Improved visual, acoustic, and neurocognitive functions after carotid endarterectomy in patients with minor stroke from severe carotid stenosis

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Objective: **Carotid endarterectomy (CEA) is an established operation performed to prevent strokes, but its other potential effects, such as improving neurocognitive, visual, and auditory functions, remain unconfirmed. This study examined these effects of CEA on patients with symptomatic carotid stenosis.**

Methods: **This was a prospective controlled study that included 80 patients with minor strokes who had severe extracranial internal carotid stenoses (>70%). Forty patients, who did not receive or who postponed the CEA due to concerns about age, fear of surgery, limited life expectancy because of cancer, or financial problems, formed the medicine-treatment group. Another 40 patients who received CEA 1 week after recruitment formed the CEA group. For both groups, visual acuity chart tests, perimetry tests, audiometry tests, and neurologic scales (National Institutes of Health Stroke Scale, Mini Mental State Examination, and Barthel Index of Activities of Daily Living) were used to assess ophthalmic functions, auditory acuity, and neurocognitive functions before treatment and 3 months after treatment. Intragroup and intergroup comparisons were conducted to examine the effect of CEA.**

Results: **No deaths or strokes occurred during the 3-month follow-up. The intragroup and intergroup comparisons of ipsilateral function showed that CEA could improve visual acuity, visual field, and auditory acuity at all tested frequencies (250 Hz, 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz) and could improve the visual field and the auditory acuity for contralateral functions at 1000 Hz. The auditory acuity at 2000 Hz and 4000 Hz were unchanged in the intragroup comparison but showed no deterioration in the intergroup comparison with the medicine group. General neurocognitive function and independent living ability were significantly improved by CEA, as shown by intergroup comparisons (change rate of National Institutes of Health Stroke Scale: −8.1% ± 9.0% vs −2.7% ± 3.0%, *P* < .001; change rate of Mini Mental State Examination: 15.5% ± 10.5% vs 1.6% ± 2.6%, *P* < .001; change rate of Barthel Index: 28.0% ± 24.6% vs 2.0% ± 5.5%, *P* < .001).**

Conclusions: **In patients with minor strokes caused by severe carotid stenosis, CEA improves neurocognitive, ophthalmic, and acoustic functions. Studies with a larger sample and longer follow-up are needed to substantiate these results, and the underlying mechanisms need further investigation. (J Vasc Surg 2015;62:635-44.)**

Although carotid endarterectomy (CEA) has been well-accepted as a stroke prevention surgery for patients with carotid arteriosclerosis,[1-3] there is insufficient evidence to confirm possible additional positive effects. The potential benefit of CEA on cognitive improvement has been proposed.[4] However, the results in the literature remain debatable. There are discrepant reports on the effects of cognitive function after CEA, ranging from improvement,[5,6] decline,[7,8] and mixed results to no change.[9,10] Cognitive function in the elderly population could be influenced by the state of visual and hearing ability,[11] so the change in these functions also required study. Ophthalmologists have found results suggesting visual acuity improvement from the procedure.[11-13] At the same time, studies have reported negative effects of CEA on visual acuity.[14] No data have been published concerning the effect of CEA on hearing ability.

These confounding results may be related to the varying severity of illness before the treatment. For example, patients with different levels of cognitive impairment (from transient or mild to permanent or severe) were included. Furthermore, many studies suffered from methodologic problems, such as the lack of a control group.[15,16] This study was designed with the goal of avoiding these disadvantages.

In China, most CEA procedures are performed on patients with symptomatic carotid stenoses and multiple

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functional impairments. For patients with symptomatic carotid stenoses who have experienced a minor stroke, the determining factors for their quality of life are locomotion, visual and auditory acuity, and neurocognitive function. These impairments are associated with disability, institutionalization, death, and result in a heavy social burden.[17] This study aimed to objectively quantify the changes in multiple functions after CEA in patients with minor stroke with severe carotid stenosis.

METHODS

The protocol for this study was approved by the participating hospital's Ethics Committee.

Patient recruitment and treatment protocol. This was a prospective cohort study that included minor stroke patients with severe extracranial internal carotid stenosis (stenosis degree >70%). Minor stroke was defined by a score of ≤5 at the time of entering this study according to the National Institutes of Health Stroke Scale (NIHSS; scores range from 0-42, with higher scores indicating greater deficits).[18] Patients with the following criteria were excluded: (1) prior treatment with carotid stenting; (2) common or external carotid artery stenosis, or both; (3) complete hemiplegia; (4) complete aphasia; (5) complete blindness in one or both eyes; (6) history of psychosis, psychiatric disorder, and other neurologic diseases, such as Alzheimer disease, that might affect neurocognitive performance; (7) middle ear diseases, assessed by an otologist, mainly according to acoustic impedance values measured by an automatic acoustic impedance meter (Zodiac 901; Madsen, Taastrup, Denmark).

The study was designed to include 80 patients, 40 in the CEA group and 40 in the group that received treatment with medicine. The recruitment of 40 patients for the CEA group required 5 months, whereas the recruitment process of 40 patients for the medicine group lasted from June 2011 to June 2013.

The 40 patients in the medicine group did not receive CEA because of advanced age (n = 4), fear of surgery (n = 3), limited life expectancy because of cancer (n = 12), or temporary financial uncertainty (n = 21). Those with temporary financial uncertainty temporarily postponed CEA and finally underwent the procedure after 3 months. Complete information on the risks of recurrent stroke without surgery, the benefits of CEA, and detailed medical management plans were provided to the patients in the medicine group or to their immediate family. Consent forms were obtained from these patients and their direct relatives. Patients in the medicine group were treated according to the standard guidelines, including aspirin (100 mg daily), atorvastatin (40 mg daily), and antihypertensive medicine to maintain blood pressure at the ideal level.[19]

Patients who were willing to receive CEA as soon as possible formed the CEA group and received the operation ≤1 week. An eversion CEA procedure was performed under general anesthesia with systemic heparinization and induced hypertension during carotid artery clamping.[20] No shunt was used during the operation in this study. The postoperative blood pressure was strictly controlled at 120 to 140/80 to 90 mm Hg to prevent post-CEA hyperperfusion syndrome. When the patients were discharged, they were prescribed aspirin (100 mg daily) and atorvastatin (40 mg daily) for long-term therapy, and cilostazol (100 mg twice daily) for 6 months. Follow-up by carotid ultrasound imaging was conducted every 6 months for the long-term.

Assessments before treatment and operation and after treatment and operation. Every included patient underwent the pretreatment and post-treatment evaluations. These examinations were conducted by independent physicians of relevant specialties who were not involved in the operation or in the administration of medication. All fees of the required examinations were covered by the provincial and national fund. These examinations are listed below.

First, carotid plaque and cerebral lesion assessment:

- Carotid computed tomography (CT) arteriography to assess the location, length, and stenosis level of the lesions, and to assess the basilar artery rings.
- CT perfusion imaging of the brain (CT perfusion and carotid CT arteriography were done in one CT scan). The four parameters used to assess cerebral flow perfusion were maximum intensity projection (MIP), flow, blood volume, and time to peak (TTP). A greater value of MIP, flow, blood volume, and a lesser value of TTP indicate improved brain perfusion.
- Cranial magnetic resonance imaging (MRI) to assess the location and range of the cerebral infarction.

Second, neurologic and cognitive function assessment:

- Muscle strength grading according to the grading system of the Medical Research Council, which has been widely used in textbooks of neurology and clinical research.[21] Muscle strength was divided into six grades: from 0 (total paralysis) to 5 (normal strength).
- The NIHSS was used to measure stroke-related neurologic deficiencies. An increase of the NIHSS score indicates neurologic deterioration.
- Mini Mental State Examination (MMSE), a neuropsychologic test to screen for cognitive impairment. To attenuate the "practice effect," different sets of questions and stimuli were used during re-examinations (Supplementary Table I, online only). The full score is 30, and lower scores indicate worse cognitive function.
- The Barthel Index of Activities of Daily Living (Barthel scale) was used to assess the degree of independence of mobility and daily activities.[22] The full score is 100, and lower marks indicate worse independent living ability.

At the start of the scales assessments, the patients were interviewed about their level of education, tobacco use, alcohol use, and psychiatric and medical history.