Extracranial-to-Intracranial Bypass Using Radial Artery Grafting for Complex Skull Base Tumors: Technical Note

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ABSTRACT

The management of complex skull base tumors that incorporate large intracranial vessels poses challenging questions. Patients who fail initial surgical resection and adjunctive therapies (i.e., radiosurgery) who present with tumor regrowth may be candidates for parent vessel occlusion and total tumor resection in combination with extracranial-to-intracranial (EC-IC) bypass to augment the sacrificed vessel territory. In this technical report, we delineate the surgical technique of performing an EC-IC bypass using a radial artery graft. Our protocol of simultaneous cranial, neck, and forearm dissections by the surgical team to perform this procedure is described in detail.

KEYWORDS: Extracranial-to-intracranial bypass, skull base tumor, radial artery graft, anastomosis, revascularization

The pioneering work of Professor Yasargil et al in the late 1960s, including the first extracranial-to-intracranial bypass (EC-IC), led to the inception of new surgical concepts for modulating cerebral blood flow.[1] Lougheed and associates in 1971 described the use of venous graft in performing EC-IC bypass.[2] Over the past 20 years, multiple authors including Sundt, Spetzler, and Sekhar and their colleagues made significant contributions in the evolving field of cerebral revascularization.[3–5] In this article we describe the technical steps of using the radial artery grafting in the management of complex skull base tumors.

INDICATIONS

The management of complex skull base tumors that incorporate large intracranial vessels poses challenging questions. Our initial approach is to resect the tumor (i.e., meningioma) while preserving the

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Figure 1 Operative photograph shows simultaneous planning for the craniotomy, cervical incision, and radial artery harvest.

incorporated vessels. However, patients who, subsequent to surgical resection and adjunctive therapies (i.e., radiosurgery), present with tumor regrowth may be candidates if they have failed other treatments for parent vessel occlusion and total tumor resection in combination with EC-IC bypass to augment the sacrificed vessel territory. We advocate the use of temporary balloon occlusion testing combined with single photon emission CT (SPECT) nuclear scan. In those patients who fail the clinical or the physiological portion of the test, and who fulfill the above criteria, we consider EC-IC bypass preceding the tumor resection. We describe below the technique for tumors incorporating the cavernous-supraclinoidal internal carotid artery and bypass technique using a radial artery graft. We advocate simultaneous cranial, neck, and forearm dissections by the surgical team which allows significantly increased efficiency in performing the procedure (Fig. 1).

CRANIOTOMY

A skull base approach, usually a cranio-orbital or a cranio-orbital-zygomatic access, is usually needed. We prefer a single-piece craniotomy which entails an osteotomy of the orbital roof and lateral margins. A high-speed drill is used to thin the zygomatic arch posteriorly which allows the radial artery to lie without kinking at the zygomatic area.

EXPOSURE OF THE CAROTID ARTERY IN THE NECK

A standard incision anterior to the sternocleidomastoid muscle to expose the common external and internal carotid arteries (CCA, ECA, and ICA) is used. Vessel loops are applied around the CCA, ECA, and the ICA. We recommend the use of the ECA as the site for the proximal anastomosis.

RADIAL ARTERY HARVEST

We work with our plastic surgery team to harvest the radial artery. The critical aspect of radial artery harvest is the length of the graft, which can be limiting. It is crucial that before the actual graft is removed communication between the neurosurgical and the plastic surgery teams is undertaken regarding the expected length needed so that if further proximal or distal dissection in the forearm is needed to increase the length of the graft, that can be done prior to actual clamping of the vessel. I prefer to personally mark the superficial wall of the radial artery with a marking pen prior to removal of the graft. This step is crucial to avoid rotation during the tunneling (Fig. 2). Once the graft is harvested, it is placed in a heparinized saline solution.

TUNNELING THE GRAFT

The graft is tunneled using a pediatric chest tube. The marked surface of the graft is kept most superficial.

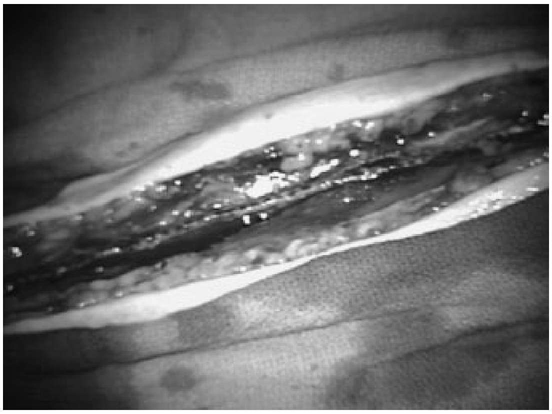


Figure 2 Operative photograph shows exposure of the radial artery with superficial marking.

INTRACRANIAL ANASTOMOSIS

We also start the patient on aspirin (81 mg) daily for 3 days prior to surgery. Intraoperative continuous electroencephalography (EEG) and somatosensory evoked potential (SSEP) are monitored. The site of the anastomosis is determined based on several factors: the intended revascularization territory, the size of donor and recipient vessels, the length of the graft, the location of the tumor, and the extension of the tumor within the sylvian fissure. Mild hypothermia is utilized. EEG burst suppression using pentobarbital is maintained during the temporary clipping period. A color background is placed behind the recipient vessel. Temporary clips are applied (Fig. 3). An arteriotomy is made using an arachnoid knife. The arteriotomy is extended using a microscissor to the width of the donor vessel lumen. The lumen of the donor vessel is expanded by "fish-mouthing" the opening. We used 9–0 nylon for M2 and M3 vessels and 8–0 nylon for the supraclinoidal ICA. We prefer a running suture technique and performing the "back" wall (i.e., the more difficult anastomosis) first followed by the front wall (Fig. 4). When the anastomosis is completed, retrograde flow is confirmed in the graft followed by positioning of a temporary clip on the graft just distal to the anastomosis.

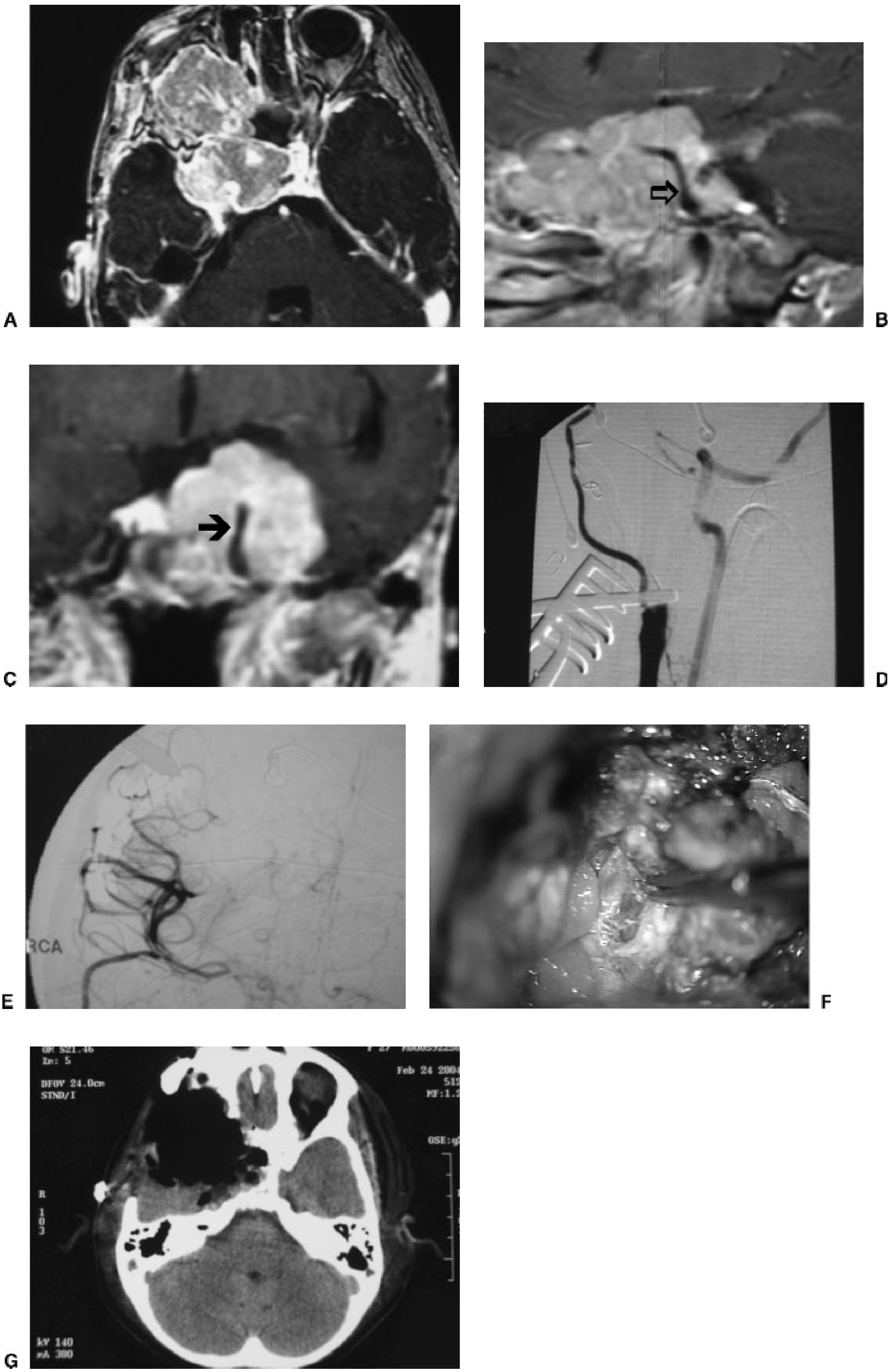
Figure 3 Trans-sylvian preparation for anastomosis. M3 recipient branch with temporary clips. Radial artery donor graft are shown.

Figure 4 Completed anastomosis is shown.

CERVICAL CAROTID ANASTOMOSIS

The graft length is cut to oppose an area of the ECA where the proximal anastomosis is planned. Yasargil

Figure 5 Anastomosis of the radial graft to the ECA in the neck is shown. Temporary clips on ECA are shown. ECA, external carotid artery.



A
B
C
D
RCA
E
F
DFOV 24.0cm
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kV 140
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long temporary clips can be used for the ECA anastomosis. Similar technique of "back" wall and "front" wall can be utilized as described above for the intracranial anastomosis. For this part, 7–0 prolene can be used (Fig. 5).

GRAFT INSPECTION

Pulsatility of the graft is not enough to confirm graft potency. Micro-doppler (Mizuho America, Inc., Beverly, MA, USA) can be used. Intraoperative angiography, in our opinion, is critical before parent vessel occlusion is performed. Flow probe technology (Transonic Systems, Inc., Ithaca, NY, USA) has allowed us to estimate the amount of flow (cc/min) within the graft.

PARENT VESSEL OCCLUSION

Once the above steps, including intraoperative angiography, have documented flow in the graft, we then advocate parent vessel occlusion during the same surgical procedure, rather than delayed (staged) occlusion. In our opinion, the risk of graft occlusion would be high if competitive flow in the parent vessel were allowed to continue. We occlude the ICA at the level of the bifurcation in the cervical area and just distal to the tumor in the supraclinoid portion. The distal occlusion must be performed proximal to the anterior choroidal and dominant posterior communicating arteries. For the middle cerebral artery (MCA), we only occlude the segment of the MCA (M2 or M3) which is incorporated in the tumor and that was bypassed. Clearly, M1 incorporation by tumor cannot be treated in this manner due to lenticulostriate perforators.

TUMOR RESECTION

This can be performed immediately following the EC-IC bypass and occlusion of the parent vessel or in a staged fashion the next day. For complex and extensive tumors, we find the second-day planned resection to be a more efficient strategy.

POSTOPERATIVE MANAGEMENT

In the immediate postoperative period, we continue the patient on daily 81 mg of aspirin. Starting at postoperative day 7, we increase the dose to 325 mg per day and would continue this indefinitely.

ILLUSTRATIVE CASES

Fig. 6 (A through G) and Fig. 7 (A through D) are examples of two patients who underwent EC-IC bypass for recurrent atypical meningiomas that were incorporating the ICA (patient in Fig. 6) and an M2 division (patient in Fig. 7).

Figure 6 (A) A 27-year-old female with two previous resections and orbital exoneration and previous radiation therapy and chemotherapy for recurrent malignant meningioma. The patient presented with tumor regrowth and symptoms. Axial T1 MRI shows tumor within the cavernous sinus and orbital regions. (B) Sagittal T1 MRI with gadolinium showing the petrous and the cavernous ICA within the tumor. (C) Coronal T1 MRI with gadolinium showing ICA within the tumor. This finding prevented the previous surgeons from achieving complete resection. The patient failed BTO in our evaluation. (D) The patient underwent radial artery EC-IC bypass. Intraoperative angiogram above showing the radial artery graft. ICA has been occluded with a clip. (E) Angiogram showing flow into the MCA territory via the graft. (F) Intraoperative photograph showing tumor adherence to the wall of the cavernous ICA. Tumor resection was staged for the second day following EC-IC bypass and deliberate occlusion of the ICA proximal and distal to the tumor. (G) Postoperative axial CT scan showing tumor resection bed. MRI, magnetic resonance imaging; ICA, internal carotid artery; BTO, balloon occlusion testing; EC-IC, external carotid-internal carotid; MCA, middle carotid artery; CT, computed tomography.

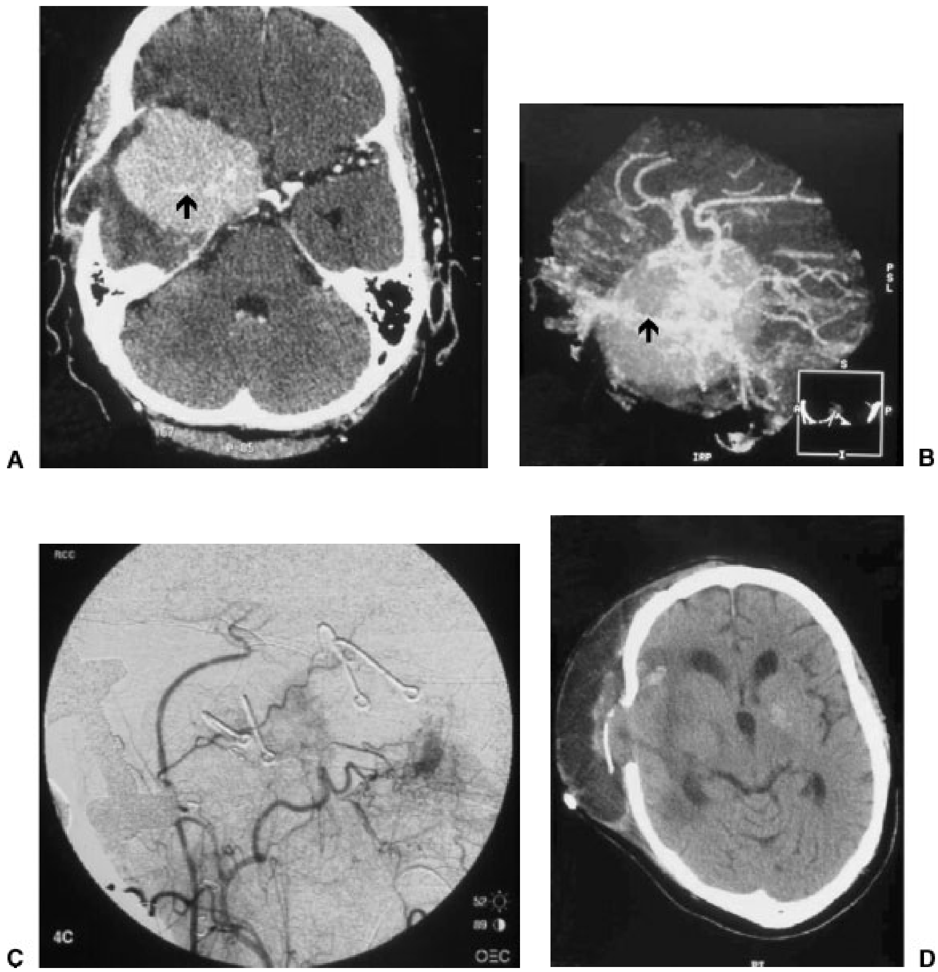

Figure 7 (A) A 45-year-old male with two previous resections of an atypical meningioma. The patient has received radiosurgery and chemotherapy. Previous resections were limited due to incorporation within the tumor of the superior division M2 (arrow). (B) Three-dimensional CT reconstruction of the blood vessels' relationship to the tumor. M2 division within the tumor shown (arrow). (C) Intraoperative angiogram shows radial artery EC-IC bypass to the distal portion of the involved M2 division. (D) Postoperative CT scan showing tumor resection within the sylvian fissure. CT, computed tomography; EC-IC, external carotid-internal carotid.

OUTCOME

From July 2000 to May 2005, we have performed at Saint Louis University Hospital five EC-IC bypass procedures using radial artery grafts for the treatment of complex recurrent skull base tumors. All five cases at the time of the bypass procedure had atypical meningiomas. The age range was 25 to 45 years with three male and two female patients. All were previously operated and previously radiated tumors and three out of the five had received adjunctive chemotherapy. Four patients had the cavernous ICA incorporation while one had an M2 division incorporated within the tumor. All had documented new growth despite the measures above. There was no EC-IC bypass-related ischemic event in this small group. One patient died 15 months later from tumor progression. The other four continue to be followed. In retrospect, in our opinion, we were able to perform more aggressive tumor resections in this group than would have been possible without the bypass procedure. However, despite aggressive treatment, cure in atypical meningiomas may not be achieved as documented in one of our patients who died at 15 months following the surgical treatment from continued tumor growth and invasion despite our maximal surgical intervention.

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