Cerebral autoregulation

• “Non-invasive near-infrared spectroscopy accurately identified the lower limit of autoregulation during normothermia and hypothermia in piglets resuscitated from arrest”

Lee et al 2011
Cerebral oximetry to assess autoregulation functionality

- Δtissue $\text{O}_2$ saturation is proportional to Δcerebral blood flow with stable metabolic rate and oxygen supply
- Lose autoregulation: cerebral oximetry becomes passive to arterial blood pressure (ABP)
- How could this direct care in the ED and CSICU for ECPR patients?

Lee et al 2016
Can Cerebral Autoregulation be assessed using NIRS on ECMO patients?

• “Manipulations of ECMO flows are associated with regional changes in cerebral autoregulation which may potentially have an important bearing on clinical outcome”

Papademetriou et al 2013
Cerebral Blood flow is passive to MAP and Cardiac output

MAP at 3L/min flow = 67 mm Hg
MAP AT 4L/min = 83 mm Hg

Cerebral Blood flow is passive to MAP and Cardiac output
• “It remains unclear how systemic hemodynamics should be adjusted to ensure adequate cerebral oxygenation”
V-A ECMO

100% ECMO flow
Overall functional autoregulation

70% ECMO flow
Pressure passive

Clinical management of V-A ECMO flows

- By trending both MAP/ECMO flows and Cerebral Oximetry one can discern the lower and upper limit of autoregulation

- When cerebral oximetry becomes passive to variations in ECMO flows and MAP this suggests inadequate cardiac output and MAP to maintain cerebral autoregulation
NIRS based care model

Optimize ECMO flows
Conclusions

- Can we use rSO$_2$ as a definitive means to assess candidacy for ECPR and good neurological outcomes?
- Can we use rSO$_2$ to improve resuscitation attempts and post arrest care?
- Does ECPR offer a greater chance of post arrest survival?
Questions/Comments