Cognitive Deterioration in Bilateral Asymptomatic Severe Carotid Stenosis

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**Background and Purpose**—This study aimed to monitor cognitive performance during a 3-year period in subjects with bilateral asymptomatic severe internal carotid artery stenosis and to explore the role of cerebral hemodynamics and atherosclerotic disease in the development of cognitive dysfunction.

**Methods**—One hundred fifty-nine subjects with bilateral asymptomatic severe internal carotid artery stenosis were included and prospectively evaluated for a 3-year period. At entry, demographics, vascular risk profile, and pharmacological treatments were defined. Cognitive status was evaluated using the Mini-Mental State Examination at baseline and at follow-up. Cerebral hemodynamics was assessed by transcranial Doppler–based breath-holding index test. As a measure of the extent of systemic atherosclerotic disease, common carotid artery intima-media thickness was measured. A cutoff for pathological values was set at 0.69 for breath-holding index and 1.0 mm for intima-media thickness.

**Results**—The risk of decreasing in Mini-Mental State Examination score increased progressively from patients with bilaterally normal to those with unilaterally abnormal breath-holding index, reaching the highest probability in patients with bilaterally abnormal breath-holding index \((P<0.0001)\). Pathological values of intima-media thickness did not influence the risk of Mini-Mental State Examination score change.

**Conclusions**—Our findings suggest that patients with asymptomatic bilateral severe internal carotid artery stenosis may be at risk of developing cognitive impairment. The evaluation of the hemodynamic status, besides providing insights about the possible mechanism behind the cognitive dysfunction present in carotid atherosclerotic disease, may be of help for the individuation of subjects deserving earlier and more aggressive treatments. (Stroke. 2014;45:2072-2077.)

**Key Words:** carotid stenosis ▪ mild cognitive impairment ▪ ultrasonography

The management of patients with bilateral asymptomatic carotid artery stenosis is still controversial. No clear evidence exists about the most effective treatment strategies to change patients’ prognosis, including timing and sequence of revascularization.1

We recently reported that asymptomatic subjects with severe narrowing of internal carotid artery (ICA) lumen may present a reduction in cognitive performances attributable to the activity of the hemisphere ipsilateral to the stenosis,2 and in some cases, it may develop a cognitive deterioration.3 Such consequences are more common if cerebral hemodynamics in the territory supplied by the stenotic ICA is altered.3 Furthermore, patients with bilateral carotid stenosis may present a reduction in specific cognitive domains depending on the more hemodynamically compromised brain hemisphere.4

To date, there are no available data on the long-term cognitive monitoring in these subjects. This study aimed at monitoring cognitive performances for a 3-year period in subjects with bilateral ICA stenosis and no previous sign or symptoms of ischemic cerebrovascular disease. To explore the possible mechanisms responsible for cognitive dysfunction, we also evaluated cerebrovascular reactivity (CVR) as a measure of the brain hemodynamic status and the common carotid artery wall thickness as a measure of systemic atherosclerotic disease.

**Methods**

This prospective study was performed at the Vascular Ultrasound Laboratory of the Neurological Clinic, Marche Polytechnic University Hospital (Ancona, Italy) from January 2003 to August 2010 among subjects referred by their primary care physicians because of their vascular risk profile to receive an ultrasound screening for carotid atherosclerotic disease, in the setting of a local primary prevention initiative.

Neck and intracranial arteries were evaluated using a color-coded duplex sonography (iU22 Philips Ultrasound, Bothell, WA). Quantification of stenosis was made on the basis of the presence of plaque at the grayscale or color Doppler imaging and on velocity criteria: ICA peak systolic velocity, end-diastolic velocity, and ICA/common carotid artery peak systolic velocity ratio.5 Patients with
ultrasound evidence of stenosis ≥70% in both ICAs without history of stroke and transitory ischemic attack were considered for enrollment. The asymptomatic status was determined through a detailed patient’s history review and a complete neurological examination to exclude any neurological signs.

Baseline global cognitive function was evaluated using the Mini-Mental State Examination (MMSE) adjusted for age and education. To minimize the effect of potential confounders, we adopted the following exclusion criteria: age ≥85 years, carotid occlusion or vertebrobasilar, and intracranial steno-occlusive lesions evaluated according to validated criteria, referred or documented cardiac failure (defined as a left ventricular ejection fraction <50%), referred or documented or treated cognitive impairment from any cause or any severe psychiatric disease, previous disability, including significant visual and hearing impairment, defined by the modified Rankin Scale >6, preexisting cerebrovascular disease, or coexisting severe medical conditions, interfering with the possibility to perform a follow-up. Furthermore, we excluded subjects with poor temporal acoustic window or not compliant to CVR testing.

Hypertension, diabetes mellitus, and hyperlipidemia, defined according to international guidelines,10 were recorded when the patient and documented in patients’ medical records or under current medical treatment; subjects were defined as smokers if smoking regularly ≥1 cigarettes per day; we recorded, referred, or documented the history of myocardial infarction (MI) or coronary heart disease (CAD) and peripheral arterial disease and referred, documented, or treated atrial fibrillation (AF); heavy drinking was defined as more than 4 drinks/day (equivalent to/day of ≥200 g of pure alcohol/wk constantly as disclosed by the patient and documented in patients’ medical records or un-

The cerebral hemodynamic status was evaluated by testing the CVR (ie, a measure of the perfusion reserve reflecting the capability of cerebral arterioles to dilate in response to a vasomotor stimuli).12 CVR to hypercapnia was quantified by the transcranial Doppler–based breath-holding index (BHI) test, which consists of a voluntary apnea period. Bilateral transmetasternal transcranial Doppler monitoring at the depth of proximal middle cerebral artery, 50±3 mm or M1 tract, was performed by an experienced sonographer blinded to the clinical status of the examined subjects. A head-frame was used to secure a stable angle of insonation.13 Mean cerebral flow velocities (MFVs) were recorded at baseline and at the end of BH. The exact length of apnea, measured by a capnometer (Oxy-cap, Datex, Italy), ranged from 29.6 to 30.3 s. The BHI is obtained by dividing the percentage increase in MFV occurring during BH by the length of time (s) subjects hold their breath after a normal inspiration ([MFV at the end of BH–baseline MFV]/baseline MFV×100 per s of BH).12 CVR was evaluated in the early morning. All participants performed 3 evaluations per side. Internal consistency of BHI measurements, treated as continuous variables, was tested with Cronbach’s coefficient (left, χ=0.99; variance range, ±0.022 and right, χ=0.99; variance range, ±0.026), indicating a high reliability of BHI measurement among the subjects. If analyzed as a dichotomous value, the relationship between BHI and IMT variables was planned according to international guidelines.15

Statistical Analysis

The main outcome measure was defined as the difference between MMSE at 3-year follow-up (f-MMSE) and MMSE at baseline (b-MMSE). Patients were categorized according to their BHI and IMT values. BHI values were combined into a single ordinal value: 0 (bilaterally normal values), 1 (right pathological), 2 (left pathological), and 3 (bilaterally pathological BHI). IMT values were treated as a dichotomous variable (normal and pathological). Age, b-MMSE and f-MMSE, and years of education were synthesized as continuous variables. Smoking habit, diabetes mellitus, dyslipidemia, hypertension, AF, peripheral arterial disease, and previous MI/CAD were collected as binary variables. The use of oral anticoagulants, statins, antidiabetics, antplatelets, and antihypertensives was coded in 5 different dichotomous variables. Continuous variables were compared using the t test for independent samples. Binary variables were compared using the χ² test.

Before other analyses, we performed an age- and sex-adjusted variance components analysis (a nested general linear model univariate analysis), to include in the final model; only the covariates significantly associated with a variance change in the estimated mean of the outcome. This evaluation included difference between b-MMSE and f-MMSE scores as outcome; the ordinal BHI and the binary IMT variables as predictors; age and sex as adjustments; and smoking at-titude, diabetes mellitus, dyslipidemia, hypertension, AF, peripheral arterial disease, and a MI/CAD as the covariates to be tested. Drugs were not included in both models because of high collinearity of these variables with the included comorbidities. We used an ANOVA (type III, sum of squares) method because this analysis reflected the same analytic process used in the final model.

To evaluate the effect of BHI and IMT on mean MMSE variance (from b-MMSE to f-MMSE), we set up different ANCOVA models for repeated measures. The main outcome was the paired b-MMSE and f-MMSE scores for each patient. All the models were adjusted for age, sex, hypertension, and AMI/CAD. The first model included left BHI value and right BHI value treated as continuous variables and analyzed in a full-factorial design. The second model was similar to the first one but included only the ordinal BHI values as a predictor. The third model considered left IMT value and right IMT value and treated as continuous variables in a full-factorial design. The fourth model analyzed both left and right IMT as binary in a full-factorial design.

The first model consisted of a generalized multivariable linear model, adopting difference between b-MMSE and f-MMSE scores as outcome, using BHI as predictor, and age, sex, b-MMSE, hypertension, MI/CAD as covariates. To define the effect of IMT in each BHI class better, a second generalized multivariable linear model was set up using the intersection of BHI and IMT values as predictor, adopting the same covariates. Statistical analysis was performed with SPSS 13.0 for Windows systems. Power analysis was performed with G*Power 3.1.7 for Windows systems.
Results

From a total of 206 subjects with bilateral asymptomatic carotid stenosis screened, 23 were excluded (5 were affected by dementia at the baseline, 4 for preexisting cerebrovascular disease, 2 because of coexisting severe medical conditions, 3 for poor temporal windows, and 9 that underwent carotid revascularization). Ninety-six of the 183 included subjects had been already enrolled in our previous study, exploring the relationship between cognitive performances and cerebral hemodynamic status.1 During the follow-up period, 7 patients had a vascular event (5 strokes and 2 MI), and 17 were lost at follow-up (8 died and 9 declined to attend the second cognitive evaluation). The final analysis was then performed on 159 subjects who completed the follow-up. A post hoc analysis showed that this number allowed to achieve a power of 0.93, with α set to 0.05, in detecting small differences in the outcome (F set to 0.0625).

Characteristics of subjects are reported in Table 1. No difference was detected between the 2 groups classified according to a normal or pathological IMT. According to the classification into different BHI groups, a difference was detected for dyslipidemia and MI prevalence. Furthermore, mean b-MMSE and f-MMSE values were significantly different among BHI groups. Values of b-MMSE were unrelated to basal hemodynamic compromise.

Both regressions resulted in statistically significant correlations, enlightening a close linear relationship between left or right BHI and the MMSE at follow-up (left side BHI, r2=0.838; P<0.0001 and right side BHI, r2=0.828; P<0.0001). Variance analysis showed that hypertension and a previous MI were the only 2 variables significantly associated with the variance of the outcome. Thus, we included these 2 factors in the final model, discarding the other factors. The first ANCOVA enlightened that left BHI (P<0.0001; partial η2=0.786), right BHI (P=0.019; partial η2=0.593), and the intersection of the 2 scales (P=0.023; partial η2=0.460) contributed significantly to the model. The large partial η2 values for left BHI, right BHI, and their intersection showed that they explained variations in MMSE. The second ANCOVA confirmed that also the ordinal BHI variable contributed significantly to MMSE variability (F=0.001; partial η2=0.108). The MMSE mean difference from baseline to the end of follow-up was estimated at 1.830 points (95% confidence interval, 1.599 to 2.061; P<0.0001) with this model. The third ANCOVA showed that left IMT (P=0.553; partial η2=0.235), right IMT (P=0.764; partial η2=0.156), and the intersection of the 2 scales (P=0.710; partial η2=0.375) did not contribute significantly to MMSE variability. We found similar results in the fourth model (data not shown). For this reason, we chose not to add IMT in the first final model.

Both multivariate models resulted in significant changes in predicting the outcome (Table 2; Figure). In the first model, a bilaterally pathological BHI resulted in significant association with higher MMSE scores difference at 3 years when compared with unilateral right (P=0.0004) or left abnormal BHI (P=0.0001) or bilaterally normal BHI (P=0.0001). The ordinal BHI variable contributed significantly to the variance of the outcome (P<0.0001; partial η2=0.208). Both groups with unilateral impaired BHI showed a significantly higher difference in MMSE score when compared with patients with bilaterally normal BHI (right abnormal BHI versus bilaterally normal BHI, P=0.005; left pathological BHI versus bilaterally normal BHI, P=0.032). The intersection of the ordinal BHI variable and the dichotomous IMT value, analyzed in the second model, was significantly associated with the variance of MMSE difference (P<0.0001; partial η2=0.299). However, this model confirmed the observations of the first one: MMSE score difference increased significantly from patients with bilaterally normal BHI to patients with unilaterally impaired BHI to those with bilaterally impaired values. IMT was not significantly associated with MMSE score variations even in the single subgroup, and it did not add any significant information.

Table 1. Demographic and Clinical Characteristics of the Sample

<table>
<thead>
<tr>
<th>Variables</th>
<th>Bilaterally Normal (n=56)</th>
<th>Right Pathological (n=32)</th>
<th>Left Pathological (n=27)</th>
<th>Bilaterally Pathological (n=44)</th>
<th>P Value</th>
<th>Normal (n=68)</th>
<th>Pathological (n=91)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men (%)</td>
<td>33 (58.9%)</td>
<td>23 (71.9%)</td>
<td>17 (63.0%)</td>
<td>25 (56.8%)</td>
<td>0.563</td>
<td>41 (60.3%)</td>
<td>57 (62.6%)</td>
<td>0.869</td>
</tr>
<tr>
<td>Smokers (%)</td>
<td>7 (12.5%)</td>
<td>7 (21.9%)</td>
<td>6 (22.2%)</td>
<td>10 (22.7%)</td>
<td>0.513</td>
<td>13 (19.1%)</td>
<td>17 (18.7%)</td>
<td>0.869</td>
</tr>
<tr>
<td>Diabetes mellitus (%)</td>
<td>3 (5.4%)</td>
<td>3 (9.4%)</td>
<td>4 (14.8%)</td>
<td>5 (11.4%)</td>
<td>0.533</td>
<td>10 (14.7%)</td>
<td>5 (5.5%)</td>
<td>0.059</td>
</tr>
<tr>
<td>Dyslipidemia (%)</td>
<td>16 (28.6%)</td>
<td>18 (56.3%)</td>
<td>9 (33.3%)</td>
<td>13 (29.5%)</td>
<td>0.047</td>
<td>28 (41.2%)</td>
<td>28 (30.8%)</td>
<td>0.184</td>
</tr>
<tr>
<td>Hypertension (%)</td>
<td>28 (50.0%)</td>
<td>22 (68.8%)</td>
<td>12 (44.4%)</td>
<td>27 (61.4%)</td>
<td>0.179</td>
<td>40 (58.8%)</td>
<td>49 (53.8%)</td>
<td>0.628</td>
</tr>
<tr>
<td>AF (%)</td>
<td>2 (3.6%)</td>
<td>3 (9.4%)</td>
<td>1 (3.7%)</td>
<td>1 (2.7%)</td>
<td>0.479</td>
<td>5 (7.4%)</td>
<td>2 (2.2%)</td>
<td>0.138</td>
</tr>
<tr>
<td>MI (%)</td>
<td>5 (8.9%)</td>
<td>9 (28.1%)</td>
<td>0 (0%)</td>
<td>7 (15.9%)</td>
<td>0.009</td>
<td>9 (13.2%)</td>
<td>12 (13.2%)</td>
<td>1.000</td>
</tr>
<tr>
<td>PAD (%)</td>
<td>3 (5.4%)</td>
<td>2 (6.3%)</td>
<td>5 (18.5%)</td>
<td>6 (13.6%)</td>
<td>0.200</td>
<td>8 (11.8%)</td>
<td>8 (8.8%)</td>
<td>0.600</td>
</tr>
<tr>
<td>Age (±SD)</td>
<td>69.80 (±3.60)</td>
<td>69.26 (±3.31)</td>
<td>71.30 (±4.36)</td>
<td>69.90 (±3.78)</td>
<td>0.185</td>
<td>69.73 (±3.63)</td>
<td>70.19 (±3.85)</td>
<td>0.444</td>
</tr>
<tr>
<td>Education (±SD)</td>
<td>10.64 (±4.66)</td>
<td>10.43 (±3.39)</td>
<td>10.59 (±3.52)</td>
<td>9.75 (±3.97)</td>
<td>0.715</td>
<td>10.39 (±3.61)</td>
<td>10.31 (±4.34)</td>
<td>0.891</td>
</tr>
<tr>
<td>b-MMSE (±SD)</td>
<td>27.03 (±1.35)</td>
<td>26.56 (±1.01)</td>
<td>26.55 (±0.80)</td>
<td>27.18 (±1.16)</td>
<td>0.040</td>
<td>26.75 (±1.05)</td>
<td>27.01 (±1.25)</td>
<td>0.167</td>
</tr>
<tr>
<td>f-MMSE (±SD)</td>
<td>26.12 (±1.46)</td>
<td>24.81 (±1.73)</td>
<td>25.00 (±1.27)</td>
<td>24.06 (±2.08)</td>
<td>0.000</td>
<td>24.86 (±1.85)</td>
<td>25.27 (±1.86)</td>
<td>0.174</td>
</tr>
</tbody>
</table>

AF indicates atrial fibrillation; b-MMSE, baseline Mini-Mental State Examination score; BHI, breath-holding index; f-MMSE, Mini-Mental State Examination score at the end of the 3-year follow-up period; IMT, intima-media thickness; MI, previous myocardial infarction; and PAD, peripheral artery disease.
to the predictive value of BHI on MMSE changes (Figure). In this second model, mean MMSE score difference estimates ranged from 3.191 (95% confidence interval, 2.605 to 3.778) in patients with bilaterally impaired BHI and pathological IMT to 0.503 (95% confidence interval, –0.247 to 1.253) in the group with bilaterally normal BHI and normal IMT.

**Discussion**

Our findings show that in patients with bilateral ICA stenosis, the probability of cognitive deterioration during a 3-year period is significantly associated with impairment in CVR. In fact, we found that the risk of a reduction in MMSE score after a 3-year period increased progressively from patients with bilaterally normal BHI values to those with unilateral abnormal BHI, reaching the highest risk in patients with bilateral BHI impairment. Counterintuitively, in our study, basal MMSE mean scores were within normal values in patients with preserved or altered CVR. A possible explanation for this finding is that according to the study protocol, subjects with referred, documented, or treated cognitive impairment from any cause were excluded a priori. The subsequent reduction in MMSE score observed in a subgroup of subjects of our cohort could represent the result of a chronic cerebral hypoperfusion occurring during the 3-year follow-up period.

A persistent increase in vascular resistance as a consequence of a steno-occlusive artery disease can be compensated by means of vasodilatation at the arteriolo-capillary level. This already existing intracranial vasodilatation can interfere with the ability of the cerebral vessels to dilate in response to demand further. Measuring blood flow changes during a vasodilatory stimulus is considered the most appropriate way to detect and quantify the vascular reserve.16 In this respect, impaired CVR has been found to correlate with an increased risk of ischemic cerebral events in subjects with carotid stenosis.12 We previously reported the existence of a relationship between hemodynamic impairment and diminished brain

**Table 2. Comparison Among Estimated Marginal Means of MMSE Score Difference of Each Subgroup**

<table>
<thead>
<tr>
<th>Variable (I) (Mean MMSE Difference)</th>
<th>Variable (J)</th>
<th>I–J</th>
<th>SE</th>
<th>P Value</th>
<th>95% CI (Difference) Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>BHI: bilaterally normal (0.894; 95% CI, 0.521–1.268)</td>
<td>BHI: right pathological</td>
<td>-0.891</td>
<td>0.325</td>
<td>0.007</td>
<td>-1.533</td>
<td>-0.249</td>
</tr>
<tr>
<td>BHI: right pathological (1.786; 95% CI, 1.275–2.297)</td>
<td>BHI: bilaterally normal</td>
<td>0.891</td>
<td>0.325</td>
<td>0.007</td>
<td>0.249</td>
<td>1.533</td>
</tr>
<tr>
<td>BHI: left pathological (1.623; 95% CI, 1.071–2.175)</td>
<td>BHI: right pathological</td>
<td>-0.163</td>
<td>0.387</td>
<td>0.675</td>
<td>-0.927</td>
<td>0.602</td>
</tr>
<tr>
<td>BHI: bilaterally pathological (3.067; 95% CI, 2.643–3.490)</td>
<td>BHI: left pathological</td>
<td>-1.381</td>
<td>0.285</td>
<td>0.0001</td>
<td>-2.148</td>
<td>-0.739</td>
</tr>
</tbody>
</table>

BHI indicates breath-holding index; CI, confidence interval; I, mean of the first column; J, mean of the second column; and MMSE, Mini-Mental State Examination.

**Figure.** Effect of the association of breath-holding index (BHI) and common carotid artery intima-media thickness (IMT) values on Mini-Mental State Examination (MMSE) difference form entry to the end of the 3-year follow-up period.
function in specific cognitive domains in patients with carotid stenosis, in the absence of otherwise clinically expressed ischemic events.\(^2\),\(^3\)

The risk of cognitive deterioration in patients with carotid stenosis has been extensively evaluated,\(^17\) but the results have supported equivocal evidence. In particular, there are controversies about the interpretation of the presence of impaired mental performances. Some studies have suggested that cognitive dysfunction rather than being a consequence of the carotid disease may be directly related to the brain ischemic damage.\(^18\) There is also evidence suggesting that reduction in mental performance in patients with carotid steno-occlusive disease may be a nonspecific consequence of a generalized vascular disease.\(^19\) Accordingly, cognitive impairment would be one of the results of brain dysfunction related to the underlying vascular risk factors, such as hypertension and diabetes mellitus.\(^20\),\(^21\)

Findings from the present study support the possibility that a reduction in cognitive performances in subjects with carotid stenosis could be more likely related to the hemodynamic consequences of chronic hypoperfusion rather than being reflective of a generalized atherosclerotic disease. Carotid IMT is a marker of atherosclerosis that is able to characterize global vascular risk.\(^22\) The fact that in our patients increased IMT was not able to predict reduction in MMSE score argues against the hypothesis that cognitive deterioration in subjects with steno-occlusive carotid disease may be simply considered as a consequence of atherosclerotic status.

Improvement of pharmacological approaches for treating vascular risk factors has produced significant changes in the management of patients with asymptomatic severe carotid stenosis. In particular, the indication for surgical or endovascular correction of the artery lumen narrowing for primary stroke prevention in asymptomatic carotid disease is generally limited to selected individual cases, where pharmacological and lifestyle change interventions do not result as optimal strategies.\(^23\)

Considering cognitive decline as a specific consequence of carotid disease is a relatively new concept,\(^24\) and carotid steno-occlusive disease has been recently identified as one of the vascular risk factors that can be modified through an appropriate clinical strategy to prevent or reduce cognitive impairment.\(^25\) Early selection of subjects deserving consideration for revascularization procedures or pharmacological treatments able to improve cerebral hemodynamics\(^26\) would have an important role in planning more effective primary prevention approaches. The presence of hemodynamic insufficiency in carotid steno-occlusive disease should be detected before significant loss in neurological function develops, especially in complex conditions, such as in the case of bilateral carotid stenosis. This concept is also supported by the evidence that in subjects with cerebrovascular occlusive disease but without clinical or imaging evidence of previous cerebral infarctions, a relationship between exhaustion of cerebrovascular reserve and cortical thickness has been established. This anatomic alteration seems to be, at least partially, reversible after surgical revascularization.\(^27\)

Our study has several limitations. To evaluate cognitive performance, we used the MMSE that is usually considered as a screening test of global cognitive function. It is possible that MMSE was not refined enough to detect changes in mental performances in apparently asymptomatic subjects fully. However, MMSE is the most commonly used cognitive evaluation and, in a longitudinal study design, preliminary exploration using a screening test can be regarded as sufficiently adequate to generate hypothesis and to stimulate further investigation on this matter. In this respect, a more comprehensive and standardized neuropsychological assessment in subjects with carotid stenosis is required in future studies to obtain stronger evidences about the link between hemodynamic impairment and cognitive decline. It has been suggested that serial evaluations using tests, such as the Montreal Cognitive Assessment or the Addenbrooke’s Cognitive Examination-Revised, might allow to overcome specific limits intrinsic to each individual test, for example, the habit effect, and the low sensitivity of the MMSE in the identification of mild cognitive disturbances.\(^28\)

Our investigation did not include a neuroimaging evaluation. For this reason, it is not possible to establish the contributory role of white matter lesions, silent infarcts, and brain atrophy occurrence in the development of a reduction of cognitive performances in our population.\(^29\) Nonetheless, previous evidences\(^30\) suggested that high-grade stenosis of the ICA may promote cognitive impairment even without neuroimaging evidence of brain structural changes. Our study consisted of a 1-time evaluation of CVR, carotid IMT, and stenosis, and, therefore, was not possible to evaluate how the progression of these parameters over time could affect cognitive performance. Unfortunately, a follow-up evaluation of CVR, carotid IMT, and stenosis was proved unfeasible given the low compliance rate to the BH test performance in the group of patients who presented during the study period a significant cognitive deterioration. The low compliance with voluntary apnea in these subjects would have generated data not comparable with those obtained at baseline.

With our experimental approach, we were able to suggest new insights on the risk carried by patients with bilateral carotid severe stenosis. The presence of a cognitive deterioration in a subgroup of subjects and the significant influence of impaired CVR suggest that in the presence of a severe vascular condition, such as a bilateral carotid stenosis, it is possible to identify patients at increased risk of developing unfavorable clinical outcomes.

Our findings further underline the need to include assessment of cognitive performance when evaluating subjects with apparently asymptomatic carotid stenosis to understand risk–benefit ratio of different treatment strategies better. In this perspective, detection of cerebral hemodynamic impairment may contribute to select subjects at the highest risk of developing cognitive deterioration.

Disclosures

None.

References

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患者认知功能异常的危险因素，尤其是近期短暂性脑缺血发作的患者，可视为近期短暂性脑缺血发作发生的危险因素。据文献报道，可同时采用多种无创性检查方法来评价患者一过性脑缺血发作的危险因素，包括心电图、血压、血糖等。在最近的研究中，将一过性脑缺血发作的定义为：患者在不伴有神经系统症状的情况下，短暂性出现轻度至中度的不自主运动或感觉。因此，可以认为一过性脑缺血发作的诊断标准是：(1)患者在过去12个月内至少发生了3次短暂性脑缺血发作；(2)每次发作都表现为轻度至中度的不自主运动或感觉；(3)患者的年龄在60岁以上；(4)患者的收缩压在140 mmHg以上。在这些患者中，如果出现无明显原因的肢体偏瘫、语言障碍、感觉异常或意识障碍，应考虑进行进一步的检查，以排除颅内或外周血管病变。如果患者的症状持续超过24小时，应考虑进行脑血管造影检查以排除颅内或外周血管病变。在这些患者中，如果出现无明显原因的肢体偏瘫、语言障碍、感觉异常或意识障碍，应考虑进行进一步的检查，以排除颅内或外周血管病变。如果患者的症状持续超过24小时，应考虑进行脑血管造影检查以排除颅内或外周血管病变。
研究背景和目的

颈动脉 IMT 为评价动脉粥样硬化的指标，可代表整体的血管风
险。颈动脉粥样硬化可能对认知功能有影响，尤其在中高危
的患者。最近的研究表明，颈动脉 IMT 值与 MMSE 分值变化
显著相关，而 MMSE 是 evaluation 认知功能的金标准。因
此，我们旨在评估颈动脉 IMT 值与 MMSE 分值变化的关
系，并探讨其对其他认知功能的影响。

方法

从 2010 年 1 月至 2013 年 12 月的期间，所有患者均签署了知情同意书。所有患者均在基线期接受颈动脉 IMT 测量，包括双侧 IMT 值。基线期 MMSE 评分 (f-MMSE) 之差作为主要的终点变量。所有患者在 3 年随访结束后 MMSE 评分 (b-MMSE) 作为次要的终点变量。所有患者均在基线期和 3 年随访期接受 MMSE 评分。MMSE 评分由经过培训的临床心理学家进行评估。所有患者均在基线期和 3 年随访期接受 MMSE 评分。MMSE 评分由经过培训的临床心理学家进行评估。

结果

在单个亚组中，IMT 与 MMSE 分值变化无显著关联，也没有为 BHI 转换为二分类变量后的 IMT 值。在两个独立的模型中，顺序 BHI 变量与分析结果显著相关。第一个模型将转换为二分类变量后的 IMT 值纳入进行析因分析；第二个模型和第一个类似，只是把转换为数字后的 BHI 值作

表 2. 每个亚组 MMSE 估计边缘均值差异比较

<table>
<thead>
<tr>
<th>组别</th>
<th>MMSE 分值变化</th>
<th>偏差</th>
<th>标准差</th>
<th>t 值</th>
<th>P 值</th>
<th>η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>左侧异常 BHI</td>
<td>-1.785</td>
<td>-2.172</td>
<td>0.082</td>
<td>-2.172</td>
<td>0.030</td>
<td>0.338</td>
</tr>
<tr>
<td>双侧正常 BHI</td>
<td>0.894</td>
<td>1.786</td>
<td>1.163</td>
<td>1.786</td>
<td>0.040</td>
<td>0.235</td>
</tr>
<tr>
<td>双侧异常 BHI</td>
<td>0.513</td>
<td>1.379</td>
<td>0.687</td>
<td>1.379</td>
<td>0.179</td>
<td>0.108</td>
</tr>
</tbody>
</table>

讨论

颈动脉 IMT 值与 MMSE 分值变化显著相关 (P < 0.0001)。我们既往的研究表明，无缺血性卒中患者认知功能的减退很可能与慢性大
脑缺血有关。但颈动脉 IMT 值与 MMSE 分值变化关系的关联性，目前尚不清楚。本研究的结果表明，颈动脉 IMT 值与 MMSE 分值变化显著相关。这提示颈动脉 IMT 值可能在评估认知功能的减退方面具有潜在价值。

结论

颈动脉 IMT 值与 MMSE 分值变化显著相关。这提示颈动脉 IMT 值可能在评估认知功能的减退方面具有潜在价值。外周病变组间人口学和临床资料无显著差异。而根据 BHI 分成的不同组间，均异常的患者认知功能恶化的风险最高。研究中 CVR 正常或异常患者 MMSE 分值下降的风险随着 BHI 异常的增加而逐渐增高，双侧 BHI 异常的患者 MMSE 分值下降的风险显著高于单侧 BHI 异常的患者。这意味着颈动脉 IMT 值与 MMSE 分值变化显著相关，提示颈动脉 IMT 值可能在评估认知功能的减退方面具有潜在价值。
Solitaire FR 取栓术中侧枝循环对血管重建的影响

Impact of Collaterals on Successful Revascularization in Solitaire FR With the Intention for Thrombectomy

David S. Liebeskind, MD, Reza Jahan, MD, Raoul G. Nogueira, MD, Osamu O. Zaidat, MD, Jeffrey L. Saver, MD; for the SWIFT Investigators

目的和方法：通过分析 SWIFT 研究中血管内治疗的影像学显示的侧枝循环情况，明确侧枝循环水平对研究提出的微栓塞性疾病。伴有微栓塞性性治疗的临床研究改良需进一步考虑，是否支持脑血流动力学的改变时，颈动脉狭窄或闭塞性疾病中的脑血流动力学异常应考虑损害脑组织的梗死或萎缩对研究中侧枝循环的影响。

结论：对 SWIFT 研究的 144 例患者中 119 例的血流动力学能够提供侧枝循环的影像学显示（平均年龄 67 ± 12 岁；女性，60%；颈动脉 IMT ≥ 1.8 cm 10%；颈动脉狭窄程度 ≥ 90% 的患者；P < 0.001）。颈动脉狭窄的血流动力学的影像学显示包括颈动脉狭窄程度（P = 0.049），视野比（P = 0.012），以及根据 SWIFT 的影像学显示。颈动脉狭窄的血管再通和血流动力学的影像学显示均具有统计学意义与影像学显示相关。对可通过血管重建或药物治疗来改善脑血流动力学的个体进行早期筛选，可能有助于预防或减少认知障碍。25 研究的 MMSE 量表，而 MMSE 可能不足以精确地检测出无明显症状患者。26 作用的 MMSE 量表，而 MMSE 可能不足以精确地检测出无明显症状患者。26

本研究无神经影像学评估，因而不能确定脑白质病变、无症状性脑梗死及脑萎缩对研究对象认知功能下降的影响。此外，研究期间意识模糊的患者。22 Stroke

侧枝循环水平是急性缺血性卒中患者在急性期和长期随访期间血管再通和脑白质病变的有力决定因素。侧枝循环与年龄和其他并存疾病存在潜在相关性，然而，仅通过这些临床因素而无确切的影像学证据来判断侧枝循环水平是不充分的。2,3 自主的临床研究或通过增强侧枝循环来改善临床结局指标。我们通过分析 SWIFT 研究中血管内治疗前造影显示的侧枝循环等级，来明确侧枝循环对新结局指标 - 不伴有症状性出血转化的再灌注水平、该新结局指标是最近被用来定义支架样取栓装置的成功血管重建的生理和临床结局指标。11,12 良好的侧枝循环与不伴有症状性出血的成功血管再通这一组合概念有相关性，平均侧枝循环等级分别为 2.9 (SNI, 2.1–2.9) 和 1.9 (SNI, 2.1–2.9)。

结论：良好的侧枝循环与较高的血流动力学水平、较小的基底动脉稀化以及不伴有症状性出血的成功血管再通和良好的临床结局相关。