Cerebral Revascularization for Difficult Skull Base Tumors: A Contemporary Series of 18 Patients

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Key words
- Graft patency
- High flow bypass
- Skull base tumor

Abbreviations and Acronyms
CT: Computed tomography
GTR: Gross total resection
ICA: Internal carotid artery
MCA: Middle cerebral artery
MRI: Magnetic resonance imaging
mRS: Modified Rankin score
SVG: Saphenous vein graft
TIA: Transient ischemic attack

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OBJECTIVE: **Cerebral revascularization has been used in treating difficult skull base tumors when the preservation of the involved native arteries is deemed challenging, and the patients are at risk of developing vascular complications. We aimed to evaluate a recent series of patients who needed high flow cerebral bypasses as part of the surgical treatment strategies for their difficult skull base tumors; to assess current indications and the results of such treatments.**

METHODS: **A prospectively collected consecutive series of patients were studied. These patients received high flow cerebral bypasses in conjunction with surgical resections of the skull base tumors during a 9-year period.**

RESULTS: **A total of 20 high flow bypasses on 18 patients were performed, as part of the treatment plan for skull base tumors. The mean age was 41 years. Four patients had preoperative transient ischemic attack symptoms, three of which had progressed to acute strokes preoperatively. Thirteen patients (72.2%) had gross total resection. There were no acute perioperative stroke or graft occlusions. The mean follow-up was 47 months (2–104 months). One patient developed asymptomatic graft stenosis 8 months after surgery, which was surgically corrected. Fifteen patients had achieved good clinical outcomes (modified Rankin scale, ≤2) at the latest follow-up; one patient died postoperatively and two died of their disease.**

CONCLUSIONS: **High flow bypass for cerebral revascularization is a good surgical option for treating certain difficult skull base tumors. High rate of graft patency and low risk of perioperative stroke can be achieved in experienced hands with concurrent high rate of gross total resection of the tumor and good clinical outcome of the patients.**

INTRODUCTION

Cerebral revascularization (bypass) for flow augmentation from extracranial-to-intracranial vasculature was first performed by Yaşargil (16) in 1967 using the superficial temporal artery and the middle cerebral artery as donor and recipient, respectively. However, the enthusiasm for this approach waned after a large prospective multicenter trial did not show advantage over medical treatment for reducing stroke or stroke-related death (13, 14). Criticisms of the study exist and on-going prospective, randomized multicenter studies are evaluating the effect of this surgical approach on patients with chronic significant ischemia and poor vascular reserve (12, 15).

Aside from flow augmentation for ischemic patients, cerebral revascularization has been established as an integral component of the surgical approaches to complex aneurysms as well as difficult skull base tumors (2, 5, 7, 11, 12). Indications for bypass for skull base tumors include: invasion of major arteries rendering sacrifice of the vessel necessary to achieve complete tumor resection, particularly for malignant or aggressive tumors; preoperative poor vascular reserve, symptoms of preoperative ischemia and high risk of intraoperative vessel injury due to tumor encasement or invasion and previous surgical and radiation treatments; acute vascular occlusion or injury intraoperatively, and preoperative evidence of intolerance of sacrifice of a major artery (5, 12).

Although various preoperative tests have been used to evaluate a patient's tolerance of a major arterial sacrifice, there is no single test modality that consistently predicts clinical outcomes after a major artery occlusion. Existing literature has shown immediate test-related as well as delayed or unexpected complications from surgeries involving a major artery sacrifice, even after a patient has passed a tolerance test (3, 4, 6, 8). Because of concerns for vascular complications after major arterial sacrifice for skull base tumor surgeries, we perform cerebral revascularization before surgical resection of skull base tumors when we consider a vascular injury is highly likely (7, 12).

The indication for bypass for the treatment of skull base tumors that encase major arteries have changed during the past 15 years, primarily due to the shift in management philosophy by using radiation therapy to treat small residual benign tumors that are densely adherent to or encasing the arteries (12). Therefore, we consider it informative to review our recent

Table 1. Clinical Characteristics

Age (mean, range [year])	41, 6—69
Sex (M/F)	8/10 (0.8:1)
Comorbidities	
Hypertension	6/18 (33.3%)
Hypercholesterolemia	2/18 (11.1%)
Smoking	2/18 (11.1%)
Diabetes	2/18 (11.1%)
Prior treatment	14/18 (77.8%)
Surgery	12/18 (66.7%)
Radiation	8/18 (44.4%)
Chemotherapy	2/18 (11.1%)
Duration of follow-up (mean, range [months]) (2 patients did not have long-term follow-up due to recent surgery and perioperative death, respectively)	
Clinical	47, 2—104
Radiographic	39, 2—96
Preoperative ischemic symptoms	
TIA	4/18 (22.2%)
Stroke	3/18 (16.7%)

F, female; M, male; TIA, transient ischemic attack.

series of patients needing high flow bypass (vessel flow >100 mL/min) for treating difficult skull base tumors, with the goal to evaluate the clinical circumstances that render bypass an integral component of the surgical approach. We analyze surgical results based on the different indications for bypass procedures. We compare our result to our previous experience as well as other contemporary series in the literature.

METHODS

Clinical Data Collection

An institutional review board-approved prospectively collected cerebrovascular registry was queried, and patients who underwent cerebral revascularization high flow bypass surgeries as part of the surgical treatment for skull base tumors, performed by the senior author (L.N.S.) from November 2003 to July 2012, were identified. Clinical data including age, gender, preoperative symptoms, preoperative and postoperative radiographic studies, tumor characteristics and pathology, previous treatments, surgical approach, bypass graft and donor, graft patency, extent of resection, surgical complications, vital status, and duration of follow-up were collected from patients' medical records when available. Preoperative and postoperative modified Rankin scale (mRS) was assigned based on patient's clinical status.

Evaluation of Patients

Preoperative magnetic resonance imaging (MRI) scans and cerebral angiograms were reviewed. Encasement, compression, or occlusion of major arteries by the tumor was evaluated. In addition, collateral blood flow and the pattern of the entire vasculature were studied. Patient's previous treatment history, tumor pathology if it was recurrent lesion, and preoperative symptoms of ischemia and hemodynamic insufficiency were considered.

Indications for Bypass

We elected to perform bypass surgeries on patients with skull base tumors based on the following four criteria:

1. Benign tumor encasing a major artery and the tumor cannot be dissected free for complete resection without damaging the artery. We typically pursue this approach with recurrent and previously radiated benign tumors (alternatively, a small residual can be left behind and patient can receive additional radiation if applicable);
2. Malignant tumor involving a major artery: complete resection is the goal set preoperatively based on the principles of oncologic treatment;
3. A major artery already occluded by the tumor and the patient is having ischemic symptoms, or there is preoperative evidence of significantly reduced cerebrovascular reserve;
4. Unplanned intraoperative injury to a major artery, and the artery cannot be repaired by direct suturing.

Because of the potential pitfalls of preoperative occlusion tests and delayed complications associated with elective carotid occlusion (3, 4, 6, 8), further management of a patient's tumor has become more risky if the patient only has one functioning internal carotid artery based on our experiences; L.N. Sekhar had adopted a "universal" bypass approach whenever there was a potential need for major artery sacrifice or a concern for vascular insufficiency postoperatively; instead of a "selective" approach only after a patient failed a preoperative occlusion test of a major artery.

Surgical Technique

Graft selection, extraction, surgical anastomosis techniques, intraoperative anesthetic regimen have all been described in details in our previous publications (7, 10-12). Various established skull base approaches were used for tumor resection depending on the tumor location, size, and the patient's most significant preoperative symptoms (9).

Immediate postoperative graft monitoring, radiographic imaging (computed tomography [CT] angiogram immediately after the operation if no intraoperative angiogram and then angiogram within 12 hours postoperatively; MRI to evaluate extent of resection) were carried out as described previously (12). All patients were maintained on aspirin for at least 1 year postoperatively. Follow-up imaging studies were carried out periodically at the time of subsequent follow-ups to monitor the status of the tumor as well as the patency of the graft.