visualization of the posterior inferior cerebellar artery. The patient, now 11 months post-operative, has shown further neurological improvement since his discharge.

Case 2

Eight years ago a 64-year-old diabetic man began having one or two minute attacks of lightheadedness, vertigo, blurred vision and occasional paresthesia in both sides of the face and the lips. Two years prior to admission, he had had one episode of vision loss in the left eye for 20 to 30 seconds.

The neurological examination on admission showed normal limits. The cerebral angiograms revealed: a) occlusion of the right vertebral artery; b) occlusion of the left vertebral artery and its distal reconstitution through the muscular branches; c) minimal irregularities of the cervical portion of the internal carotid artery on the right; and d) a very irregular and markedly narrowed left internal carotid artery within the cavernous sinus (figs. 2a, 2b, 2c, 2d). He first underwent a left superficial temporal-middle cerebral artery anastomosis. Angiograms two weeks later showed a patent anastomosis (figs. 3a, 3b).

While waiting at home to have an OA-Caudal Loop-PICA anastomosis for symptoms of posterior circulation insufficiency, he showed further deterioration characterized by difficulty in swallowing and articulation and involuntary right face movements. Therefore, after immediate readmission, he underwent a right OA-Left Caudal Loop-PICA anastomosis. A day after surgery, the patient's dysarthria had improved and he no longer had dysphagia or facial movements. A right brachial angiogram ten days post-operatively revealed a patent anastomosis (figs. 4a, 4b, 4c, 4d). On discharge, the patient had no neurological abnormality except for mild dysarthria. Seven months after operation he showed no speech abnormality.

Case 3

A 57-year-old man without hypertension or diabetes suddenly experienced pain in the right occipital region, neck and shoulder. A few seconds later, he noted weakness of the right side of his body, he was unable to move his right upper limb, and his gait was unsteady.

Neurological examination on admission revealed weakness of the right limbs, diminution of pain sensation on the left side of the body except for the face, mild ptosis of the right eyelid and a slightly smaller right pupil indicating bilateral medullary ischemia. The angiograms showed: a) occlusion of the right vertebral artery with partial reconstitution at the first cervical vertebra via occipital collaterals; b) 50% narrowing of the origin of the left vertebral artery and 30% narrowing of its distal portion near the foramen magnum; c) 50% narrowing of the right internal carotid artery at the cervical bifurcation and in its petrous and cavernous portions; d) minor atherosclerotic changes of the cavernous portion of the left internal carotid artery; and e) bilateral hypoplastic posterior communicating arteries.

The patient's neurological deficit gradually improved and he underwent a right OA-Left Caudal Loop-PICA anastomosis seven weeks after onset of his stroke. Post-operative angiograms ten days later revealed a patent anastomosis. The arteries, however, appeared narrowed, possibly due to spasm or edema or both. At discharge, the patient was neurologically intact, and remained so 5 months post-operatively.
FIGURE 2a. (Case 2) An anteroposterior view of the right brachial angiogram to show occlusion of the right vertebral artery at its origin from the subclavian artery.

FIGURE 2b. (Case 2) An anteroposterior view of the left brachial angiogram to show occlusion of the left vertebral artery at its origin. The vertebral artery is partially reconstituted distally by the thyrocervical artery and muscular branches.

FIGURE 2c. (Case 2) A lateral view of the right brachial angiogram to show the cervical carotid and its intracranial branches. Atherosclerotic changes are seen both in the extra and intracranial arteries. None of the branches of the vertebrobasilar system is visualized.

FIGURE 2d. (Case 2) A lateral view of the left carotid angiogram to show a very irregular and markedly narrowed internal carotid artery within the cavernous sinus (arrow).
ANASTOMOSIS FOR BRAIN STEM ISCHEMIA

Case 4

A 63-year-old man with untreated arterial hypertension experienced sudden numbness of the right face, numbness of the left lower limb and difficulty in talking a few hours before admission to the hospital. Shortly after admission, he began having transient episodes of vertebrobasilar insufficiency characterized by vertigo, right face numbness, right sixth nerve paresis, right facial paresis, weakness of the right palate, deviation of the tongue toward the left side, dysarthria, right Horner's syndrome, numbness of the left limbs, left hemiparesis, and semiconsciousness (transient attacks of Wallenberg syndrome).

He was treated with anti-hypertensive and anti-coagulant medications but since his condition was deteriorating and he developed a left hemiparesis, the anti-coagulant was discontinued and cerebral angiography performed. The angiograms showed: a) occlusion of the right vertebral artery at the level of the first cervical vertebra; b) a hypoplastic left vertebral artery terminating in the PICA; c) no basilar artery filling; d) 75% stenosis of the right internal carotid artery at the level of the cavernous sinus; and e) hypoplastic right posterior communicating artery. The left carotid artery and its branches were not studied.

A right OA-Caudal Loop PICA anastomosis was performed 36 days following admission. He recovered from the operation but continued having transient attacks of vertebrobasilar insufficiency for several days and then gradually improved. Angiograms 37 days post-operation showed the anastomosis was patent. Nevertheless, the recipient cerebellar artery and its branches were narrowed. This was thought to be either due to spasm or edema or both. Three months after the operation, the patient was ambulatory and, except for a mild hemiparesis, he had no other neurological abnormality.

Case 5

A 57-year-old normotensive man began having symptoms of vertebrobasilar insufficiency five years prior to hospital admission. These were attacks of dizziness with and without posture change, lightheadedness, blurred vision, double vision, imbalance and occipital headaches. The attacks lasted 5 to 30 minutes and were not usually associated with loss of consciousness. Nevertheless, he reported a few black-out spells, one of which occurred in a car after he turned his head. About four months prior to admission, he experienced episodes of hot, burning and numb feeling of the left face and
FIGURE 4a. (Case 2) A lateral view of the post-operative right brachial angiogram to show the occipital-posterior inferior cerebellar artery anastomosis. The arrow points to the enlarged occipital artery.

FIGURE 4b. (Case 2) A later phase of the angiogram seen in Fig. 4a to show further filling of the cerebellar arteries. The lower arrow points to the occipital artery entering the posterior fossa.

FIGURE 4c. (Case 2) An anteroposterior view of the post-operative right brachial angiogram to show the occipital artery (left arrow) and the site of right occipital artery-left posterior inferior cerebellar artery anastomosis (midline arrow).

FIGURE 4d. (Case 2) A later phase of the angiogram seen in Fig. 4c. The left arrow shows the occipital artery and the midline arrow the site of anastomosis.
body and questionable left upper limb weakness lasting 5–10 minutes. He had also noted occasional difficulty in swallowing. Apart from a moderate hearing impairment, he was neurologically intact.

The cerebral angiograms showed: a) 70% stenosis of the right vertebral artery; b) occlusion of the left vertebral artery; c) 25% stenosis of the right cervical carotid bifurcation; d) slight stenosis of the left cervical internal carotid artery; and e) bilateral hypoplasia of the posterior communicating arteries.

A left OA-Caudal Loop-PICA anastomosis was performed. A post-operative angiogram 10 days later showed a patent anastomosis and improvement of the circulation. On discharge, the patient was symptom free, and remained so 3 months post-operatively.

Discussion

The pioneer experimental work of Jacobson and Suarez and other investigators in the early 1960's convincingly showed that vessels as narrow as one mm can be repaired and kept patent provided that the repair was done under the operating microscope. Subsequently it was demonstrated that such vessels remained patent for years and also that other complicated procedures, such as extracranial-intracranial anastomosis or bypass grafts, could be established in both anterior and posterior circulation with relatively good success. These results encouraged surgeons to apply this technique in some of the stroke patients and anastomose one of the scalp arteries such as the superficial temporal or occipital artery to one of the temporal branches of the middle cerebral artery. The patients who underwent these operations usually suffered from TIAs or small strokes due to insufficiency of flow in the middle cerebral artery, due either to unilateral or bilateral carotid artery occlusion or severe stenosis or occlusion of the middle cerebral artery. It was hoped that the operation would improve the middle cerebral artery circulation thus relieving the TIAs or preventing further strokes.

This paper is concerned with impairment of blood flow in the vertebrobasilar system and a method to improve it. Atherosclerotic disease of the vertebrobasilar system is not as common as in the carotid system. On the other hand, anatomical variations that may worsen an already impaired posterior circulation are seen more frequently in the vertebrobasilar system than in the carotid system. It is rare to find a carotid artery which is congenitally one mm or less (inadequate) in diameter. Nevertheless, one of the vertebral arteries is one mm or less in 10% of the normal population. Also, there is marked discrepancy in size of the vertebral arteries. The left vertebral artery is larger than the right in 51% and a ratio in diameter of two to one is found in 22% of the population. Such discrepancies are rare in the carotid artery. In addition, the posterior communicating arteries are one mm or less in 49% of the population. Both the unilateral vertebral artery hypoplasia and bilateral posterior communicating artery hypoplasia would further impair the posterior circulation when atherosclerotic disease is present and thus the brain stem stroke may develop. It is under these circumstances that an OA-Caudal Loop-PICA anastomosis could be of therapeutic and preventive value. The best candidates seem to be the patients who have brain stem TIAs or have had a brain stem stroke with either complete or partial recovery and who are ambulatory.

The surgical techniques consist of isolation of the occipital artery through a hockey stick scalp and upper neck incision, a small unilateral occipital craniectomy, removal of the posterior arch of the atlas, isolation of the ipsilateral or contralateral caudal loop of the PICA in the region of the cerebellar tonsil and a microsuture end-to-side anastomosis of the occipital artery to the caudal loop of the PICA (fig. 1).

The five patients reported here tolerated the operation well and there was no morbidity or mortality. The post-operative angiograms showed patent anastomosis in all of the patients and improved circulation in three. In two patients the posterior inferior cerebellar artery appeared narrowed. A similar finding had been noted in the superficial temporal-middle cerebral artery branch anastomosis which had proved to be transient.

It is of note that one of the patients (Case 2), who had transient attacks of dysphagia and dysarthria, improved significantly a day after surgery.

This procedure may prove beneficial in a selected group of patients who suffer from brain stem strokes due to insufficiency of the posterior circulation and who cannot be treated with the conventional gross proximal surgical procedures.

References

Possible prevention of brain stem stroke by microvascular anastomosis in the vertebrobasilar system.
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