MONITORING CEREBRAL PERFUSION IN CAROTID ENDARTERECTOMY

With the INVOS™ cerebral/somatic oximeter

The common methods of monitoring bilateral cerebral perfusion adequacy and identifying the need for shunting during carotid endarterectomy (CEA) under general anesthesia are electroencephalogram (EEG), stump pressure (SP), or transcranial Doppler (TCD) monitoring.

This clinical evidence guide explores how INVOS™ monitoring technology can be a practical and continuous method to monitor perfusion and identify patients who may benefit from shunting, either alone or in combination with other monitoring modalities.
INVOS™ monitoring technology can be used to identify patients at risk for cerebral ischemia during CEA.

Near infrared spectroscopy monitoring during carotid endarterectomy: which threshold value is critical?
Mille T, Tachimiri ME, Klersy C, et al.

<table>
<thead>
<tr>
<th>Study design</th>
<th>Single-center, retrospective study (Italy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arms</td>
<td>Single arm: INVOS™ monitoring technology</td>
</tr>
<tr>
<td>Objective</td>
<td>Identify the relative change from baseline rSO₂ values 2 minutes after clamping that is predictive of impending cerebral ischemia</td>
</tr>
<tr>
<td>N</td>
<td>594</td>
</tr>
<tr>
<td>Population</td>
<td>CEA patients under general anesthesia</td>
</tr>
<tr>
<td>Threshold for intervention</td>
<td>No interventions were described and no shunts were placed</td>
</tr>
</tbody>
</table>

Results
- 20/594 patients (3.4%) presented with neurological complications
- 16/594 patients (2.7%) showed an early decrease in rSO₂ >20% from baseline
  - 6/16 patients (37.5%) showing an early decrease in rSO₂ >20% from baseline also presented with neurological complications
  - 14/578 of the remaining patients (2%) showing a decrease in rSO₂ <20% from baseline presented with neurological complications (p = 0.0001)
- An rSO₂ decrease of 11.7% from baseline at 2 minutes after clamping was identified as the optimal threshold to identify patients with a neurological complication:
  - Positive predictive value (PPV) = 10%
  - Negative predictive value (NPV) = 99%
  - Sensitivity = 75%
  - Specificity = 77%
- A threshold of 20% was associated with lower sensitivity (30%), higher specificity (98%), with a PPV and NPV of 37% and 98%, respectively, for identifying patients with neurological complications

Conclusions
Near-infrared spectroscopy (NIRS) monitoring technology is a useful method to detect cerebral ischemia during CEA.
INVOS™ technology may be an effective monitoring method compared to EEG to inform shunt selection during CEA.

Near-infrared spectroscopy to indicate selective shunt use during carotid endarterectomy
Pennekamp CWA, Immink RV, den Ruijter HM, et al.

<table>
<thead>
<tr>
<th>Study design</th>
<th>Single-center, prospective observational study (The Netherlands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arms</td>
<td>Single arm: concomitant monitoring with INVOS™ technology, EEG, and TCD</td>
</tr>
<tr>
<td>Objective</td>
<td>Compare the ability of INVOS™ monitoring technology and TCD to EEG in detecting cerebral ischemia and determining the need for shunting</td>
</tr>
<tr>
<td>N</td>
<td>151</td>
</tr>
<tr>
<td>Population</td>
<td>CEA patients under general anesthesia with a sufficient TCD window</td>
</tr>
<tr>
<td>Definition of desaturation</td>
<td>rSO₂ ≥16% from baseline value</td>
</tr>
<tr>
<td>Threshold for intervention</td>
<td>Shunt was placed when EEG detected the occurrence of new delta or theta activity</td>
</tr>
<tr>
<td>Results</td>
<td>• 17/151 (11%) of patients were shunted based on EEG changes</td>
</tr>
<tr>
<td></td>
<td>– In 16/17 cases, rSO₂ also dropped to ≥16% from baseline</td>
</tr>
<tr>
<td></td>
<td>– In 5/134 of the remaining patients not shunted, rSO₂ dropped to ≥16% from baseline value without EEG changes</td>
</tr>
<tr>
<td></td>
<td>– 129 patients showed no change in EEG or rSO₂, drop of ≥16% from baseline value</td>
</tr>
<tr>
<td></td>
<td>• Compared to EEG, rSO₂ demonstrated the following regarding indications for shunting:</td>
</tr>
<tr>
<td></td>
<td>– PPV = 76%</td>
</tr>
<tr>
<td></td>
<td>– NPV = 99%</td>
</tr>
<tr>
<td></td>
<td>– Sensitivity = 94%</td>
</tr>
<tr>
<td></td>
<td>– Specificity = 96%</td>
</tr>
<tr>
<td></td>
<td>• Similar results were seen with TCD, although the PPV and specificity were lower at 53% and 90%, respectively</td>
</tr>
<tr>
<td></td>
<td>• A trend toward higher incidence of stroke in shunted patients was seen (11.8% vs. 1.5%; p = 0.06)</td>
</tr>
<tr>
<td>Conclusions</td>
<td>NIRS monitoring technology may be effective for shunt selection. The optimal threshold for shunt selection requires further study.</td>
</tr>
</tbody>
</table>
INVOS™ monitoring technology combined with stump pressure measurements provides an effective means of identifying patients for shunt placement during CEA.

**Combined stump pressure and oximetry for shunt use during carotid endarterectomy**


<table>
<thead>
<tr>
<th>Study design</th>
<th>Single-center, prospective trial (Canada)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arms</td>
<td>Single arm: continuous INVOS™ monitoring technology and stump pressure monitoring</td>
</tr>
<tr>
<td>Objective</td>
<td>Compare rSO₂ to stump pressure monitoring for shunt use and symptomatic cross-clamp ischemia</td>
</tr>
<tr>
<td>N</td>
<td>300</td>
</tr>
<tr>
<td>Population</td>
<td>CEA patients under general anesthesia</td>
</tr>
<tr>
<td>Threshold for intervention</td>
<td>Shunt was placed if a decrease ≥10% from baseline and/or mean stump pressure &lt;40 mm Hg was observed</td>
</tr>
</tbody>
</table>
| Results                 | • 16% and 21% of patients experienced a drop in rSO₂ or stump pressure, respectively, that met the requirement for shunting  
                          • 75/300 (25%) patients were shunted  
                          – 38 (50%) for low rSO₂ + low stump pressure  
                          – 11 (15%) for low rSO₂  
                          – 26 (35%) for low stump pressure  
                          • Only one patient included in the study presented with postoperative neurological defects  
                          – The patient had experienced a 10% drop in rSO₂ from baseline and a stump pressure of 40 mm Hg (these values were considered to be borderline for shunting; therefore it was not performed) |
| Conclusions             | Monitoring both rSO₂ and stump pressure eliminated cross-clamp ischemia almost entirely and could be an effective way of identifying patients for shunting. |
INVOS™ monitoring technology paired with an interventional algorithm can inform the need for shunt placement during CEA.

**Evaluation of an intraoperative algorithm based on near-infrared refracted spectroscopy monitoring, in the intraoperative decision for shunt placement, in patients undergoing carotid endarterectomy**


### Study design
Multicenter, prospective, randomized controlled trial (Greece)

### Arms
- **GROUP A:** INVOS™ monitoring technology and use of an interventional protocol to restore rSO₂
- **GROUP B:** INVOS™ monitoring technology without the use of an interventional protocol
- **GROUP C:** Control, no INVOS™ monitoring technology used

### Objective
Examine the effect of using NIRS monitoring with an interventional protocol on the decision to place a shunt

### N
253

### Population
CEA patients under general anesthesia

### Threshold for intervention
rSO₂ < 80% of baseline value prompted use of interventional protocol, including consideration to place a shunt

### Results
- The incidences of shunt placement were significantly different between groups (p < 0.001):
  - Group A = 27.7%
  - Group B = 59.5%
  - Group C = 100%
- Compared to group A, patients in groups B and C had a 3.7 and 70.6 times greater likelihood of receiving a shunt, respectively
- Compared to group B, group C had a 19.4 times greater likelihood of receiving a shunt
- There were no significant differences in the incidences of postoperative neurologic deficits among the three groups

### Conclusions
NIRS monitoring technology paired with the use of a specific treatment algorithm may aid in the selective shunting of patients undergoing CEA.
A selection of clinical studies using INVOS™ technology intraoperatively in carotid endarterectomy surgery


