**Brief Report**

**Attention Deficits After Aneurysmal Subarachnoid Hemorrhage Measured Using the Test of Variables of Attention**

Svante Wallmark, MD; Erik Lundström, MD, PhD; Johan Wikström, MD, PhD; Elisabeth Ronne-Engström, MD, PhD

**Background and Purpose**—The aim of this pilot study was to assess attention deficits in patients with aneurysmal subarachnoid hemorrhage using the test of variables of attention (TOVA). This is a computer-based continuous performance test providing objective measures of attention. We also compared the TOVA results with the attention and concentration domains of Montgomery Åsberg Depression Rating Scale and Montreal cognitive assessment, 2 examiner-administered neuropsychological instruments.

**Methods**—Nineteen patients with moderate to good recovery (Glasgow outcome scale, 4–5) were assessed using the TOVA, Montgomery Åsberg Depression Rating Scale, and Montreal cognitive assessment. The measurements were done when the patients visited the hospital for a routine magnetic resonance imaging control of the aneurysm.

**Results**—TOVA performance was pathological in 58%. The dominating pattern was a worsening of performance in the second half of the test, commonly a failing to react to correct stimuli. We found no correlation between TOVA and the performance in concentration and attention domains of Montgomery Åsberg Depression Rating Scale and Montreal cognitive assessment.

**Conclusions**—Attention deficits, measured by the TOVA, were common after subarachnoid hemorrhage. This should be further studied to improve outcome. *(Stroke. 2015;46:00-00. DOI: 10.1161/STROKEAHA.115.009092.)*

**Key Words:** aneurysm ▪ rehabilitation ▪ subarachnoid hemorrhage

Those surviving an aneurysmal subarachnoid hemorrhage (SAH) often have cognitive problems such as memory deficits and language impairments. Problems maintaining attention are common, but most studies investigating attention deficits have used examiner-administered neuropsychological instruments.1–3 Continuous performance tests have several potential advantages and receive increasing attention.4 The test of variables of attention (TOVA) is a continuous performance test that has been used after traumatic brain injury4 and sickle cell disease,7 but has apart from that never been used in patients with stroke.

The aim of this pilot study was to assess attention deficits in a group of SAH patients using the TOVA. We also compared the TOVA with the concentration and attention domains in Montgomery Åsberg Depression Rating Scale (MADRS) and Montreal cognitive assessment (MoCA),2 2 examiner-administered neuropsychological instruments.

**Materials and Methods** Eligible patients were those treated for aneurysmal SAH at Uppsala University Hospital, with good recovery or moderate disability (Glasgow outcome scale, 4–5), and that had a routine magnetic resonance imaging control planned during 2013. Clinical condition at admission was measured using the World Federation of Neurosurgical Societies scale,11 the amount of blood visualized on the initial computed tomography scan graded using the Fisher scale,12 aneurysm location as in anterior or posterior circulation, and aneurysm treatment method as coiling or clipping. Vasospasm was considered present when treatment according to the unit’s protocols had been given and infections when proven by bacterial cultures and treated. At the magnetic resonance imaging follow-up the presence of hydrocephalus, brain infarctions, and remnants of intracerebral hemorrhages was noted. The TOVA, MADRS, and MoCA assessments were performed completely in connection with the routine magnetic resonance imaging control.

The clinical version of the auditory TOVA was used in which a high and a low tone are played in a predefined order for 21.6 minutes. When a high tone is played the patient is supposed to press a button, failing to do so is an error of omission. When a low tone is played the patient should not press the button, pressing the button is an error of commission. The first half of the test has a high:low tone ratio of 1:3.5, whereas the second half has a ratio of 3.5:1. Each half is divided into quarters. The results are compared with a normative sample and presented in standard scores.13 Standard scores have an average of 100. If a standard score is <80, the test is considered pathological.

The TOVA results were compared with the concentration and attention domains in MADRS and MoCA, 2 examiner-administered neuropsychological instruments. Fatigue was assessed using a visual

Received February 23, 2015; final revision received February 26, 2015; accepted February 26, 2015.

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*Stroke* is available at [http://stroke.ahajournals.org](http://stroke.ahajournals.org) DOI: 10.1161/STROKEAHA.115.009092
analogue scale between 0 and 100 in which the patient stated his/her subjective energy.

**Statistical Analysis**

Mann–Whitney $U$ test was used to analyze differences between patients with normal and pathological TOVA in age, education, World Federation of Neurosurgical Societies scale, Fisher scale, fatigue, MADRS, and MoCA; and $\chi^2$ test in sex, vasospasm, aneurysm location, treatment, infection, hydrocephalus, brain infarction, and intracerebral hemorrhage.

**Ethics**

The ethics review board in Uppsala approved the study. Patients were included after written informed consent.

**Table.** Patient Characteristics for All Patients, for Those With Normal TOVA, and for Those With Pathological TOVA

<table>
<thead>
<tr>
<th></th>
<th>All Patients (n=19)</th>
<th>Normal TOVA (n=8)</th>
<th>Pathological TOVA (n=11)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>57 (14)</td>
<td>50 (14)</td>
<td>62 (12)</td>
<td>0.10</td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>15 (79)</td>
<td>5 (63)</td>
<td>10 (91)</td>
<td>0.13</td>
</tr>
<tr>
<td>Education, y, mean (SD)</td>
<td>13 (4)</td>
<td>14 (2)</td>
<td>11 (4)</td>
<td>0.08</td>
</tr>
<tr>
<td>WFNS, median (IQR)</td>
<td>1 (1–3)</td>
<td>1 (1–1.5)</td>
<td>1 (1–4)</td>
<td>0.60</td>
</tr>
<tr>
<td>Fisher scale, median (IQR)</td>
<td>3 (3–4)</td>
<td>3 (3–3.5)</td>
<td>3 (3–4)</td>
<td>0.84</td>
</tr>
<tr>
<td>Vasospasm, n (%)</td>
<td>6 (32)</td>
<td>2 (25)</td>
<td>4 (36)</td>
<td>0.60</td>
</tr>
<tr>
<td>Anterior aneurysm, n (%)</td>
<td>17 (89)</td>
<td>8 (100)</td>
<td>9 (82)</td>
<td>0.20</td>
</tr>
<tr>
<td>Colling, n (%)</td>
<td>18 (95)</td>
<td>8 (100)</td>
<td>10 (91)</td>
<td>0.38</td>
</tr>
<tr>
<td>Infection, n (%)</td>
<td>7 (37)</td>
<td>0 (0)</td>
<td>7 (64)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Hydrocephalus, n (%)</td>
<td>1 (5)</td>
<td>0 (0)</td>
<td>1 (9)</td>
<td>0.38</td>
</tr>
<tr>
<td>Brain infarction, n (%)</td>
<td>8 (42)</td>
<td>4 (50)</td>
<td>4 (36)</td>
<td>0.55</td>
</tr>
<tr>
<td>Intracerebral hemorrhage, n (%)</td>
<td>4 (21)</td>
<td>1 (13)</td>
<td>3 (27)</td>
<td>0.44</td>
</tr>
</tbody>
</table>

IQR indicates interquartile range; TOVA, test of variables of attention; and WFNS, World Federation of Neurosurgical Societies.

**Figure.** The response time, response time variability, commission errors, and omission errors reported in standard scores. Standard scores <80 (grid line) are considered pathological.
Results

Nineteen patients were recruited at median 7 (6–20) months after ictus; patient characteristics are presented in the Table. Initially, 6 patients had a normal and 13 patients a pathological TOVA performance according to the computer software. The results from 2 patients with pathological TOVA were considered normal after analyses indicated that the pathological results were because of external distractions. After these considerations 8 patients had a normal TOVA and 11 patients (58%) had a pathological TOVA. All patients with infection during the acute phase had pathological results on the TOVA (see Table).

The standard scores are presented in the Figure. The dominating pattern was a worsening of performance in the second half of the test, commonly a failing to react to correct stimuli (omission errors).

The patients with pathological TOVA scored lower on the fatiguescale compared with those with normal TOVA (44 and 64, respectively; \(P=0.01\)). There were no differences in the concentration and attention domains of MADRS or MoCA when comparing patients with normal TOVA with those with pathological (\(P=0.21\) and \(P=0.49\), respectively).

Discussion

The pattern of poor performance in the second half of the test, when there were frequent targets, brings up the question whether the patients fatigued, had trouble working under pressure, or both. The patients with pathological TOVA expressed more problems with fatigue, indicating that fatigue would be associated with attention deficits. This study also raises the question whether infection in the acute phase affects attention after SAH.

The TOVA results were not correlated to the concentration and attention domains in MADRS or MoCA. One explanation is that continuous performance tests are qualitatively and technically different from examiner-administered instruments.\(^4\) Also, MADRS and MoCA are instruments originally designed for assessing depressive symptoms and cognitive functions, respectively. It could therefore be difficult to compare the 3 methods, as they do not seem to measure the same expression of attention deficits.

There is a visual version of the TOVA. However, in this pilot study, we chose the auditory version because of a possible risk for epileptic seizures in SAH patients exposed to flashing screens. There is however no data supporting this risk, and in a planned larger study on SAH patients we will use both modalities.

This is a pilot study on a selected group of patients and a larger study including a more general SAH population would provide results more representative of SAH patients.

Sources of Funding

Hedström’s, Lindell’s, and Larsson’s Foundation at Uppsala University supported the study.

Disclosures

None.

References

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Stroke. published online March 19, 2015;
Stroke is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://stroke.ahajournals.org/content/early/2015/03/19/STROKEAHA.115.009092

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