Cerebral Hemodynamics in Symptomatic and Asymptomatic Patients with Severe Unilateral Carotid Stenosis before and after Carotid Endarterectomy

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**Background.** Data concerning hemodynamic status prior to and after carotid endarterectomy (CEA) in symptomatic and asymptomatic patients is insufficient. Transcranial Doppler (TCD) provides information regarding compensatory collateral flow as well as mechanisms of cerebral autoregulation in patients with carotid stenosis.

**Patients and methods.** Forty eight symptomatic and 81 asymptomatic patients with unilateral severe carotid stenosis were examined by TCD before and in early postoperative period after CEA.

**Results.** Cigarette smoking was the only risk factor significantly more frequent in symptomatic patients. Preoperative anterior cerebral artery (ACA) and middle cerebral artery (MCA) asymmetry, basilar artery velocity and number of ophthalmic arteries with reversed flow, were not significantly different between the two groups. Pulsatility index, cerebrovascular reactivity and flow acceleration on the side of stenosis were significantly lower in symptomatic patients. After surgery there was a significant improvement of all TCD parameters in symptomatic as well as asymptomatic patients.

**Conclusions.** The exhausted ability of cerebral autoregulation is an important factor differentiating between symptomatic and asymptomatic patients with severe carotid stenosis. Successful surgery provides good recovery of cerebral hemodynamics in both symptomatic and asymptomatic patients.

Keywords: Transcranial doppler; Carotid endarterectomy; Cerebral hemodynamics.
group). There was no peri- and intraoperative mortality. The rate of intra- and perioperative cerebrovascular complications was 4.7% (3 patients with minor stroke and 3 patients with disabling stroke).

TCD examination included: measurement of cerebral blood flow velocity (CBFV) in both middle cerebral arteries (MCAs), anterior cerebral arteries (ACAs), basilar artery (BA) and ophthalmic arteries (OA). Additionally, the following indexes were calculated: asymmetry of MCAs velocities - by peak velocity (V peak) and mean velocity (V mean), asymmetry of ACAs by V peak and V mean, flow acceleration (FA) and pulsatility index (PI). The normal range of CBFV in main cerebral vessels (MCA, ACA and BA) are well known and generally accepted. The normal ranges of other TCD parameters were taken according to the literature data as follows: asymmetry in MCAs and ACAs less than 25%, PI - 0.83 ± 0.12, FA - 532 ± 39 cm/sec².

Cerebrovascular reactivity was measured using intra-venous injection of AZL - 13 mg/kg. Monitoring of MCA velocity was performed on the side of the stenosis during five minutes before and 15 minutes after injection. Before CEA, CVR was examined in 32 symptomatic patients and in 36 asymptomatic non-consecutive patients on the side of stenosis. Postoperatively, CVR was assessed in 26 symptomatic (81.2%) and 31 asymptomatic (86.1%) patients. Of 11 patients without repeated CVR examination after CEA, 7 were lost to follow up, 2 patients had early significant restenosis and 2 refused the second CVR test.

Statistics. Pre and post-surgery parameters were each compared separately using two-tailed paired t-tests. Significance was taken as \( p \leq 0.05 \). Microsoft Excel (Microsoft Corp., Redmond, WA, USA) was used for the data management and statistical calculations.

Results

TCD parameters in symptomatic and asymptomatic patients prior to surgery are presented in Table 2. The difference between the groups was not statistically significant in ACA and MCA asymmetry, BA velocity as well as the number of OA arteries with reversed flow. Pulsatility index, CVR and FA on the side of stenosis were significantly lower in symptomatic patients. The TCD parameters before and after surgery in symptomatic and asymptomatic patients are presented in Table 3 and 4 respectively. Postoperatively there was a significant improvement of all abnormal TCD parameters in symptomatic patients and in asymmetry of both ACA and MCA velocities as well as in CVR in asymptomatic patients.

Discussion

The mechanisms determining the presence of symptoms in patients with carotid stenosis are not...
completely understood. The data concerning hemodynamic status before and after CEA in symptomatic as compared to asymptomatic patients are insufficient.

We used broad spectrum TCD parameters to evaluate the peculiarities of cerebral hemodynamics as well as autoregulation reserve in symptomatic and asymptomatic patients with unilateral severe ICA stenosis. The other goal of this study was to compare the influence of CEA on cerebral hemodynamics in both groups in early postoperative period. The cerebral autoregulation reserves were estimated by PI, FA, and CVR indexes. The integrative efficacy of both autoregulation mechanisms and collateral circulation was evaluated by the asymmetry of CBFV in ACA and MCA between sides. The main finding of this study was that all parameters reflecting an autoregualtion mechanisms were significantly lower in symptomatic patients, while there was no difference between the groups in asymmetry indexes. Thus it seems that exhaustion of compensatory abilities of autoregulation may be an important hemodynamic mechanism resulting in neurological symptoms in those patients with severe carotid stenosis. This finding is consistent with the available literature. Soinne et al. studied 46 patients with unilateral severe carotid stenosis who underwent contrast magnetic resonance imaging (MRI) and TCD before and after CEA. The authors found that the ipsilateral PI was initially significantly lower in the symptomatic than in the asymptomatic patients, undergoing a similar pattern of improvement with no significant postoperative difference. The main advantage of the study was the potential to observe and correlate the changes in magnetic resonance cerebral perfusion with TCD assessment. However, the number of patients in this study was small and the TCD battery was narrow. Kim et al. showed that the proportion of patients with stenosis-related MRI abnormality was significantly higher in patients with a hemodynamic change on TCD. Markus and Cullinane revealed that severely reduced CVR but not the PI of the middle cerebral artery predicts the risk of ipsilateral stroke and TIA in patients with carotid occlusion, and to a lesser extent in asymptomatic carotid stenosis. Orosz et al. showed a statistically significant difference of cerebrovascular reserve between the affected and non-affected side in the symptomatic patients with carotid stenosis. Silvestrini et al. noted significant difference in CVR between symptomatic and asymptomatic patients with severe carotid stenosis. On the other hand, Lucertini et al. as well as Nighoghossian et al. did not find significant differences in CVR between symptomatic and asymptomatic patients. There are limited data in evaluation of asymmetry indexes by TCD in patients with carotid stenosis. Brint et al. retrospectively analysed the significance of side to side MCA flow velocity differences. The authors showed that asymmetric subjects had 3.7 times greater chance of having a stroke on brain CT or MRI.

The other main result of our study was good restoration of cerebral blood flow velocities in MCAs and ACAs measured by TCD after CEA in both groups of patients. In symptomatic as well as in asymptomatic patients all asymmetry indexes which were abnormal before surgery improved significantly after CEA, with no difference between groups. The literature data confirms good restoration of cerebral blood flow in both symptomatic and asymptomatic patients with carotid stenosis after CEA.

It is interesting that there was no change in BA velocity before and after surgery in either group. Thus, evidently, this parameter is not sensitive enough as the index of changes of posterior flow in patients with high unilateral ICA stenosis before and after the surgery. On the other hand, CVR was the only index from those reflecting autoregulation (CVR, PI, FA), which was disturbed before and improved significantly after surgery in both groups of patients. This is evidently because CVR was the only functional test reflecting the compensatory capacity of compromised cerebral hemodynamics under the vasodilator challenge.

Demographic data and risk factors analysis showed smoking to be only factor, which was significantly higher in symptomatic patients. Both short-term and long-term effects of smoking on cerebrovascular reactivity have been established. Short-term use of nicotine leads to the significant increase

### Table 4. TCD parameters before and after the surgery in asymptomatic patients

<table>
<thead>
<tr>
<th>TCD parameters</th>
<th>Before the surgery</th>
<th>After the surgery</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCA asymmetry (V peak) (%)</td>
<td>19.5 ± 15.1</td>
<td>14.3 ± 11</td>
<td>0.02</td>
</tr>
<tr>
<td>MCA asymmetry (V mean) (%)</td>
<td>20.8 ± 14.6</td>
<td>16 ± 10.8</td>
<td>0.02</td>
</tr>
<tr>
<td>ACA asymmetry (V peak) (%)</td>
<td>34.6 ± 10.6</td>
<td>24.7 ± 17.8</td>
<td>0.01</td>
</tr>
<tr>
<td>ACA asymmetry (V mean) (%)</td>
<td>34.2 ± 20.7</td>
<td>25.2 ± 17.5</td>
<td>0.01</td>
</tr>
<tr>
<td>Peak Basilar artery velocity (cm/sec)</td>
<td>54.1 ± 20.8</td>
<td>58 ± 13.8</td>
<td>NS</td>
</tr>
<tr>
<td>Ophthalmic artery retrograde flow (%) stenotic side</td>
<td>14.8</td>
<td>0</td>
<td>0.001</td>
</tr>
<tr>
<td>FA (cm/sec)</td>
<td>350.3 ± 190.9</td>
<td>361.3 ± 156</td>
<td>NS</td>
</tr>
<tr>
<td>CVR (%) stenotic side</td>
<td>33.3 ± 15.7</td>
<td>54.8 ± 20.8</td>
<td>0.02</td>
</tr>
<tr>
<td>PI stenotic side</td>
<td>1.03 ± 0.26</td>
<td>1 ± 0.18</td>
<td>NS</td>
</tr>
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</table>
in CBFV, and long-term use leads to CBFV decrease. Neu et al. assessed CVR in 33 patients with unipolar depression and 26 healthy controls. The authors showed that smoking was associated with a significant reduction in CVR, whereas age and gender had no significant influence. Silvestrini et al. studied 24 healthy young smokers and 24 healthy controls matched for age and sex. The authors suggested that a failure of cerebrovascular regulation occurs after smoking. Therefore we can speculate that the constant dilatation of arterioles with smoking leads to exhaustion of their ability to dilate under vasodilator challenge afterwards. Thus, it seems that the negative influence of smoking on the autoregulation mechanisms is an important factor in the origin of neurovascular complications in patients with severe carotid stenosis. Some of the limitations of this study include small size and subset of patients undergoing CVR measurements, the differences in smoking between the populations studied and the fact that the hemodynamic measurements were not correlated with anatomical integrity of the circle of Willis.

It is well known, that not only hemodynamic but also embolic factors take a part in the development of cerebro-vascular complications in patients with severe carotid stenosis. Thus, the future investigation of all factors associated with severe carotid stenosis will help in prediction whether a patient will or will not suffer from neurovascular complications.

References


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