Revascularization for Complex Skull Base Tumors

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ABSTRACT

We discuss revascularization techniques for complex skull base lesions utilizing high-flow arterial bypass. At present, the radial artery is the donor graft utilized in most circumstances at our institution. The knowledge of revascularization techniques is very important to achieve radical resection in lesions where arterial compromise is documented.

KEYWORDS: Skull base tumors, high-flow cerebral bypass, radial artery graft, microvascular anastomosis

OVERVIEW

Several complex skull base lesions compromise cerebral blood flow. The goal in managing these lesions is to achieve the most extensive resection with minimal new neurological deficits. In some of these situations, a main arterial trunk must be sacrificed. The risk of producing ischemia in the territories that are perfused by these arteries fostered the development of cerebral revascularization techniques in the setting of giant aneurysms.¹⁻⁸ The technique of bypass for managing vascular cerebral pathology is not recent. Yasargil^{8a} described in 1969 a bypass between superficial temporal artery and the middle cerebral artery. Loughheed, in 1971,^{8b} performed the first bypass using a venous graft between the common carotid and the internal

carotid arteries. Spetzler in 1974 described a bypass between the occipital artery and the middle cerebral artery. Story in 1978 made a bypass using saphenous vein between the common carotid artery and a cortical branch of the middle cerebral artery and that same year described a bypass from external carotid artery to the middle cerebral artery using a synthetic tube of polytetrafluoroethylene. In 1979, Miller published the utilization of a bypass between the middle meningeal artery and the middle cerebral artery. In 1980, Spetzler described a bypass between the subclavian artery and the middle cerebral artery using saphenous vein.^{8c} Gelber that same year published the handling of intracavernous or giant aneurysms of internal carotid artery with carotid ligation combined with the use of bypass from the superficial temporary artery.⁷ Fisch, also in 1980,

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described a bypass between the cervical and petrous internal carotid artery.^{8d} In 1990, Spetzler reviewed the bypass between the petrous and supraclinoid internal carotid artery.^{8e} Serbinenko described that same year the association of endovascular occlusion with venous bypass for intracavernous or nonclippable giant aneurysms of the internal carotid artery.⁹ In this last decade, based on the works mentioned, different experiences with many technical variations have been published for the treatment of complex aneurysms and skull base tumors sharing the same principles.¹⁻⁵

Reviewing the historical development of bypass procedures makes it evident that the donor vessel, the recipient artery, and the interposition graft all have variable sizes and characteristics. Which combination of these to use depends on the goals of the procedure and the required flow.³

In 1992, our department began performing high-flow bypass procedures using long saphenous vein grafts to treat complex aneurysms.^{10,11} Some years ago, we started to use radial artery grafts due to their advantages.

SURGICAL TECHNIQUE

We will describe the surgical steps of the radial artery bypass (Figs. 1-10). This technique has been reviewed in detail previously.^{12,13}

Figure 1 Surgical position and cranial and cervical incisions for the accomplishment of bypass.

Figure 2 View of the craniotomy, cervical dissection, and endotracheal tube for passage of the graft.

Cervical Exposure

Exposure of the Bifurcation of the Common Carotid Artery The bifurcation of the common carotid artery is exposed using the technique described by Sundt in 1982.¹⁴ After identifying the angle of the jaw, a key point of reference for location of the carotid bifurcation, an incision ~5 cm long is performed following the anterior edge of the sternocleidomastoid muscle (Fig. 1). By means of careful dissection with strict hemostasis, the dissection progresses toward the depth, with the operator

Figure 3 Graft after harvest with a vascular clamp at its proximal end and a catheter at the distal end, as well as the ties on the collateral branches.

Figure 4 Proximal anastomosis before filling the bypass. The ties can be seen and the hypoglossal nerve protected by a cardiac surgery tape.

Figure 7 General view of the surgical exposure after releasing the clamps and passing the graft through the endotracheal tube.

Figure 5 General view of the exposure after the proximal anastomosis but prior to filling the bypass. The edges of the endotracheal tube can be seen in the cervical and cranial regions.

Figure 8 View of the branch of the middle cerebral artery after dissection, isolation by latex, vessel temporary clipping, and arteriotomy. The middle cerebral artery is fully prepared for the graft.

Figure 6 Proximal anastomosis with the graft full of blood after releasing the clamps but prior to removing the endotracheal tube.

Figure 9 Magnified view of a successful distal anastomosis with satisfactory micro Doppler pattern.

Figure 10 Final view of the bypass before closure of the wounds.

identifying superiorly the digastric muscle and the hypoglossal nerve which cross the carotid artery. The common carotid artery and internal and external carotids are then each exposed for a length of 3 cm, separating them from the internal jugular vein (Fig. 2). The next step is to isolate the common internal and external carotid arteries with rubber dams. The proximal anastomosis will utilize the external carotid artery.

Craniotomy We describe an interfascial pterional approach (Fig. 2). The patient is positioned with the head discretely rotated to the opposite side and with an important extension (deflection) of the head toward the ground. This positioning facilitates the opening of the sylvian cistern because the M1 segment of the middle cerebral artery acquires a perpendicular position in relation to the view of the neurosurgeon. Rigorous hemostasis is critical during this exposure since the patient will be anticoagulated for accomplishment of the anastomosis.

Subcutaneous Tunnel Preparation Using a hemostatic clamp with a blunt end, the tunnel is started below the zygoma, immediately anterior to the most posterior end of the zygomatic process of the temporal bone (Fig. 2). The clamp perforates the insertion of the temporalis muscle in front of the condyle of the jaw and it is then directed laterally following the ascending branch of the

mandible until its angle. At that point, the clamp perforates the insertion of the masseter muscle and the parotid fascia and finishes in the anterosuperior portion of the cervical incision. A number 7 endotracheal tube is introduced in the tunnel in the cephalic direction. Both ends are cut and the tube is left "in situ," thereby constituting a rigid tunnel for the passage of the graft.

Preparation of the Artery The correct preparation of the arterial graft is of great importance since lack of attention to these critical details is an important cause of failure of the procedure. Graft preparation is performed by a vascular surgeon, who evaluates the forearm to be selected; the Allen's test is done to assess the collateral flow of the hand. The harvest of the radial artery is done at the same time as the opening of the sylvian fissure (see section below, Intracranial Exposure). See Figure 3.

Intracranial Exposure The procedure continues with the dissection of the middle cerebral artery in the sylvian fissure. Simultaneously, the radial artery graft is harvested (see above). The arachnoid fibers are carefully opened and the sylvian fissure is widely dissected, exposing the M1 segment of the middle cerebral artery as well as the bifurcation and proximal portion of M2 segment. The site for the anastomosis is selected from one of the M2 trunks. Generally, the superior branch is easier to expose, and in most cases, is significantly larger than the inferior branch. After isolating the M2 branch in suitable form, the recipient vessel is left on a small rubber dam for the distal anastomosis.

Proximal Anastomosis Anastomosis is made end-to-side between the external carotid artery and the graft. The graft is prepared by removing the adventitia with care; the end is cut in "fish-mouth" form to increase the area of anastomosis. All the branches of the external carotid artery are temporarily suture ligated and the flow is interrupted with the use of clamps or aneurysm clips. An arteriotomy is made in the axis of the artery to match the length of the edge of the graft already prepared. The

anastomosis, with nylon suture monofilament or Prolene 6-0 or 7-0, is then performed with continuous suturing. It is very important to ensure adequate blood flow through the graft after the restoration of circulation to the external carotid artery. If the anastomosis obtained is not satisfactory, then it must be reevaluated. See Figures 4 to 6.

Introduction of the Graft into the Skull through the Tunnel After releasing all ties of the external carotid artery, the graft full of blood is introduced through the endotracheal tube (tunnel). This maneuver aims to reduce all the possible kinking of the graft. After the artery has passed, the polyethylene tube is withdrawn. See Figures 5 to 7.

Distal Anastomosis The external carotid artery is then clamped at the level of the anastomosis and the graft is flushed with heparinized solution to minimize thrombosis. The graft is measured in situ after removing the blood, since a measurement with the graft full of blood could be an insufficient estimate of the total length or an uncomfortable length for the distal anastomosis. As soon as the distal extremity of the graft is prepared in "fish-mouth" fashion and the recipient segment of the middle cerebral artery or posterior cerebral artery is isolated between two microvascular clamps, an arteriotomy of ~8 to 10 mm is made along the artery main axis. The distal anastomosis is performed with the same technique as that of the proximal level using 9-0 or 10-0 nylon or Prolene continuous sutures. Before closing the last knot, the flow is reestablished to avoid arterial embolism. Then, the external carotid is clamped and the last knot is closed. Clamps are removed in the following sequence: distal portion of the middle cerebral artery, proximal portion of the middle cerebral artery, distal segment of external carotid artery, and finally proximal segment of the external carotid artery. Once the flow is reestablished, bleeding points are identified; with relative frequency one or two extra stitches are necessary. This is frequent in cases where a great disproportion exists between the thickness of the graft and the recipient artery, but this is more frequent when a

venous graft is used. The perfusion of the graft can be determined by the palpation of the pulse of the graft that must be similar to the carotid. An intraoperative micro Doppler can also be used, with the advantage that it also indicates the speed of the flow through the graft. See Figures 8 to 10.

Closure It is extremely important at this stage to be certain that the subcutaneous tunnel allows a free circulation of the blood through the graft, avoiding any compression or folds that could predispose to occlusion of the bypass. Once the temporalis muscle covers the graft, the risk of injury of the graft at the entry point in the skull is low. It is important to repeat that hemostasis must be obsessively checked to avoid postsurgical hematomas.

DISCUSSION

Cerebral revascularization techniques are an important tool in the armamentarium of the modern cerebrovascular and skull base surgeon. The massive utilization of modern imaging techniques in the study of headache and other banal neurological diseases has produced a more frequent detection of silent cerebral pathology. Some cases are asymptomatic or oligosymptomatic complex or giant aneurysms. Standard microsurgical reconstruction of the parent vessel is not always feasible, and the collateral flow is not adequate to trap the vessel without ischemic morbidity. On the other hand, many cases are treated by endovascular techniques, and in most cases the only treatment offered includes the endovascular sacrifice of the parent vessel.¹⁵ This is not a minor issue since the different invasive and noninvasive tests do not reliably predict the competence of the collateral flow after the exclusion of a carotid artery. For example, the negative balloon occlusion test has up to 20% of delayed ischemic events.¹⁶⁻¹⁸ In young people, the increased risk of de novo aneurysm formation in the contralateral carotid artery should also be considered. To date, only microsurgery by means of a

high-flow bypass can restore the normal brain flow and prevent the aforementioned complications.

Other important pathologies include skull base tumors. The most frequent lesions in the skull base are meningiomas, and in this setting, cavernous sinus meningiomas. Currently, there is some consensus to treat these lesions conservatively when cranial nerve function is intact by resecting the lateral compartment of the lesion and subsequently following the remnant radiographically or treating it with radiosurgery.^{19,20} However, in many cases, these lesions have an aggressive behavior despite conservative surgical resection and radiotherapy. Often, there is severe encasement of the carotid artery and sacrifice of the vessel is necessary for a radical resection of the lesion. In the experience of Sekhar and Patel,¹⁸ permanent occlusion of the internal carotid artery during skull base surgery, in patients who underwent endovascular occlusion of the internal carotid artery followed by surgical excision of the carotid artery and tumor removal, had the highest morbidity rates. Sekhar and colleagues have one of the largest published experiences in the aggressive management of these lesions, with good outcomes.²¹ Thus, for at least a subset of patients with benign tumors, high-flow revascularization techniques have a defined role in the neurosurgical treatment algorithm.^{20,21} Currently, even in cases of skull base metastatic carcinomas, some authors have demonstrated the improvement of patients' outcomes with aggressive removal of the lesion. They propose, in selected groups of patients, "en bloc" resection in the case of carotid artery involvement and high-flow bypass to avoid ischemic complications.²⁰⁻²³

The rationale for using a radial artery graft is the better luminal diameter match between the graft and the recipient artery (M2 or PCA). Another benefit of the arterial graft is the absence of valves and varices which can predispose the graft to occlusion with thrombus during manipulation.²⁴ Nevertheless, the most important drawback is the presence of arterial spasm, with failure of the bypass. This can be partially solved with the aid of calcium-channel antagonist and with endovascular angio-

plasty. Another useful maneuver is the pressure distention technique described by Sekhar and associates^{12,13} to minimize spasm during the extraction of the graft.

ILLUSTRATIVE CASE

We present a case of a 26-year-old male with a long-term oculomotor cranial nerves impairment, with a subsequent ophthalmoplegia. See Figures 11 to 15. The biopsy of the lesion revealed a meningioma. A computed tomography scan, magnetic resonance imaging scan, and a digital subtraction angiography were obtained as preoperative studies. The communicating arteries were absent on angiography. An aggressive resection was planned with a simultaneous revascularization procedure to prevent cerebral infarction. A complete resection was achieved. The patient was discharged without new deficits. The control angiography revealed a completely functional bypass.

Figure 11 Contrast-enhanced computed tomography scan of a 26-year-old patient with a large right petroclival meningioma.

Figure 12 Preoperative digital subtraction angiography demonstrating significant tumor involvement of the internal carotid artery.

CONCLUSION

Revascularization procedures in skull base surgery are an important part of the armamentarium of any skull base team. The total resection of the tumor

Figure 14 Postoperative digital subtraction angiography showing the exclusion of the internal carotid artery and the functional bypass.

is forbidden in several circumstances due to the morbidity and mortality associated with ischemic complications. The possibility of a revascularization procedure, such as bypass, must always be considered in the select group of tumor patients with encasement of a major arterial trunk.

Figure 13 Postoperative computed tomography scan after total gross resection of the lesion.

Figure 15 Preoperative digital subtraction angiography showing a normal venous phase in the same patient.

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