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.

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, and in some cases, it may develop a cognitive deterioration. Such consequences are more common if cerebral hemodynamics in the territory supplied by the stenotic ICA is altered. Furthermore, patients with bilateral carotid stenosis may present a reduction in specific cognitive domains depending on the more hemodynamically compromised brain hemisphere. 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. 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 general 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 more than clearly moderate drinking (ie, estimated intake ≥21 cigarettes per day; we recorded, referred, or treated atrial fibrillation (AF); heavy drinking was defined as more than clearly moderate drinking (ie, estimated intake ≥200 g of pure alcohol/wk constantly as disclosed by the patient or a relative)). Pharmacological treatment of vascular risk factors was planned according to international guidelines.15

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 transtemporal cranial 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 percentage increase in MFV occurring during BH by the length of time 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 α coefficient (left, ω=0.99; variance range, ±0.022 and right, ω=0.99; variance range, ±0.026), indicating a high reliability of BHI measurement among the 3 different readings. Similarly, if analyzed as a dichotomous value (normal versus pathological value), we observed a high Cohen κ index on both sides (left, κ=0.98; right, κ=0.99; P<0.05, result obtained by comparing the 3 readings per each side). Using a binary approach, we did not observe discrepancies among observations: all BHI values resulting pathological at the first measurement were pathological also in the second and in the third one. The mean BHI value of the 3 tests was included in the analysis. On the basis of our previous results, we classified cerebral hemodynamic parameters as either impaired (BHI<0.69) or normal (BHI≥0.69).15 On the basis of BHI values, we classified subjects into bilaterally preserved CVR; bilaterally impaired CVR; and right CVR impaired and left CVR impaired.

Measurements of intima-media thickness (IMT) were performed at baseline according with international guidelines.14 To measure IMT, a semiautomatic software (QLAB version 8; Philips Medical Systems, Andover, MA) was used to improve measurement reliability and reproducibility.14 Carotid IMT was defined as the mean of both left and right side measurements. A cutoff for pathological values was set at 1.0 mm.14 All neck vessels ultrasound examinations were performed by the same 2 experienced operators. Inter-reader reliability was assessed by having the 2 sonographers blindly selected and redigitized a B-mode image from the 20-s videotape recording of a randomly selected set of 200 studies originally read by a third sonographer. One sonographer reread 130 studies for an inter-reader correlation coefficient of 0.88, and the second sonographer reread 70 studies for an inter-reader correlation coefficient of 0.85. Intra-reader variability was assessed by having the 2 sonographers reread 30 randomly selected studies and resulted 0.92 and 0.91, respectively.

Patients were followed up for 3 years. Every 6 months, a clinical examination was performed. At the end of the follow-up period, all patients were reassessed with MMSE.

The study was approved by the ethics committee of the Marche Polytechnic University. All participants and caregivers gave their informed written consent according to the Declaration of Helsinki.

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 (bilateral 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, antplateletants, 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.

The relationship between f-MMSE and the predictors was analyzed first with 2 linear regression models, treating f-MMSE as a dependent variable and the continuous BHI values (left and right) as independent predictors.

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 attitude, 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 value 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 final 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 variables as a predictor. The second 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.

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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. " 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 a t 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 (P=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=0.00001) 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>1.000</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>2 (7.2%)</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 and pathological IMT to 0.503 (95% confidence interval, –0.247 to 1.253) in the group with bilaterally normal BHI and normal IMT.

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)</th>
<th>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>
<td></td>
</tr>
<tr>
<td>BHI: right pathological (1.786; 95% CI, 1.275–2.297)</td>
<td>BHI: left pathological</td>
<td>−0.729</td>
<td>0.337</td>
<td>0.032</td>
<td>−1.394</td>
<td>−0.063</td>
<td></td>
</tr>
<tr>
<td>BHI: bilaterally pathological</td>
<td>BHI: right pathological</td>
<td>−2.172</td>
<td>0.285</td>
<td>0.0001</td>
<td>−2.735</td>
<td>−1.609</td>
<td></td>
</tr>
<tr>
<td>BHI: left pathological (1.623; 95% CI, 1.071–2.175)</td>
<td>BHI: left pathological</td>
<td>−0.729</td>
<td>0.337</td>
<td>0.032</td>
<td>−1.394</td>
<td>−0.063</td>
<td></td>
</tr>
<tr>
<td>BHI: right pathological</td>
<td>BHI: left pathological</td>
<td>−0.163</td>
<td>0.387</td>
<td>0.675</td>
<td>−0.927</td>
<td>0.602</td>
<td></td>
</tr>
<tr>
<td>BHI: left pathological (3.067; 95% CI, 2.643–3.490)</td>
<td>BHI: right pathological</td>
<td>2.172</td>
<td>0.285</td>
<td>0.0001</td>
<td>1.609</td>
<td>2.375</td>
<td></td>
</tr>
<tr>
<td>BHI: right pathological</td>
<td>BHI: left pathological</td>
<td>1.443</td>
<td>0.356</td>
<td>0.0001</td>
<td>0.614</td>
<td>1.948</td>
<td></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.\textsuperscript{2,3}

The risk of cognitive deterioration in patients with carotid stenosis has been extensively evaluated,\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{23}

Considering cognitive decline as a specific consequence of carotid disease is a relatively new concept,\textsuperscript{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.\textsuperscript{25} Early selection of subjects deserving consideration for revascularization procedures or pharmacological treatments able to improve cerebral hemodynamics\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{29} Nonetheless, previous evidences\textsuperscript{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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无症状性双侧颈动脉重度狭窄与认知恶化

Cognitive Deterioration in Bilateral Asymptomatic Severe Carotid Stenosis

Laura Buratti, MD; Clotilde Balanici, MD; Giovanna Vitucci, MD; Lorenzo Falsetti, MD; Claudia Altamura, MD; Emma Avitabile, MD; Leandro Provinciali, MD; Fabrizio Vernieri, MD; Mauro Silvestrini, MD

背景和目的：本研究旨在观察无症状性双侧颈动脉内膜中层厚度糖尿患者认知的动态，以探讨双侧颈动脉内膜中层厚度与认知功能障碍的关系。

方法：本研究纳入159例无症状性双侧颈动脉重度狭窄患者，并对其进行3年的随访研究，登记患者的年龄、性别、吸烟史、饮酒史、高血压病、糖尿病、高脂血症、心脏病、脑血管病史。所有患者均无明显的神经系统症状和体征。

结果：本研究纳入159例无症状性双侧颈动脉重度狭窄患者，其中包括154例（50%）男性，平均年龄（51±9）岁。平均颈动脉内中膜厚度（IMT）为1.0±0.3mm。

结论：无症状性双侧颈动脉重度狭窄患者的认知可能因内膜中层厚度的增加而恶化。
颈动脉 IMT 值转换为二分类变量:正常或异常。 年龄、f-MMSE、b-MMSE、吸烟、男性等变量作为连续变量的比较采用 t 检验,二分类资料的比较采用卡方检验。血脂异常与心肌梗死的发生率有差异,同时平均基线 MMSE 和终点平均 MMSE 差异的估计值均显著地大于平均 MMSE 差异的 95% 置信区间。

**表1. 双侧颈动脉 IMT 值比较**

<table>
<thead>
<tr>
<th>组别</th>
<th>IMT (mm)</th>
<th>P值</th>
</tr>
</thead>
<tbody>
<tr>
<td>双侧正常 (n=32)</td>
<td>24.06 (±2.08)</td>
<td>0.600</td>
</tr>
<tr>
<td>右侧异常 (n=44)</td>
<td>24.86 (±1.85)</td>
<td>0.533</td>
</tr>
<tr>
<td>左侧异常 (n=44)</td>
<td>26.55 (±1.05)</td>
<td>0.179</td>
</tr>
</tbody>
</table>

**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>I-J</th>
<th>SE</th>
<th>P值</th>
</tr>
</thead>
<tbody>
<tr>
<td>双侧正常 vs 右侧异常</td>
<td>1.830 (95% CI, 1.599~2.061)</td>
<td>0.007</td>
<td></td>
</tr>
<tr>
<td>双侧正常 vs 左侧异常</td>
<td>1.786 (95% CI, 1.275~2.297)</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>右侧异常 vs 左侧异常</td>
<td>1.443 (95% CI, 0.891~2.172)</td>
<td>0.0001</td>
<td></td>
</tr>
</tbody>
</table>

**表3. 二分类变量的比较**

<table>
<thead>
<tr>
<th>组别</th>
<th>IMT</th>
<th>P值</th>
</tr>
</thead>
<tbody>
<tr>
<td>双侧正常 (n=32)</td>
<td>0.91 (±0.91)</td>
<td>0.513</td>
</tr>
<tr>
<td>右侧异常 (n=44)</td>
<td>0.98 (±0.98)</td>
<td>0.536</td>
</tr>
<tr>
<td>左侧异常 (n=44)</td>
<td>0.89 (±0.89)</td>
<td>0.536</td>
</tr>
</tbody>
</table>

**图1. 平均年 MMSE 差异的比较**

<table>
<thead>
<tr>
<th>组别</th>
<th>年 MMSE 差异 (I-J)</th>
<th>SE</th>
<th>P值</th>
</tr>
</thead>
<tbody>
<tr>
<td>双侧正常 vs 右侧异常</td>
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<td></td>
</tr>
</tbody>
</table>

**图2. 密度图分析**

<table>
<thead>
<tr>
<th>组别</th>
<th>年 MMSE 差异</th>
<th>SE</th>
<th>P值</th>
</tr>
</thead>
<tbody>
<tr>
<td>双侧正常 vs 右侧异常</td>
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<td></td>
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</tbody>
</table>
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; Raul G. Nogueira, MD; Osama O. Zaidat, MD; Jeffrey L. Saver, MD; for the SWIFT Investigators

目的和方法

通过分析 SWIFT 研究中血管造影影像显示的侧枝循环情况，明确侧肢循环水平对研究提出的终点事件——伴有或无症状性脑血管闭塞的患者中有无显著疗效。本研究的终点事件包括Stroke 5 级的临床终点事件以及 mRS 评分。

方法

SWIFT 研究采用临床终点事件和自诊中使用 Morishita 装置和 nimodipine 对抗治疗。在及早诊断和治疗方面，该研究提出了基础治疗的模式。

研究结果

研究结果表明，侧肢循环水平对研究提出的终点事件——伴有或无症状性脑血管闭塞的患者中有无显著疗效。本研究的终点事件包括 Stroke 5 级的临床终点事件以及 mRS 评分。