SURGICAL RECONSTRUCTION OF OCCLUDED CERVICAL CAROTID ARTERY

REPORT OF A SUCCESSFUL CASE WITH 4-YEAR FOLLOW UP AND THREE EXAMPLES WITHOUT SUCH TREATMENT*

H. HAMLIN, M.D., W. H. SWEET, M.D., AND W. M. LOUGHEED, M.D.†

Neurosurgical Service, Massachusetts General Hospital, Boston, Massachusetts

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The clinical syndrome of occlusive disease of the carotid arterial system has been well described.1–7,11 Predilection for arteriosclerotic thickening of the wall of the vessel and formation of plaques has been shown to be at the bifurcation of the common carotid artery and on up into the internal trunk.1,12 Thrombotic disease of the carotid tree cephalad from the aortic arch, including temporal and ophthalmic branches, has also been attributed in rare instances to infection or trauma.14 Narrowing of the lumen can advance so insidiously that recurrent and progressive neurologic deficit may be overlooked or not ascribed to decrements of carotid-cerebral blood flow. Successful direct treatment of the abnormality depends on its prompt recognition and evaluation to ascertain the possible value of surgical reconstruction of the affected artery.

CASE REPORTS

Case 1. A 64-year-old man (right-handed) was admitted to hospital on Feb. 21, 1950, having experienced drooping of the right side of the mouth and weakness of both legs 8 years previously, lasting 8–9 months. He had had a fainting spell 5 years back with loss of consciousness. Three weeks before hospitalization he became drowsy and his tongue and mouth pulled to the left, clearing rapidly. One week before admission the left arm became weak and vision began to fail, beginning with diplopia and declining to perception of light and gross movements of the hand within 3–4 days. (The sketchy history probably omitted other interval episodes of neurological difficulty.)

Examination. There was poor comprehension because of difficulty in language. The patient was mentally dull but oriented and able to perform simple commands. He could not read letters 4 inches high but named a few objects adequately visualized. There were nystagmoid movements of the eyes on lateral gaze; pupils and fundi were normal; fields of vision revealed large central scotomata surrounding points of fixation and extending beyond blind spots. There was weakness of the left lower face and left arm, with slight increase in deep reflexes generally; plantar reflexes were equivocal; sensation was grossly intact. Blood pressure was 220/100.

Laboratory Studies. Hemoglobin was 16 gm. per cent, hematocrit 50 per cent, and count of white blood cells 8,800/c.mm. Cerebrospinal fluid was slightly xantho-

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† Medical Arts Building, Toronto 5, Ontario.
communicating view using grams chromic; protein was 60–80 mg. per cent. Hinton was negative, blood urea nitrogen 16 mg. per cent, and alkaline phosphatase 3.5 K.A. units (normal). Electrocardiogram showed frequent premature beats and indication of hypertension. Roentgenograms of skull and chest were unremarkable.

**Course.** Bilateral percutaneous carotid arteriography was carried out at one stage using 35 per cent Diodrast. Upon injection of the left carotid the anteroposterior view showed the internal carotid dividing into its anterior and middle branches as well as the contralateral anterior and middle branches filling via the anterior communicating artery, all vessels being in normal relationship. Upon injection of the right side there was no filling of the internal carotid in both anteroposterior and lateral projections although the needle was shown well placed in the common trunk with filling of the external carotid system. Following arteriography pupillary inequality developed and the patient was responsive only to painful stimuli. Subsequent spinal puncture revealed a pressure of 140 mm. and slightly yellow cerebrospinal fluid. He remained comatose and expired 3 days later.

**Autopsy** disclosed advanced atherosclerosis involving all major cerebral arteries. There was extensive and complete obstruction of the right internal carotid but the anterior and middle cerebral arteries on both sides were open; both posterior communicating arteries were extremely narrowed and questionably patent. The brain showed fresh thrombotic occlusion obstructing the full length of a tortuous basilar artery, superimposed on arteriosclerotic plaques with patchy chronic ischemic infarction and acute softening in both occipital and both temporal lobes, thalami, pons and cerebellum. Multiple old infarcts with cystic degeneration were noted in the internal capsule, putamen, and globus pallidus on each side. Generalized arteriosclerosis was widespread in major arteries elsewhere.

**Comment.** The brain of this man had achieved remarkable toleration to progressive occlusion of the right carotid artery in the face of extensive cerebral arteriosclerosis by the development of compensatory supply through the contralateral circle of Willis and probably meningeal anastomoses and the homolateral ophthalmic artery as well. Cerebrovascular survival during the last 3 days of life apparently was maintained almost entirely by the left carotid artery. The extensive old capsular and lenticular lesions bilaterally came as a surprise in view of the relatively minor degree of neurologic loss recorded during his hospitalization. Basilar narrowing was undoubtedly in progress for several years before it was rendered complete by ill-conceived carotid arteriography. Competent observers, including several neurologists and neurosurgeons and two ophthalmologists, suspected a prechiasmal or retrobulbar lesion, perchance a neoplasm of the middle fossa. The possibility of occlusive carotid or cerebrovascular disease was not mentioned by any one of them; apparently no one chose to palpate the carotids in the neck. In retrospect, absent pulsation might have been noted on the right side. Two-stage angiography should then have been performed at 24-hour interval using the less irritating Thorotrast; or surgical exploration of the right cervical carotid system might have disclosed the lesion and sufficient healthy subcranial segment of internal carotid artery available above the site of thrombosis to permit reconstruction. We suggest that such an at-
tempt would have been warranted and that its success might have augmented the marginal cerebral circulation in this particular patient.

Case 2. A 46-year-old machine tool worker got up one night in December 1953 to void and became aware of left-sided headache and right-sided weakness. He had to lean on furniture and noted blurred vision in the left eye. He managed to get back to bed. The next morning he was free of weakness but had mild left-sided headache for 12 hours. Four days later, he again awoke with faint left-sided headache and blurred vision. His right side was weak, with a limping gait. He tried to drive his car to work but collided against the garage door to his right. He returned home to bed and improved during the next hours, but was admitted to hospital the same day, where left open carotid arteriography was performed.

Examination. Details concerning history were vague. Cranial nerves were normal. Visual fields were full to confrontation. Grip of the right hand was weak, with drifting of outstretched arm. Left carotid pulse seemed less forceful than right. Blood pressure was 110/75.

Laboratory studies revealed normal clotting time, normal electrocardiogram, negative Hinton, normal hemogram, and normal urine. Fasting blood sugar was 90, nonprotein nitrogen 28 and cholesterol 252.

Diagnosis. Clot in left internal carotid.

Course. Patient was observed closely for recurrence of neurologic disturbance. Arteriogram was considered to show no filling of the left internal carotid above the siphon (Fig. 1). The treatment contemplated was intracranial approach under hypothermia, with removal of thrombus by direct incision of artery. If hemiplegia did not recur for several days the clot might have become organized and adherent so that thrombectomy or resection and graft might be necessary.
This man recovered without recurrence of neurological deficit. No anticoagulants or other medication were administered. He returned to work and has remained well up to the most recent follow up (December 1957).

Case 3. A 48-year-old man (right-handed) began to have occipital headaches early in 1951 and several months later experienced episodes of blurred vision and occasional blindness in the left eye, each lasting for 5–10 minutes over a period of 3 weeks. Two days before hospitalization on April 23, 1951 weakness of the right arm and leg caused him to fall while getting out of bed and he was aware of difficulty in talking and visual loss in the left eye. Symptoms improved during the next 48 hours but his wife noted a drooping of his right lower face, incoherent speech, and that he unknowingly burned the middle finger of his right hand.

Examination. Pupils, visual fields on confrontation, and fundi appeared normal. Left carotid pulsation was poor by palpation and absent above the bifurcation. There was weakness of right arm and leg with hypalgesia and hypesthesia over the dorsal aspect of the right hand and fingers 3-4-5, fading out over the forearm. Plantar response on the right was extensor. Blood pressure was 150/110.

Laboratory Studies. Hemoglobin was 15.6 gm. per cent. Count of white blood cells was 14,000, with 81 polymorphonuclear leucocytes and 16 lymphocytes. Blood glucose was 93 and urea nitrogen 11 mg. per cent. Hinton was negative. Spinal fluid pressure was 150 mm.; protein 137 mg. per cent. Electrocardiogram was nor-

Fig. 2. Case 3. Arrows point to irregular narrow carotid artery in neck partially obscured by larger external carotid.
mal. Electroencephalogram displayed left temporal slow waves of low voltage. Roentgenograms of skull were not remarkable.

Course. Percutaneous needling of the left common carotid was not successful. The vessel was exposed and required three punctures to obtain a satisfactory backflow prior to injection of contrast medium (Fig. 2) which showed beaded narrowing of the internal trunk up to its siphon and poor filling of the anterior and middle cerebral branches with normal caliber and filling of the external carotid. Irregular narrowing of the internal carotid artery extended from the bifurcation to itscranial entrance. The sclerotic condition of the artery was also demonstrated by surgical exploration, thus definitely excluding the feasibility of any reconstructive procedure. Cervical sympathectomy was performed, creating homolateral ptosis and miosis. No anticoagulants were given.

This man has been working in manufacture of jewelry for over 6 years with no recurrence of focal neurologic deficit (last follow up November 1957).

Case 4. A 50-year-old widow (right-handed) had periodic near-blackout spells for 8 weeks since March 1953, consisting of feeling of faintness and dim vision for 1–2 minutes, clearing if she bent her head forward; she also experienced unrelated intermittent numbness of the 3rd, 4th and 5th fingers of the right hand. On the day of stroke (May 2, 1953) she tended to doze while driving and that evening after supper suddenly became unable to speak clearly and drooping of the right lower face developed with paralysis of right arm and leg. She was hospitalized for 4 weeks under a diagnosis of cerebral thrombosis during which time improvement became manifest by slight return of movement in the right arm and leg and vocalization of a few syllables.

Examination (June 10, 1953). There was no spontaneous speech and she was unable to understand written words but could repeat a few words upon dictation, and perform addition and subtraction of single digits and indicate the use of common objects. There was indefinite right lower quadrantopsia by confrontation. The right lower face was weak. She could move her right shoulder but no other parts of right upper limb; she was able to elevate right leg 14° from bed, but there was no motion of foot or toes. There was early spasticity of right arm and leg and atrophy of the musculature of the hand. Pinprick evoked less response over right limbs than left; localization of touch and graphesthesia were absent on right hand, poor on forearm, and fair on leg. Sense of pressure was impaired in right forearm and hand. Tendon reflexes were hyperactive on right with ankle clonus and extensor plantar response.

Course. Five weeks after the ictus open left internal carotid arteriography (Fig. 3A) was performed above the bifurcation which was found to be firm and sclerotic on palpation.

Operation. Surgical reconstruction of the left internal carotid was performed 2 days later (June 11, 1953) under local and intravenous barbiturate anesthesia. The bifurcation was resected and found to be narrowed to a whorl-shaped pinpoint opening by an arteriosclerotic plaque (Fig. 4). The external carotid was ligated and the proximal end of the common trunk was sutured to the tortuous and adequately sound remainder of the internal carotid.

Postoperative Course. It was planned to maintain clotting time at 2–3 times normal, but by error, 20,000 units of high potency heparin were administered intravenously after operation (2 cc. of a 10,000 µ./cc. preparation or 10 times the usual 1,000 µ./cc. dosage). Clotting time was 60 minutes 5 hours later, 12 minutes at
Fig. 3. Case 4. (A) Preoperative open internal carotid angiogram. Injection, even though rostral to site of occlusion at bifurcation of common carotid, reveals only thready filling of middle cerebral branches. (B) Five months after reconstruction. Open common carotid angiography—Injection 2 cm. above clavicle. In lateral view there is excellent anterior cerebral filling but middle cerebral branches are still poorly outlined. Identical technique was used for both arteriograms.

8 1/2 hours and 4 minutes at 12 hours; at this time the customary intravenous dose of 2,000 units of heparin was administered and repeated after 2 hours. Approximately 15 hours later a clinical observer noted, "Patient speaks distinctly—moves

Fig. 4. Case 4. Serial transverse sections of resected carotid artery showing degree of arteriosclerotic closure at several levels: (1) common trunk; (2) residual pinpoint lumen at bifurcation; (3) occlusion of internal is almost complete 2 cm. above bifurcation; (4) at 4 cm. both internal and external are patent.
right lower face, not right arm—flexes and extends right thigh actively.” Clotting times were maintained between 4 and 55 minutes for the next 6 days by giving 145,000 units of depot heparin distributed through 5 doses as indicated. Two days later flexion was noted for the first time at the right elbow. Ten days postoperatively she was able to name the days of the week and to pronounce her name after a long delay; anomia was still severe but she could select the correct name for an object among a set of choices presented verbally. Five months following carotid reconstruction open arteriography revealed a minimal constriction at the site of the anastomosis (Fig. 5) and a pattern of cerebral vascularity (Fig. 3B) that appeared to represent improvement of collateral supply over the preoperative condition (Fig. 3A). By this time the patient was walking without manual or mechanical assistance and was making consistent improvement in speech and other related mental functions.

Examination (Jan. 14, 1957). Patient appeared to be in good health and was alert and clearly oriented. Pulsation of left carotid was palpable throughout its cervical course. She understood what was said to her and cooperated well with examiner. She comprehended printed and written words and sentences of ordinary content, and recognized pictures of objects and scenes with respect to identity, color, and meaning. Speech difficulty appeared to be mainly motor. Subject carried out directions with respect to parts of body, right and left and spatial relationship; identified common objects presented to sight and touch despite limitation in ideational and nominal speech. She is said to have a vocabulary of several hundred words—recited serial figures, months of the year, days of the week, simple poetic verses and a few books of the Bible. She repeated words and short phrases on dictation but with hesitation and frequent errors; reading aloud was also confined to short words and phrases. She learned to write with her left hand and produced words and statements, such as name and address and similar remarks, spontaneously and by dictation. Easy arithmetic was performed in both verbal and written answers to problems, but she was unable to subtract serial 7s or to perform multiplication. She would scan a newspaper or magazine page with considerable interest, then pass it to someone to read aloud, the content of which she understood and enjoyed. She indicated that improvement in her mental faculties has continued over the past 4½ years and has been enhanced by coaching from her relatives and by radio and television.

Neurologic Examination. Functions of the cranial nerves were good. The optic fundi appeared normal and visual fields were full by confrontation. Slight asymmetry of face was more noticeable during emotional expression. Right arm was maintained in typical posture of hemiplegic flexion—especially thumb, fingers, and

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**Fig. 5. Case 4.** In anteroposterior view of neck anastomosis is functioning well. Arrow points to site of suture.

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wrist; there was paralysis of hand and fingers but a fair range of active motion at elbow and shoulder. Right leg was moderately spastic but circumduction gait was remarkably efficient and she avoided scuffing; reflexes were hyperactive in right limbs with pyramidal tract signs. Mistakes were noted in testing sense of distal position, recognition of objects and graphesthesia.

**Cortical Function Test** (Feb. 4, 1958). Testing done with this 54-year-old woman indicated adequate comprehension of spoken language and good comprehension and memory for nonlanguage visual materials. Comprehension of reading was somewhat impaired. The most marked impairment was inability to express ideas in speech. There was some dysarthria. Writing was also difficult for her. Her attitude throughout the testing was favorable—i.e., she was most cooperative, tried persistently, and did not become disturbed by her difficulties.

On the aphasia test she was often hesitant and slow about evoking words, and when she did so, there were likely to be mispronunciations. For example when asked to evoke words spontaneously, she depended upon things she could see or touch, and there were some substitutions of sound in the names she evoked. She was able to evoke words to complete sentences fairly well and could do most of the automatic word series but with occasional mispronunciations. However, there were a few omissions in the alphabet and in her recitation of a rhyme there were some mispronunciations. In repetitive speech tests she had some trouble with articulation. Also she omitted part of the longest sentence. She was able to evoke opposites to about half the stimulus words given, both orally and in print. Having the stimulus word supplied in a sentence for association helped her occasionally.

Although she was not able to use words well enough to make simple explanations she could use some words without the connectives (e.g., her reply to the question: "How do you make a sandwich?" was "meat, butter, and bread") and she was able to do some naming. She named the common objects with some hesitation and named most of the colors correctly. Also she named letters and some numbers. For the geometrical forms she gave either a description ("round" for "circle") or an association ("the sky" for a star) or a concrete term ("a box" for the square). Although she readily identified both her own and examiner's hands and fingers as examiner gave the names, patient was not able to supply very many of the names herself. Once she gave an association—for the right middle finger she said "sew with" meaning that that is the finger on which the thimble is worn.

She demonstrated her recognition of simple sounds in a test of auditory agnosia, but she could not name these except for coughing. Tactile recognition could not be tested in the right hand, but in the left hand it was adequate except for two coins, both of which she identified as a button.

Comprehension of spoken language was good for single words (e.g., pointing to objects as examiner named them), and for simple questions, but was not as good for the more difficult material of the absurdities. She followed single and twofold oral commands readily and did one of the threefold commands. However, on the other, she did only two commissions correctly. One of these was awkward and slow to perform with her left hand and that probably contributed to her forgetting the third.

Comprehension of printed language was accurate for single words (e.g., matching objects and colors with their printed names) and for single and twofold printed commands. She even did two of the more complex commands correctly, but was a
little insecure about one of these. On questioning she indicated that she reads only
the newspaper and that she has trouble seeing ordinary print but that she could see
the print used here.

She attempted all writing with her left hand. She wrote her name legibly and
was also able to write the date correctly. There were misspellings in the names of
common objects and colors. She at first said it was "no use" to try propositional
writing, but when urged to attempt a sentence about the weather she said orally,
"air, the sun shining, clouds," but was only able to write "sir clow." From dictation
she wrote single letters correctly except for substituting z for s. She wrote primer
words correctly but could not write sentences from dictation. She copied correctly
from print.

On the nonverbal scale of the Wechsler-Bellevue, she was quick to grasp the
various tasks and, even though she had to use only the nonpreferred left hand, she
was able to obtain an average score. This indicates good retention of mental ability
when language is not involved. Her drawings of designs from memory indicated very
good visual memory. Auditory memory was more limited. She was able to do only
the simplest problems in mental arithmetic, but she could do written arithmetic
quite accurately. Even though orally she once named the wrong process, she carried
out the correct one. Ability to spell words orally was quite limited. Her oral reading
was done in telegraphic style. She seemed to be reading ahead to get the gist of the
material and this may help account for some of the omissions. There were also
some substitutions of words.

Comment. The most impressive and indeed crucial improvement in this
patient following reconstruction of the carotid artery was in the domain of
comprehension and expression of language. The promptness with which bet-
terment succeeded operation and the degree to which it progressed consti-
tute the principal basis for our conclusion that the procedure was beneficial.
The postoperative arteriogram (Fig. 3B) demonstrates that augmented
nutrition of the language areas had been derived largely from collaterals of
anterior cerebral vascular supply. Moreover, the extent of clinical improve-
ment suggests that occlusive disease in the territory of the middle cerebral
artery should not deter surgical effort to restore the main truncal arterial
supply.

DISCUSSION

The fact that several major arteries supplying the brain are affected by
arteriosclerosis, which is exemplified by Case 1, ought not to preclude sur-
gery on a reparable stenosis of the internal carotid, but should rather hasten
such procedure lest vital collateral supply be lost by irreversible progress of
the disease. The capacity for cerebral vascularity to improve in the face of
serious carotid sclerosis is demonstrated by Case 3 and brings to mind the
thought that even a temporarily functioning graft might tide the brain over
such a crucial period while collateral supply is evolving.12,15

Thrombo-endarterectomy alone or resection of a solidly blocked segment
of carotid artery has seldom been proven beneficial in cases of complete
obstruction; but timely replacement by graft or by-pass installation would
seem to be a promising procedure.\textsuperscript{2,10} Anastomosis of a distally patent segment of internal to external carotid artery has been tried with equivocal results.\textsuperscript{10} Successful renewal by autogenous vein graft has been described in cases of occlusion or threatened occlusion.\textsuperscript{8} However, the ultimate functional durability of any type of graft cannot yet be predicted.*

A case similar to our Case 4 has been recorded by Eastcott et al.\textsuperscript{3} who relieved a patient from attacks of hemiplegia for 5 months up to the time of their report by removal of a narrowed portion of internal carotid with restoration by direct anastomosis to the common trunk. This would seem to be the ideal maneuver in such a situation; and it was unfortunate for our patient that she was not referred for treatment before her ischemic attacks culminated in cerebral infarction.

**SUMMARY AND CONCLUSIONS**

1. Three patients with carotid arterial disease are described in whom surgical treatment was not feasible: one who succumbed to fatal coma precipitated by ill-advised bilateral Diodrast angiography in the presence of widespread arteriosclerosis and one who recovered without any treatment; and another who, despite diffuse disease of the internal carotid that rendered arteriorrhaphy impossible, went on to develop satisfactory collateral supply following cervical sympathectomy (although we make no therapeutic claim for the operative procedure).

2. Analysis of a case of successful reconstruction of a thrombosed internal carotid artery, followed for over 4 years with comparable original and late postoperative angiograms, indicates that the neurologic effects of abrupt and poorly compensated occlusion may be ameliorated even by relatively late revascularization of the impoverished cerebral hemisphere.

3. Whenever the diagnosis of occlusion or insufficiency of the internal carotid artery has become established it is recommended that prompt investigation be directed toward the feasibility of resection of the involved segment, with or without thrombectomy or endarterectomy, for possible reconstruction by the method that seems to offer the best chance of success.

**REFERENCES**


*Dr. R. R. Linton states that arterial homografts are known to have functioned well for 3–4 years; autogenous vein grafts should function longer—he cites one such which continues to do well since its installation in 1930. Synthetic substances have also been utilized for carotid reconstruction (cf. papers by several authors, Arch. Surg., Chicago, 1938, 76: 281–909).
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