Comparison of Blood Flow and Patency in Arterial and Vein Grafts to Basilar Artery

BY C. J. WHANG, M.D., J. ROBERT MOZINGO, M.D., AND A. L. RHOTON, JR., M.D.

Abstract:
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Blood flow and patency rates obtained by lingual to basilar artery anastomosis were compared with those obtained by saphenous vein bypass graft from the carotid to the basilar artery in two groups of ten dogs. Flow was measured by an electromagnetic technique while blood pressure and blood gases were monitored. Graft patency also was determined by angiography and histological examination. The arterial and venous grafts carried more than enough blood to maintain a normal flow (9.5 ml per minute) through the basilar system of dogs.

Immediately after anastomosis, average flow through the vein grafts was 15.5 ml per minute (range 10 to 20 ml per minute) and through the arterial anastomosis 15.6 ml per minute (range 10 to 24 ml per minute). Six weeks later, average flow through the vein graft was 11.5 ml per minute and through the arterial graft 13 ml per minute. With induced hypertension, flow increased in the arterial grafts to an average of 26.2 ml per minute and in the vein grafts 24 ml per minute. Hypercarbia increased arterial graft flow to an average of 27.8 ml per minute and vein graft flow to 23.5 ml per minute.

By angiography, graft patency was shown in only 80% of the grafts at one week and in 60% at six weeks postoperatively, even though all grafts were patent by flow and histological determinations. This failure of angiography represents a limitation of the radiographical resolution in millimeter-sized vessels.

Additional Key Words
microvascular surgery  cerebral revascularization  vascular grafts  angiography

The increased accuracy of suture placement provided by microsurgical technique now permits direct surgical anastomosis of extracranial to intracranial arteries and the construction of bypass vein grafts from extracranial to intracranial arteries. Examples of such procedures which have been done in man are superficial temporal artery to middle cerebral artery anastomosis and vein grafts between cervical common carotid artery and supraclinoid internal carotid artery.1-2 Cerebral revascularization procedures have been limited largely to the carotid circulation in man, although revascularization with the basilar system has been tried in animals. Experimental studies have demonstrated that such anastomatic or bypass procedures involving small vessels remain patent for a year or longer and that these anastomoses or bypass grafts provide an adequate blood flow through the new system.3,4

Although microsurgery has made bypass procedures between intracranial and extracranial arteries feasible, few studies have been done to evaluate the physiological and clinical results of these surgical approaches to cerebral revascularization.

The following reports quantitative measurements of blood flow in a basal state and the effects of physiological variables on flow, and compares flow and patency rates obtained by two experimental methods aimed at re-establishing flow in the canine basilar artery.

Methods

Procedures evaluated are lingual artery to basilar artery anastomosis and autogenous saphenous vein graft between common carotid artery and basilar artery. All blood flow measurements were recorded with an electromagnetic blood flow meter (Statham 2202).

GROUP 1: LINGUAL ARTERY-BASILAR ARTERY ANASTOMOSIS

Ten healthy mongrel dogs weighing 17 to 22 kg were anesthetized with sodium pentothal (25 mg per kilogram intravenously) and maintained with an endotracheally delivered methoxyflurane/oxygen mixture. Ventilation was adjusted to maintain normocarbia during the procedure. With the animal in the supine position, using sterile technique, a 6 cm right paramedian incision was made at the midline. The hypoglossal nerve was identified and a 5 to 6 cm segment of subjacent lingual artery was mobilized just distal to its origin from the external carotid artery. Blood flow was measured in the intact lingual artery. All branches of the lingual artery were ligated and divided. The trachea and esophagus were retracted medially. The paired longus colli muscles were separated to expose the clivus (basioccipital bone) from the tympanic bullae superiorly to the condylar notches inferiorly. The
Pharyngeal cavity was not entered with this approach. The remainder of the operative procedure was performed using surgical magnification of X16 and X25.

A 9 x 12 mm clival craniectomy was made with a 2 mm cutting diamond dental drill. A temporary clip was applied at the origin of the lingual artery. The distal end of the lingual artery was sectioned and the lumen was irrigated with heparin-saline solution. The dura was opened and reflected laterally. The basilar artery was thus exposed, freed from overlying arachnoid and permanently ligated with 7-0 silk at the verteobasilar junction. A temporary ligature was applied approximately 5 to 6 mm distally. A 1 to 1.5 mm elliptical arteriotomy was made in the ventral wall of the basilar artery between the ligatures. An end-to-side lingual artery-basilar artery anastomosis requiring 12 to 16 interrupted sutures of 10-0 nylon was done (fig. 1). The distal temporary ligature was removed from the basilar artery and retrograde filling of the graft initially confirmed anastomotic patency. The clip from the proximal lingual artery was removed. Blood flow through the lingual-basilar arterial anastomosis was recorded at normocarbia. The wound was closed in layers. Antibiotics were given for the next seven days.

**GROUP 2: CAROTID-BASILAR SAPHENOUS VEIN BYPASS**

In this group of ten healthy mongrel dogs weighing between 17 and 23 kg, the anesthesia and operative approach to the basilar artery were identical to that of Group 1. A 6 to 7 cm segment of autogenous medial saphenous vein, with a 0.8 to 1.5 mm external diameter, was dissected from the hindlimb. Side branches were ligated with 6-0 silk or surgical clips. A 1.27 mm (external diameter) silastic tube was passed through the lumen of the vein, and the cannulized vein was placed in a heparin-saline solution. The carotid artery was dissected free at the bifurcation. A segment of basilar artery was isolated between two ligatures as in Group 1. A small arteriotomy was made in the basilar artery and the proximal end of the vein was anastomosed to the basilar artery in an end-to-side fashion with 12 to 16 interrupted sutures of 10-0 nylon.

A segment of the previously isolated common carotid artery at the bifurcation was then temporarily occluded between two Heifetz clips (Week) and a small arteriotomy was made. The lumen of the carotid artery was irrigated with heparin-saline solution. The distal end of the vein graft was anastomosed to the carotid artery in an end-to-side fashion with 10 to 14 sutures of 10-0 nylon. The temporary ligature in the basilar artery distal to the anastomosis was removed to initially confirm anastomotic patency. The two temporary clips on the carotid artery were then removed. After completion of the anastomosis, blood flow in the vein graft was measured at normocarbia.

**Follow-Up**

All animals underwent common carotid angiography using Conray-60 to evaluate angiographical evidence of graft patency at one (fig. 2) and six (figs. 3 and 4) weeks postoperatively. After the second angiographical evaluation, the wound was reopened for blood flow measurements. Blood flow response to hypercarbia and hypertension was assessed. Pao2 was altered by changing ventilatory rate and hypertension induced by intravenous Ephedrine (2.5 mg). Blood pressure was monitored and recorded on a polygraph with a catheter placed in the abdominal aorta through the left femoral artery and connected to a Statham pressure transducer (P23Dc). All animals were then killed by a saline-formalin perfusion technique for histological examination of the brain and graft.

**Results**

**NEUROLOGICAL DEFICITS**

Neurological evaluation was assessed preoperatively and postoperatively.
BLOOD FLOW AND PATENCY IN BASILAR ARTERY GRAFTS

and during each postoperative day. No permanent neurological deficits occurred in any animal operated upon. Transient hindlimb paraparesis and tendency to circle to the left were noted in three animals. These transient neurological deficits cleared within three days postoperatively. No CSF fistulas or infections occurred.

BLOOD FLOW IN GROUP 1

At normocarbia, average blood flow in the intact lingual artery prior to anastomosis was 16.5 ml per minute with a range of 11 to 21 ml per minute. Immediately after completion of the lingual-basilar anastomosis, average lingual arterial graft blood flow was 15.6 ml per minute with a range of 10 to 24 ml per minute.

Six weeks postoperatively at normocarbia, average blood flow through the lingual arterial grafts was 13 ml per minute with a range of 10 to 16 ml per minute. With hypercarbia (Paco₂ 62 to 78) average blood flow through the arterial graft was 27.8 ml per minute with a range of 17 to 54 ml per minute; and, with Ephedrine-induced hypertension (180 to 200 mm Hg, from a baseline of 110 to 120 mm Hg), mean systemic arterial pressure was 26.2 ml per minute with a range of 18 to 36 ml per minute (table 1).

BLOOD FLOW IN GROUP 2

At normocarbia, average blood flow in the carotid-basilar vein bypass grafts was 15.5 ml per minute with a range of 10 to 20 ml per minute. Six weeks postoperatively at normocarbia, average blood flow was 11.5 ml per minute with a range of 10 to 13 ml per minute. With hypercarbia (Paco₂ 72 to 76), blood flow averaged 23.5 ml per minute with a range of 18 to 28 ml per minute, and with induced hypertension was 24 ml per minute with a range of 22 to 26 ml per minute (table 1).

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**TABLE 1**

<table>
<thead>
<tr>
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<td>24.0</td>
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<tr>
<td>Hypertension</td>
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**FIGURE 3**

Right carotid angiogram representative of lingual artery (1) to basilar artery (2) grafts patent at six weeks postoperatively.

**FIGURE 4**

Right carotid angiogram representative of saphenous vein (1) bypass grafts between common carotid and basilar (2) arteries patent at six weeks postoperatively.
ANGIOGRAPHICALLY PATENCY

Carotid angiography was done on all animals in Group 1 and seven animals in Group 2 at one week postoperatively. Patency in Group 1 and Group 2 was 90% and 70%, respectively. Carotid angiography was repeated on nine animals in Group 1 and six animals in Group 2 at six weeks postoperatively. Patency in Group 1 and Group 2 was 70% and 50%, respectively, at six weeks.

PATENCY BY ELECTROMAGNETIC FLOW TECHNIQUE

Blood flow in the arterial and vein grafts was measured in all animals in Groups 1 and 2 immediately after completion of the anastomosis. All grafts were found to be patent. At six weeks postoperatively, blood flow was measured in nine of ten animals in Group 1 and six of ten animals in Group 2. All of these grafts were found patent by blood flow measurement.

COMPLICATION

One animal of Group 1 had a neck hematoma due to rupture of a branch of the lingual artery after the first angiogram, and was excluded from further study. Four animals of Group 2 were killed 4 to 10 days postoperatively due to hemorrhage from a branch of the vein graft related to migration of a hemoclip.

Discussion

Using an electromagnetic blood flow meter we have measured blood flow quantitatively through arterial and venous grafts between carotid and basilar arteries in the dog. We have been unable to find in the literature documented blood flow measurements through the lingual artery in dogs. Our measurement of the average blood flow through the intact lingual artery was 16.5 ml per minute. Average normal blood flow of the basilar artery in dogs has been recorded as 9.5 ml per minute.

These arterial and venous grafts carried more than enough blood to maintain a normal flow rate through the basilar system of the dogs. Continuous gradual increase of blood flow through the graft was significant with a range of 17 ml per minute to 54 ml per minute in the lingual-basilar arterial anastomoses, and 18 ml per minute to 28 ml per minute in the carotid-basilar bypass vein grafts with hypercarbia. An increase in mean blood flow through the grafts with hypertension also was significant with a range of 18 to 36 ml per minute in the lingual-basilar anastomoses and 22 to 26 ml per minute in the vein bypass grafts. A greater increase in blood flow with hypercarbia and hypertension was found in the arterial grafts than in the venous grafts.

The grafts in all surviving animals were patent by blood flow measurements and by histological examination at six weeks postoperatively, even though patency could not be determined consistently by angiography. This discrepancy of patency rate between angiography and flow meter technique reflects a limitation of the radiographical resolution in these small arteries. Khodadad found angiographically that the patency rate was greater in arterial grafts compared to vein grafts, both acutely and long-term. Our study agrees with his angiographical findings. At six weeks postoperatively, all grafts were patent by blood flow measurements, whereas angiography disclosed a patency rate of only 70%.

References

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