Near Infrared Spectroscopy for the Detection of Desaturations in Vulnerable Ischemic Brain Tissue
A Pilot Study at the Stroke Unit Bedside

Marcel J.H. Aries, MD; Adriaan D. Coumou, MD; Jan Willem J. Elting, PhD; Joep J. van der Harst, MD; Berry P.H. Kremer, PhD; Patrick C.A.J. Vroomen, PhD

Background and Purpose—There is uncertainty whether bilateral near infrared spectroscopy (NIRS) can be used for monitoring of patients with acute stroke.

Methods—The NIRS responsiveness to systemic and stroke-related changes was studied overnight by assessing the effects of brief peripheral arterial oxygenation and mean arterial pressure alterations in the affected versus nonaffected hemisphere in 9 patients with acute stroke.

Results—Significantly more NIRS drops were registered in the affected compared with the nonaffected hemisphere (477 drops versus 184, \( P < 0.001 \)). In the affected hemispheres, nearly all peripheral arterial oxygenation drops (n=128; 96%) were detected by NIRS; in the nonaffected hemispheres only 23% (n=30; \( P = 0.17 \)). Only a few mean arterial pressure drops were followed by a significant NIRS drop. This was however significantly different between both hemispheres (32% versus 13%, \( P = 0.01 \)).

Conclusions—This pilot study found good responsiveness of NIRS signal to systemic and stroke-related changes at the bedside but requires confirmation in a larger sample. (Stroke. 2012;43:00-00.)

Key Words: blood pressure • NIRS • peripheral arterial oxygen saturation • stroke

In patients on stroke units, parameters like blood pressure (BP) and peripheral arterial oxygenation (SpO₂) are continuously monitored. It would probably be more relevant to be informed bedside on cerebral perfusion and metabolism. Near infrared spectroscopy (NIRS) allows noninvasive measurement of regional cerebral oxygen saturation with high time resolution. NIRS measurements are derived from a sample volume of one third of arterial blood and intra- or extracellular tissue and two thirds of venous blood. Relative contributions vary depending on several systemic (eg, BP and oxygenation) and local stroke-related factors (eg, ischemia and autoregulation).1 As such, NIRS may provide a useful summary measure of factors that determine blood oxygenation in the early cerebral venous phase. A first requirement for use of NIRS in stroke unit monitoring would be that NIRS measurements are responsive to such systemic and stroke-related changes.

In this pilot study, NIRS responsiveness was studied by assessing the effects of brief SpO₂ and BP alterations in the affected versus nonaffected hemisphere. Obstructive sleep apnea syndrome, highly prevalent in patients with acute stroke, serves as an attractive in vivo model for such changes.

Questions addressed in this study in the first 24 hours after stroke are: (1) does bilateral frontal NIRS change after nocturnal SpO₂ change and relative hypotension (responsiveness to systemic changes); and (2) can NIRS demonstrate differences between affected and nonaffected hemispheres after SpO₂ and BP changes (responsiveness to stroke-related changes)?

Method

Patients

After local ethics committee approval and with informed consent, 9 patients were studied overnight within 24 hours after anterior circulation stroke. Patients with severe aphasia and hemodynamic instability were excluded. All patients received standard stroke unit care and work-up including ultrasound examination of extracranial vessels. Measurements were started from 10:00 PM onward, ending the next morning or at the patient’s request.

Near Infrared Spectroscopy

The INVOS 5100C device (Somanetics Corp, Detroit, MI) was used with a sampling frequency of 0.2 Hz. Adhesive optodes were placed on each side of the forehead according to the manufacturer’s recommendations. NIRS was incorporated into a continuous over-
Results

Nine patients were included with a total overnight recording time of 2,898 minutes (range, 115–580 minutes) representing 49 hours. Patient characteristics are presented in Table 1. Ultrasound bedside examination demonstrated flow in both middle cerebral arteries insonated at a depth of 40 to 50 mm in all patients. Table 2 provides individual nocturnal changes in NIRS and its relation with significant SpO2 and mean arterial pressure drops. Two patients had problematic SpO2 measurements. Overall, 133 significant SpO2 and 414 significant mean arterial pressure drops were recorded. Significantly more NIRS drops were registered in the affected compared with the nonaffected hemisphere (477 drops versus 184, P<0.001). In the affected hemispheres, 96% of 133 SpO2 drops were detected by NIRS; in the nonaffected hemispheres, only 23% of 133 (P=0.17). Only a few mean arterial pressure drops were followed by a significant NIRS drop, 32% in affected versus 13% in nonaffected hemisphere (P=0.01; Table 2). In comparison to lacunar stroke, the difference in NIRS drops between affected and nonaffected hemispheres was more pronounced in cortical stroke (127 versus 70 and 350 versus 114 drops, respectively). No correlation between overnight disability score change and NIRS drops was found (Table 2).

Discussion

In this pilot study, 96% of systemic desaturations were rapidly followed by local cerebral desaturations as measured by NIRS. Also, BP drops were more likely to be followed by NIRS drops in the affected than in the nonaffected hemisphere. Local nocturnal cerebral desaturations were more than twice as likely in the affected hemisphere.

NIRS is noninvasive and easy to use in a stroke unit setting, although experience in acute stroke is limited. In 1 study, different regional cerebral oxygen saturation patterns in both hemispheres were demonstrated for patients with space-occupying stroke. Real-time NIRS assessment may be used to manage brain swelling and planning of hemicraniectomy.3 Our results suggest that NIRS can also be used for detection of less severe complications such as systemic events that could harm the ischemic brain. Nearly all SpO2 drops (96%) were detected by NIRS. A similar positive correlation between SpO2 changes and cerebral regional cerebral oxygen saturation during sleep has been reported in patients with obstructive sleep apnea with clear improvement after continuous positive airway pressure treatment.4 These results support the sensitivity of NIRS to SpO2 in an acute stroke population. Our data suggest that NIRS measurements reflect responses that are specific to the affected hemisphere, especially for cortical stroke. This responsiveness to stroke-related changes makes NIRS an attractive technique when studying vulnerability of ischemic brain tissue to changes in the internal environment.

A limitation of our study is the small patient sample. Also, a large proportion of the NIRS drops was not explained by periods of SpO2 drop and/or relative hypotension, pointing to the complex multifactorial contributions to the NIRS signal.5 More studies are needed to understand the interplay between local regional cerebral oxygen saturation changes and cerebral perfusion pressure, SpO2, intrathoracal pressure changes, CO2 levels, collateral flow, and local oxygen consumption and distribution patterns.

In summary, this pilot study found good responsiveness of NIRS signal to systemic challenges and stroke-related changes albeit in a small sample. After confirmation in a larger sample, further studies would need to (1) delineate the exact meaning and prognostic significance of NIRS
changes in ischemic brain; and (2) elucidate the mechanisms behind NIRS changes not explained by systemic desaturations.

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**Disclosures**
None.

**References**

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**Table 2. Nocturnal Changes in NIRS and the Relationship With Significant MAP and Peripheral Arterial Oxygenation Drops (n=9)**

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Recording Time, min</th>
<th>Stroke Subtype</th>
<th>Overnight NIHSS Improvement</th>
<th>Total SpO2 Drop (&gt;4%)</th>
<th>Total MAP Drop (&gt;20%)</th>
<th>Hemisphere</th>
<th>Total NIRS Drop (&gt;4%)</th>
<th>SpO2 Drop Detected by NIRS (%)</th>
<th>MAP Drop Detected by NIRS (%)</th>
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</thead>
<tbody>
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<td>1</td>
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<td>PACI</td>
<td>0</td>
<td>33</td>
<td>AH</td>
<td>2</td>
<td>13</td>
<td>1 (3)</td>
<td></td>
</tr>
<tr>
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<td>139</td>
<td>LACI</td>
<td>0</td>
<td>11</td>
<td>AH</td>
<td>23</td>
<td>6 (55)</td>
<td>6 (21)</td>
<td></td>
</tr>
<tr>
<td>3</td>
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<td>PACI</td>
<td>0</td>
<td>3</td>
<td>AH</td>
<td>17</td>
<td>3 (100)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
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<td>163</td>
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<td>0</td>
<td>16</td>
<td>AH</td>
<td>14</td>
<td>4 (25)</td>
<td></td>
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</tr>
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<td>424</td>
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<td>2</td>
<td>2</td>
<td>AH</td>
<td>85</td>
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<td>3 (50)</td>
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<td>6</td>
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<td>TACI</td>
<td>1</td>
<td>52</td>
<td>AH</td>
<td>13</td>
<td>13</td>
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<td>0</td>
<td>19</td>
<td>AH</td>
<td>5</td>
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<td>0</td>
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<td>AH</td>
<td>122</td>
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<td>9</td>
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<td>101</td>
<td>AH</td>
<td>196</td>
<td>101 (100)</td>
<td>90 (45)</td>
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<tr>
<td>Total</td>
<td>2,898</td>
<td></td>
<td>133</td>
<td>414</td>
<td></td>
<td>477</td>
<td>128 (96)</td>
<td>131 (32)</td>
<td></td>
</tr>
</tbody>
</table>

Values are numbers (%).

NIRS indicates near infrared spectroscopy; MAP, mean arterial pressure; NIHSS, National Institutes of Health Stroke Scale; SpO2, peripheral arterial oxygen; PACI, partial anterior circulation infarction; LACI, lacunar circulation infarction; TACI, total anterior circulation infarction; AH, affected hemisphere; NAH, nonaffected hemisphere.
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