Perioperative Approach in the Surgical Management of Carotid Body Tumors

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Background: Now, surgical resection still remains the gold standard for the treatment of carotid body tumors (CBTs). Although advances in surgical techniques and the introduction of sensitive imaging modalities have significantly reduced mortality, the incidence of perioperative neurovascular complications, especially cranial nerve deficit and intraoperative hemorrhage, remains considerable. To solve these problems, preoperative embolization has been suggested; the reported benefits of preoperative embolization performed <48 hours before surgery include a reduction in tumor size, decreased blood loss, and improved visualization, theoretically reducing neurologic morbidity by lessening the risk of stroke and damage to cranial nerves. The purpose of this study was to review our experience in the surgical management of CBTs with preoperative embolization and evaluate the outcomes and complications according to the Shamblin classification.

Methods: Thirty-two patients who had been diagnosed with and surgically treated for CBTs were enrolled from January 2005 till July 2010. All perioperative scans were evaluated by computed tomography angiography. We reviewed patient demographics, radiographic findings, and surgical outcomes collected from medical records.

Results: Thirty-two patients underwent surgical excision without mortality. Angiography with selective preoperative tumor embolization was performed on 21 patients. The median blood loss, operation time, and hospital stay for these patients were significantly reduced compared with those without embolization. There were no recurrences or delayed complications at the median follow-up of 20 months.

Conclusion: Embolization as an adjunctive tool was beneficial for CBT surgery outcomes. Embolization should only be undertaken in those vessels that can be subselectively catheterized and determined not to allow free reflux of contrast medium into the internal carotid artery. Tumor embolization was performed on patients with Cook detachable coils, which are highly effective for supply artery closure if properly selected, and complications can be minimized by proper selection and positioning of the coil. Operation within 48 hours after embolization is recommended to minimize revascularization edema or a local inflammatory response.

INTRODUCTION

The carotid body is physiologically important in controlling blood pressure, heart rate, and respiration, and is acutely stimulated by hypoxia, hypercapnia, and acidosis. First described in 1743 by von Haller, a carotid body tumor (CBT) occurs in the chain of neuroectodermal tissue, which extends from the aortopulmonary window to the base of the skull. 1, 2 Although they are frequently

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Ann Vasc Surg 2012; 26: 775–782
DOI: 10.1016/j.avsg.2012.01.020
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benign, local aggressive behavior of these tumors often produces symptoms and may be life threatening.\textsuperscript{3,4}

Surgery has been the preferred treatment for CBTs that are deemed resectable; however, the optimal surgical management of these tumors is still controversial.\textsuperscript{5} Although advances in surgical techniques and the introduction of sensitive imaging modalities have significantly reduced mortality, the incidence of perioperative neurovascular complications, especially cranial nerve deficit and intraoperative hemorrhage, remains considerable. Significant morbidity may accompany surgical excision owing to intraoperative bleeding, cranial nerve injuries, and stroke.\textsuperscript{6,7} Preoperative embolization has been shown to reduce potential intraoperative blood loss and provide the surgeon with much comfort and safety in excising the tumor, thus reducing the operation time and morbidity.\textsuperscript{8–10} However, controversy concerning the role of preoperative superselective angiography with embolization of CBTs has persisted since the completion of the first preoperative embolization procedure in 1980 by Schick et al.\textsuperscript{11} Some literature supports embolization of larger tumors only, whereas some authors are using embolization for midsize tumors as well. However, other authors have asserted that although blood loss may be reduced after preoperative embolization, transfusion requirements are not affected, and the embolization procedure adds a significant risk for stroke.\textsuperscript{12}

Now, surgical resection still remains the gold standard for CBT treatment; however, the impact of adjunctive procedures such as carotid reconstruction and tumor embolization has not been well characterized in large series. The purpose of this study was to review our experience in the surgical management of CBTs with preoperative embolization and evaluate the outcomes and complications according to the Shamblin classification.

**PATIENT POPULATION AND METHODS**

The medical records of all patients admitted with CBTs to The Second Affiliated Hospital of Harbin Medical University in the period from January 2005 till July 2010 were reviewed. Preoperative, intraoperative, and postoperative data were analyzed for each patient. The study was carried out according to the principles of the Declaration of Helsinki, and patients gave written informed consent. In all cases, radiography, including computed tomography (CT), ultrasonography, and/or magnetic resonance imaging (MRI), was used to delineate the CBT, but the diagnosis was confirmed with standard digital subtraction carotid angiography (DSA).

DSA was carried out in those cases scheduled for endovascular preoperative embolization performed to reduce tumor vascularity and size. During DSA, contemporary balloon internal carotid blockade (Mata test) was performed to determine the patient’s tolerance to carotid cross-clamping. The sensitivity of this test was improved by the use of transcranial Doppler monitoring. Patients were informed about the transarterial embolization; informed consent was obtained before the procedures; and the patients were treated under local anesthesia of the groin. Surgery was performed within 48 hours of embolization to avoid recruitment of collateral blood supply and to minimize inflammatory reaction in patients who were given preoperative embolization.

A detailed diagnostic angiography was performed via the femoral artery before the embolization. Angiograms were performed in multiple projections to obtain the best views for controlling potential embolic agent reflux during the injections. In all cases, angiography showed a hypervascular mass with early and intense tumor blush, arterial feeders, and early-draining veins. It was noted that preoperative embolization may not always be necessary in the management of these tumors, especially with small tumors (<4 cm). Embolization should only be undertaken in those vessels that can be subselectively catheterized and determined not to allow free reflux of contrast medium into the internal carotid artery (ICA). Embolization should be performed slowly, especially as flow to the tumor becomes reduced.

Using a right transfemoral artery approach, we placed a 5-F catheter (Cobra 2; Cook, Bloomington, IN) through a 5-F introducer sheath (Cordis, Miami, FL) and positioned the catheter in the common carotid artery (CCA) or external carotid artery (ECA). CBT arteriograms were obtained with the patient in various positions. Computer-assisted measurements of the main branch artery were used. High-resolution digital fluoroscopy with biplanar road-mapping capability and subtraction techniques was used to enable image-guided safe catheterization of the damaged artery by a variable-stiffness 0.018-inch Tracker or Fast Tracker microcatheter (Target Therapeutics, Fremont, CA). A 3,000-U bolus of heparin was administered to the patient to prevent thrombosis during temporary arterial occlusion. Repeated arteriography was performed during and at completion of embolization,
Confirming patency of the major branch artery and occlusion of CBT.

For occlusion of the branch artery, different embolic materials were available: polyvinyl alcohol particles in the range of 150 to 500 μm (Contour; Interventional Therapeutics Corporation, San Francisco, CA), fibered platinum coils (Target Therapeutics), and electrolytically detachable coils (Guglielmi detachable coils, Target Therapeutics), used alone or in a mixture. In 20 patients, a combination of different embolic materials was used. There were no complications during embolization.

Surgical excision was performed via a standard cervical approach. The surgical procedures are briefly described as follows: CBTs were exposed through a transverse cervical incision. All neurovascular structures were identified, and periaortic dissections of the carotid artery were performed. Proximal and distal control of the ICA, ECA, and CCA was obtained before tumor resection. Any feeding vessels supplying the tumor were ligated early, and the ECA was selectively ligated for complete tumor resection. Surgeons performed carotid artery reconstruction using an autologous saphenous vein when the carotid was resected. The amount of blood loss was determined intraoperatively. All the operated tumors were submitted to histologic examination.

Follow-up of the patients was performed with clinical examinations, and patients were subjected to head and neck CT or MRI when indicated. Neck angio-CT and angio-MRI were used to define tumor feeding vessels, the relationship with the adjacent structures, and the cranial extension in the neck for a better planning of the best surgical approach. Total body angio-CT was not performed to minimize the risks related to the high dose of radiation burden for CT. Follow-up period ranged from 12 months to 4 years, with a mean follow-up of 20 months. Patients were seen in the out patient clinic monthly for the first 3 months and then half annually. Investigation was requested if there was a complaint or a finding suggestive of recurrence. SPSS version 13.0 (SPSS Inc., Chicago, IL) was used for statistical analysis. Differences between the two groups were analyzed by Mann–Whitney U test. Significance was defined as \( P < 0.05 \).

RESULTS

Thirty-two patients were treated in this period. The age of our patients ranged from 28 to 61 years, with a mean age of 47 years. In our patient population, there were 22 male and 10 female patients. Thirteen tumors (41%) were located in the right and 19 (59%) in the left. No patient had a family history of paraganglioma. Thirty patients presented with painless slowly growing neck mass just anterior to the sternomastoid muscle at the level of the hyoid bone, and two patients had a painful mass with skin changes over it. No patient had functioning CBT that presented with palpitations, tachycardia, and hypertension accompanying elevated catecholamine level. No preoperative cranial nerve deficit was observed. There was no evidence of lymph node involvement or distant metastases. The median tumor size of 32 CBTs was 4.3 cm (range: 2.5–6.0 cm). All patients were diagnosed by DSA with contrast, which showed a vascular tumor. In all cases, angiography showed a hypervascular mass with early and intense tumor blush, arterial feeders, and early-draining veins.

All 32 patients underwent surgical excision. From 2005 to 2010, eight patients underwent surgical excision alone (EX), 21 patients underwent surgical excision with preoperative superselective angiography with embolization (EX + EMB) (Fig. 1), and three patients underwent surgical excision with carotid artery reconstruction (EX + REC). Complete excision of the tumor was achieved in all patients. No patient had blood transfusion. Three patients had hypoglossal nerve palsy, which improved in one patient and partially in the other two patients. Perioperative mortality was nil. The pathologic results confirmed the diagnosis of CBT in all cases and showed no evidence of local recurrence or distant metastasis during the time of follow-up.

During surgery, there were 19 patients with medium-sized tumors intimately associated with and compressing carotid vessels (Shamblin II), and 10 patients had tumors involving the carotid vessels (Shamblin III). Three patients had tumors away from both carotid vessels (Shamblin I; Fig. 2). In all Shamblin-II CBTs, a subadventitial tumor excision was performed (Fig. 3). No patient in this group underwent ligation of the carotid artery. In the Shamblin III group, two patients underwent ligation of the ECA because of excessive bleeding, as this decreases the tumor vascularity and local bleeding.

Angiography with primary transarterial embolization was performed in 21 cases with well-defined arterial feeders from the ECA, 24 to 48 hours before surgery (Fig. 1). The ascending pharyngeal artery was a major feeding artery for tumors. Tumor embolization was performed on 21 patients with Cook detachable coils after superselection of feeding arteries. The others were unable to undergo embolization because they had numerous feeding arteries that could reduce the effect of embolization and...
because of the potential high risk of cerebral infarction by embolic particles.

The complications of the surgical treatments of CBT include cerebrovascular complications such as stroke, postsurgical neurological complications such as cranial nerve deficit (the hypoglossal nerve and the vagus nerve appeared to be most vulnerable to injury from the sacrifice or retraction), postoperative hemorrhage or hematoma, cardiac complications, and postoperative respiratory failure. One of the major risks of preoperative embolization is the risk of stroke from preoperative embolization, which has been reported as high as 17% in single-center experiences. The definitive diagnostic procedure for CBT evaluation is carotid angiography, which provides more information about the primary tumor, which may help in preoperative planning. But, in the whole study, no stroke occurred during DSA and embolization procedures. None of the patients who underwent surgical excision with preoperative superselective angiography with embolization (EX + EMB) demonstrated complications after angiography or embolization.

In our study, only hypoglossal nerve injury occurred in three patients. Only one patient suffered from numbness of the face due to the embolization of ECA, and recovered 2 weeks after the surgery. No postoperative hemorrhage or hematoma occurred in EX + EMB. Two postoperative hemorrhages occurred in EX.

Main complications from DSA procedures included stroke, artery injury at access site, renal function, and contrast reaction. Aforementioned Complications did not occur in the study.
Tumor size and Shamblin group were not significantly different between the embolization and nonembolization groups (\(P > 0.05\)). The median intraoperative blood loss was 280 mL (range: 50–850 mL) in the embolization group and 450 mL (range: 100–1,000 mL) in the nonembolization group. The median operation time for EX + EMB and EX groups was 180 and 220 minutes, respectively, and hospitalization was 5 and 8 days, respectively. Compared with the nonembolization group, the median blood loss, operation time, and hospital stay of the embolization group were significantly reduced (\(P < 0.05\)) (Table I).

According to the Shamblin classification, the median tumor size was 3.0 cm (range: 2.5–4.2 cm) in Shamblin I and II and 4.7 cm (range: 3.1–6.0) in Shamblin III (\(P = 0.016\)). The median intraoperative blood loss was 240 mL (range: 50–400 mL) in Shamblin I and II and 580 mL (range: 300–1,000 mL) in Shamblin III (\(P = 0.002\)). Operation time, including ICA reconstruction time, was 150 minutes (range: 130–180 minutes) in Shamblin I and II and 260 minutes (range: 160–320 minutes) in Shamblin III (\(P = 0.028\)). Hospitalization was 8 days in both groups (Table II). The ECA was ligated in two patients during operation.

A portion of the ICA had to be resected in three patients, and they all belonged to Shamblin III. For the three cases with ICA resection, saphenous vein interposition was performed. Complications were significantly more frequent when CBT surgery was combined with carotid artery reconstruction.

**DISCUSSION**

Carotid body is a highly specialized, round, reddish-brown organ, 2 to 6 mm in size, that is located in the semiadventitial tissue of the CCA bifurcation; it is supplied by feeding vessels running from the ascending pharyngeal artery—a branch of ECA—and is innervated through the glosopharyngeal and vagus nerves.\(^{14,15}\) CBTs grow slowly and can remain asymptomatic for many years. The most common presentation of CBT patients is a painless mass in the anterior neck.\(^{16}\) Symptomatic lesions may indicate more extensive tumors or malignant transformation: hoarseness may indicate vagus nerve involvement, Horner syndrome indicates invasion or compression of cervical sympathetic chain, and syncope may be due to carotid sinus or ICA compression, hypoglossal or glosopharyngeal nerves may be involved too.\(^{17}\) CBTs were reported to be malignant in 10%, familial in 10%, and bilateral in 10% of sporadic cases; bilaterality may reach 30% in the familial cases.\(^{18,19}\) Metastatic malignant CBT occurs in 5% of cases, and, usually, metastasis is confined to the neck. Multicentricity of paragangliomas can occur in up to 25% of patients.\(^{20}\) None of our patients had malignant tumors. Also, cases were neither familial nor bilateral.

Although most CBTs are benign and slow growing, surgical excision is the treatment of choice. Some authors have found that radiotherapy is effective in inhibiting further growth of CBTs. However, it is often considered to be an alternative treatment modality for patients who cannot undergo surgery owing to extensive involvement, multiple tumors, and high operative risk.\(^{21}\) During operation, all neurovascular structures should be identified to reduce complications. Proximal and distal control of the carotid arteries with early ligation of feeding arteries is important to achieve complete tumor resection.

It has been previously noted that preoperative embolization may not always be necessary in the management of these tumors, especially with small...
tumors measuring <4 cm. The complications of this technique appear to be acceptably low, but the benefits of preoperative embolization can only be realized by the involvement of an experienced angiographer. Careful angiographic evaluation of blood supply to the tumor is essential to discern individual feeding vessels. Embolization should only be undertaken in those vessels that can be subselectively catheterized and determined not to allow free reflux of contrast medium into the ICA. Embolization should be performed slowly, especially as flow to the tumor becomes reduced. In addition, complete obliteration of all tumor vascularity is not required to be efficacious in reducing size and vascularity. Operation within 48 hours after embolization is recommended to minimize revascularization edema or a local inflammatory response.22,23

There has been controversy concerning the usefulness of preoperative embolization. Some authors prefer routine preoperative embolization because it can lower blood flow and decrease tumor size.11,24 Others have found that selective preoperative embolization can facilitate tumor excision with less blood loss, particularly in larger tumors (Shamblin type II and III),5,6,25,26 whereas some groups disagree on preoperative routine embolization owing to postembolization morbidity, such as the potential risk of stroke by embolic particles.12,25

In our series, angiography with primary transarterial embolization was performed in 21 cases with well-defined arterial feeders from ECA, 24 to 48 hours before surgery. None of the patients demonstrated complications after angiography or embolization. In our study, compared with the nonembolization group, the median blood loss, operation time, and hospital stay of the embolization group were significantly reduced (P < 0.05). These results suggest preoperative embolization can reduce intraoperative blood loss significantly. Hemostasis can easily be achieved during resection of CBTs when the course of the ascending pharyngeal artery is taken into consideration. In our setting, preoperative angiography with embolization showed less nerve injury compared with the nonembolized group.

A reliable preoperative evaluation of tumor details concerning their size, extent, and relationship with adjacent vessels can be obtained by combining the two techniques, and allows us to plan when a multidisciplinary approach involving the fields of vascular surgery, otolaryngology, maxillofacial surgery, and radiology should be used to treat these patients. The early detection and accurate measurements of larger lesions also provide an additional advantage by decreasing the need for preoperative embolization and its attendant risks. An early diagnosis permits an earlier treatment of smaller CBTs, thus minimizing the risk of cranial nerve and vessel injuries. The goals of CBT angiography are to provide a vascular roadmap for surgeons, search for multicentric synchronous tumors, and enable preoperative embolization for prophylactic hemostasis. Additionally, it could evaluate collateral arterial and venous circulation of the brain if an inevitable sacrifice of major vessels were necessary.5

Shamblin III had a high risk of postoperative neurovascular complications. Therefore, early detection and prompt surgical resection of CBTs will decrease surgical morbidity. When CBT surgery requires carotid artery reconstruction, it carries significant morbidity and mortality that may not be appreciated from smaller studies. According to Shamblin

### Table I. Comparison of surgical excision alone (EX) and surgical excision with preoperative superselective angiography with embolization (EX + EMB)

<table>
<thead>
<tr>
<th>Shamblin group Type I: 1; type II: 5; type III: 2</th>
<th>Shamblin group Type I: 2; type II: 14; type III: 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tumor size (cm) 3.9 (2.5–5.5)</td>
<td>Tumor size (cm) 4.5 (2.8–6.0)</td>
</tr>
<tr>
<td>Estimated blood loss (mL) 450 (100–1,000)</td>
<td>Estimated blood loss (mL) 280 (50–850)</td>
</tr>
<tr>
<td>Operation time (min) 220 (170–260)</td>
<td>Operation time (min) 180 (160–220)</td>
</tr>
<tr>
<td>Hospitalization (d) 8 (6–11)</td>
<td>Hospitalization (d) 5 (4–8)</td>
</tr>
</tbody>
</table>

### Table II. Surgical records of tumors according to Shamblin group

<table>
<thead>
<tr>
<th>Shamblin I and II (n = 21)</th>
<th>Shamblin III (n = 10)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tumor size (cm) 3.0 (2.5–4.2)</td>
<td>4.7 (3.1–6.0)</td>
<td>0.016</td>
</tr>
<tr>
<td>Estimated blood loss (mL) 240 (50–400)</td>
<td>580 (300–1,000)</td>
<td>0.002</td>
</tr>
<tr>
<td>Operation time (min) 150 (130–180)</td>
<td>260 (160–320)</td>
<td>0.028</td>
</tr>
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</table>
classification, the bigger is the CBT, the higher is the risk of cranial nerve injury and vascular injury. If the size of CBT is > 5 cm, mortality is 1% to 3% after surgical intervention. Neurological morbidity is not best described by this system, and there is a need for a modified Shamblin classification.27

The low complication and embolization rates illustrate the ease of implantation and the safety of detachable coils. The fact that we had only one patient with minor flow disturbance in the feeder artery is probably owing to the fact that we attempted to leave only half a curl or less in the artery. Using the ampulla instead of the minimal ductal diameter for sizing of the coil is probably one of the factors contributing to the low embolization rate. Angiography prerelease with the coil still attached was helpful because stability and position could be assessed, which added to the low complica-
tion rate. On a practical note, we found it relatively easy to reposition the coil more than once.

Abud et al. described direct embolic intratumoral injections with cyanoacrylate glue in a series of CBTs with complete devascularization of the tumors and no postembolization or perioperative complications.28 Similarly, Elhammady et al. performed direct intratumoral injection with ethylene-vinyl alcohol copolymer and achieved similar results without complications.29 Tripp et al. described the use of covered stents to achieve tumor devascularization while reducing the risk of stroke.30

In addition, a team approach involving head and neck and vascular surgeons and interventional radiologists for the evaluation and management of these lesions will improve treatment outcomes.

CONCLUSION

Careful angiographic evaluation of blood supply to the tumor is essential to discern individual feeding vessels. Embolization should only be undertaken in those vessels that can be subselectively catheterized and determined not to allow free reflux of contrast medium into the ICA. Embolization should be performed slowly, especially as flow to the tumor becomes reduced. After superselection of feeding arteries, tumor embolization was performed on patients with Cook detachable coils, which are highly effective for supply artery closure if properly selected, and complications can be minimized by proper selection and positioning of the coil. In addition, complete obliteration of all tumor vascularity is not required to be efficacious in reducing size and vascularity. Operation within 48 hours after embolization is recommended to minimize revascularization edema or a local inflammatory response.

REFERENCES