Original Article

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Carotid body tumors: A 10-year observation study of clinical presentation and surgical outcomes

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Abstract

Background: This study aimed to evaluate the relationship between Shamblin classification, operative parameters, and postoperative neurological outcomes in patients undergoing carotid body tumor (CBT) surgery, and to assess the potential benefit of preoperative embolization.

Methods: A retrospective analysis was conducted on 52 patients (41 males, 11 females; mean age 47.2±14.8 years) who underwent CBT resection between January 2008 and June 2023 at a tertiary care center. Demographic, clinical, and perioperative variables were reviewed. Tumors were classified according to the modified Shamblin system. Postoperative neurological complications, operation time, blood loss, and hospital stay were analyzed. Statistical comparisons were performed using appropriate parametric and non-parametric tests, with $p<0.05$ considered significant.

Results: Nineteen patients (36.5%) had Shamblin class I, 25 (48.1%) class II, and 8 (15.3%) class III tumors. Preoperative embolization was performed in one patient. Neurological complications occurred in 11 patients (21.2%), including hypoglossal and vagus nerve injuries. A significant correlation was observed between higher Shamblin class and increased operation time, intraoperative blood loss, and postoperative neurological deficits ($p<0.01$). Hospital stay was also significantly longer in patients with neurological complications.

Conclusion: Advanced Shamblin classification is associated with greater surgical complexity and higher neurological morbidity. While preoperative embolization may reduce bleeding, its neuroprotective effect remains uncertain. Surgical resection remains the cornerstone of CBT management, with careful dissection crucial to minimizing complications.

Keywords: Carotid body tumor, paraganglioma, Shamblin classification, preoperative embolization.

Paragangliomas originating from the paraganglion cells of the carotid body, located at the bifurcation of the common carotid artery in the head and neck region, are known as carotid body tumors (CBTs). These tumors were first described by von Haller in 1743.[1] CBTs are rare, with an incidence of 1-3 per 100,000, and are typically asymptomatic, slow-growing, and incidentally discovered. They are usually sporadic and benign, although 5-30% may be malignant.

CBTs are often present as a painless, pulsatile mass, which can encase or compress adjacent nerves and the carotid artery, potentially leading to nerve injuries, arterial damage, or stroke. They most commonly occur in the fourth and fifth decades of life, with a female predominance (4:1). CBTs are highly vascularized, typically receiving blood supply from the external carotid artery (ECA), and they grow at a rate of approximately 2 cm over 5 years.[2,3]

To prevent local invasion and metastasis, early surgical excision is recommended, with reported success rates ranging from 50% to 80%.[4] Surgical planning should be based on the Shamblin classification, with the goal of complete tumor resection while minimizing neurovascular complications.[5]

Chronic hypoxia, especially in individuals living at high altitudes, is associated with an increased incidence of CBT. Additionally, patients with cirrhosis or chronic obstructive pulmonary disease may also have a higher risk, as the carotid body functions as a chemoreceptor.[6] Hypoxia, acidosis, and hypercapnia stimulate these chemoreceptors, activating the sympathetic nervous system, which leads to increased respiratory rate and blood pressure.

Involvement of the glossopharyngeal, vagus, spinal accessory, and hypoglossal nerves can result in symptoms such as hoarseness, dysphagia, and stridor.[7] An autosomal dominant inheritance pattern is observed in 10-30% of cases. The mortality rate among untreated malignant cases is approximately 8%.[8]

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Diagnostic tools include duplex ultrasonography (DUS), computed tomographic angiography (CTA), magnetic resonance imaging and digital subtraction angiography (DSA). Fontaine's sign, in which the tumor is mobile laterally but restricted vertically, is a characteristic clinical feature.[9]

To reduce perioperative blood loss and surgical complications, preoperative embolization (EMB) may be performed 24-48 hours before surgery. In this study, we aim to evaluate the outcomes of preoperative EMB in patients who underwent CBT surgery.

Methods

Study Design and Patients

Between January 2008 and June 2023, a total of 52 patients (41 male, 11 female; mean age 47.22±14.79 years) who underwent resection surgery for CBTs classified as Shamblin I-III at a tertiary care center and met the inclusion criteria were consecutively enrolled in this retrospective observational study. The study was conducted in accordance with the Declaration of Helsinki and approved by the İstanbul University-Cerrahpaşa's Ethics Committee (approval number: E-83045809-604.01.01-679490, date: 08.05.2023). Written informed consent was obtained from all participants.

Data Collection

Basic demographic data, including age, gender, symptom duration, and risk factors, as well as mid-term postoperative outcomes such as primary recurrence rates, need for reintervention, and the presence of comorbidities (e.g., diabetes mellitus, hypertension), were analyzed. Table 1 summarizes the baseline demographic and clinical characteristics. Additional factors included laboratory findings, duration of surgery, need for blood transfusion, medical history, necessity for concomitant procedures, length of hospital stay, postoperative stroke incidence, midterm follow up and cranial nerve injury (CNI). Table 2 summarizes the post-operative outcomes.

Preliminary diagnosis was made using DUS and confirmed with CTA and magnetic resonance angiography. Patients lacking adequate medical records, pathology reports, CTA results, or confirmation of Shamblin classification were excluded.

Definitions and patient data were retrospectively retrieved from the hospital's electronic medical records. A detailed medical history and physical examination were conducted. The decision for preoperative EMB was made in consultation with interventional radiologists. EMB was performed 0-3 days prior to surgical resection using Gel foam, hydrogel, polyvinyl alcohol, or direct bucrylate injection.

According to the Shamblin classification,[5] Group I refers to localized tumors that surround the carotid arteries by less than 90 degrees. Group II refers to tumors that partially encase the carotid arteries, between 90 and 180 degrees. Group III refers to larger tumors that encase the carotid vessels, with circumferential involvement.

Procedural Details

All patients underwent surgery under general anesthesia with endotracheal intubation in the supine position, with the neck rotated to the contralateral side. Routine near-infrared spectroscopy (NIRS) monitoring was performed in all patients during surgery. A standard longitudinal cervical incision was made along the anterior border of the sternocleidomastoid muscle to expose the carotid artery. The sternocleidomastoid muscle was mobilized laterally. The internal

Table 1. Baseline data of patients who underwent surgery for glomus caroticum tumors

	Without postoperative neurological deficits (n=41)	Postoperative neurological deficits (n=11)	p-value
Age (years, mean ± SD	47.61±13.98	46.82±18.17	0.79
Gender (F/M %)	9/32 (21.9%)	2/9 (18.1%)	0.78
Symptom at diagnosis (%)			
Headache	10 (24.4%)	1 (9.4%)	0.26
Mass	28 (68.3%)	8 (72.7%)	0.77
Senkop	1 (2.4%)	-	1
Sore throat	1 (2.4%)	-	1
Tinnitus	1 (2.4%)	1 (9.4%)	0.308
Asymptomatic	-	1 (9.1%)	1
DM	4 (9.8%)	1 (9.1%)	0.94
HT	11 (26.8%)	2 (18.2%)	0.55
Side (right/left)	20/19	5/5	0.84
Bilateral	2	1	0.59
Previous contralateral surgery	-	3/8	0.001
Shamblin classification			
Type I	20	-	0.001
Type II	16	8	0.08
Type III	5	3	0.34
Mean diameter (cm)	3.1±1.3	4.29±2	0.02

SD: Standard deviation; F: Female; M: Male; DM: Diabetes mellitus, HT: Hypertension.

Table 2. Postoperative comparison of outcomes

	Without postoperative neurological deficits (n=41)	Postoperative neurological deficits (n=11)	p-value
Duration of surgery	92.44±34.71	153.12±29.32	0.001
Post operative bleeding (mL)	220±36	390±24	0.001
Length of hospital stay	4.53±4.22	9.18±7.92	0.001
Superior thyroid artery ligation	5	8	0.002
External carotid artery ligation	1	4	0.005
Post operative hematoma	-	3	0.007

jugular vein, hypoglossal nerve, vagus nerve, and spinal accessory nerve were identified. Extensive dissection was avoided to preserve these structures after controlling the common, internal, and external carotid arteries.

Bipolar diathermy was used for capsular-adventitial or sub-adventitial dissection. Ligation of the ECA was performed just distal to the bifurcation. The tumor, carefully skeletonized, was dissected free from the internal carotid artery (ICA). To facilitate dissection, branches of the ECA were ligated. In cases where carotid artery clamping was necessary, 5000 IU of unfractionated heparin was administered.

During surgery, the tumor's location, color, consistency, texture, capsule integrity, its relationship to the internal and external carotid arteries at the bifurcation, blood supply, and potential skull base invasion were evaluated. As previously mentioned, some patients had undergone preoperative EMB. A transcervical approach was used for tumor resection. Ligation of the ECA was preferred in patients with Shamblin type III tumors who demonstrated significant tumor perfusion from the ECA after intraoperative clamping.

Gross pathology, molecular pathology, and immunohistochemistry analyses were performed. Resection and vascular reconstruction techniques varied depending on tumor size, rigidity, and adhesion to the carotid artery.

On the first postoperative night, all patients were monitored in the intensive care unit and subsequently transferred to the cardiovascular surgery ward. Patient records from admission to discharge were retrospectively evaluated.

Statistical Analysis

The Statistical Package for Social Sciences for Windows version 21 (SPSS Inc., Chicago, IL, USA) was used to compare the data. The Kolmogorov-Smirnov test was used to analyze normally distributed continuous variables. Categorical variables were presented as percentages and frequencies. Continuous variables were presented as the mean ± standard deviation. Continuous variables were compared using the t-test and the Mann-Whitney U test. The primary patency rates and survival rates were analyzed using the Kaplan-Meier. The categorical data were tested using the chi-square test or Fisher's exact test. A p-value of <0.05 was considered statistically significant.

Results

Sample Sizes, Demographics, and Baseline Risk Factors

Of the patients, 41 were male and 11 were female, with a mean age of 47.29±14.89 years (range, 18-79 years). The mean postoperative follow-up period was 64±13.6 months. The mean tumor diameter was 3.75±1.58 cm. Only one patient was asymptomatic. Thirty-six patients (69.2%) presented with a progressively enlarging neck mass, 11 (21.2%) with headache, 2 (3.8%) with earache, 1 (1.9%) with syncope, 1 (1.9%) with dizziness, and 1 (1.9%) with sore throat. Three patients (5.7%) had a history of contralateral glomus tumor.

The lesions were located on the left in 25 patients (48.1%), on the right in 24 (46.2%), and bilaterally in 3 (5.8%). According to the Shamblin classification (MSC), there were 19 class I tumors (36.5%), 25 class II (48.1%), and 8 class III (15.3%). Thirteen patients (25%) had pre-existing hypertension, 5 (9.6%) had type 2 diabetes mellitus, and 4 (7.6%) were active smokers (Table 1). Fortunately, no persistent cranial nerve deficits were observed. Recurrent paraganglioma was detected in one patient, and a previous contralateral paraganglioma was present in only three patients. The same preoperative protocol, operative approach, and postoperative follow-up strategy were applied to all patients.

Surgical Outcomes

Preoperative EMB was performed in only one patient. In all patients with type I and II lesions, the lesions were primarily excised. The superior thyroid artery was ligated in 13 patients (25%), and the ECA in 5 patients (9.6%) to reduce blood supply to the lesion. Embolectomy of the ICA was required in one patient (1.9%) due to distal ICA pulse deficit during surgery, and a saphenous vein bypass was performed in another patient (1.9%) because of total involvement of the carotid bifurcation in a Shamblin type III lesion. Preoperative computed tomography angiography revealed no carotid lesions in any patient. In one patient who underwent saphenous vein interposition to the ICA and in another patient who underwent ICA embolectomy, an intraluminal shunt was not used because no decrease greater than 20% in NIRS values was observed. In one case, cardiopulmonary bypass was required due to an internal jugular vein injury near the skull base; the otolaryngology team was consulted, and repair was performed with a sternocleidomastoid flap. Histopathological examination was performed on all masses resected after surgery; however, only two patients had malignant lesions and subsequently received postoperative chemoradiotherapy.

Neurological complications developed in 11 patients (21.1%) among those One patient (1.9%) developed postoperative hemiplegia. Of those 11 patients, 3 patients were among class 3 Shamblin. Three patients (5.7%) developed hematomas. No postoperative deaths occurred. Five patients (9.6%) had hypoglossal nerve palsy, 4 (7.6%) had vagus nerve palsy, and 1 (1.9%) had superior laryngeal nerve injury. Forty-one patients (78.8%) had no nerve damage after resection (Table 2). The mean hospital stay was 5.53±5.46 days (range, 3-30 days), mean

operative time was 105.24±23.56 minutes, and mean intraoperative blood loss was 256.5±125 mL. ICA and common carotid artery clamping were performed in only one patient (Tables 2 and 3).

Comparison of Outcomes

When comparing patients with and without postoperative neurological deficits, no statistically significant differences were observed in terms of age (p=0.773), sex (p=0.27), symptom status (p=0.239), tumor side (p=0.866), comorbidities (p=0.511), history of contralateral glomus tumor (p=0.595), or tumor size (p=0.574). However, hospital stay was significantly longer in patients with neurological deficits (p<0.01). Post-hoc analysis showed significant differences among Shamblin class I, II, and III tumors between patients with and without neurological deficits (p<0.01).

Positive correlation was found between tumor size and postoperative neurological complications (p<0.01, r=0.633), Shamblin classification and postoperative neurological complications (p<0.01, r=0.641) (Tables 2 and 3).

Discussion

In this study, we evaluated the outcomes and compared CBTs treated over the last 15 years in a tertiary referral clinic. The study revealed that neurological outcomes, operation time, and consequently hospital stay were associated with tumor size and Shamblin classification. The most affected nerves were the hypoglossal and vagus nerves. As the Shamblin class increased, complication rates, operation duration, and intraoperative blood loss also increased.

The effect of preoperative EMB and the criteria for selecting patients for this procedure remain uncertain. Although some meta-analyses have demonstrated reduced intraoperative bleeding and shorter operative time,[10] other studies have suggested that preoperative EMB reduces blood loss but has no effect on transient nerve injury.[11] Additional radiation therapy is used for extensive resections that require sacrifice of neurovascular structures. To reduce postoperative complications such as hoarseness and dysphagia due to ipsilateral vagal nerve paresis, botulinum toxin and hyaluronic acid have been applied to decrease aspiration in patients with glottic insufficiency.[12]

Surgical treatment remains the gold-standard approach for CBTs.[13] Shamblin classification is based on carotid artery infiltration and the degree of vascularity.[14] Shunts are usually required for Shamblin Group III tumors, whereas complete resection of the external and internal carotid arteries with graft interposition may be necessary for Shamblin III tumors.[15] In our study, shunts were not used in any of the patients.

Delicate neurovascular structures in the carotid region should be preserved during surgery to achieve complete excision.[16] In cases of high vascularity, selective angiography with EMB is typically performed, especially in Shamblin class III tumors, though it may also be considered for selected class II cases.[14] In addition, radiotherapy used concomitantly with surgery or as a single treatment may provide considerable benefit in the management of CBTs and may reduce surgery-induced neurovascular complications. However, complete tumor resolution through radiotherapy alone is rarely observed.[17] Although there is still no consensus in the literature regarding preoperative EMB, studies have reported differing opinions about whether it should be performed. Abu-Ghanem et al.[18] reported that preoperative EMB has no benefit over surgical treatment alone. Conversely, a meta-analysis conducted by Texakalidis et al.[19] found a statistically significant reduction in blood loss and operative time.

CBTs can extend to the skull base as their size increases. In our study, we concluded that Shamblin class III tumors were associated with greater surgical risks. Robertson et al.[20] reported a strong association between stroke risk and CBT grade: Class I carries a 15% risk, class II a 25% risk, and class III up to 60%, possibly due to increased blood loss. They also found that the risk of CNI rises with higher classes—4% in class I, 14% in class II, and 17% in class III.

According to a meta-analysis by Mitre et al.,[21] there was no difference between patients with and without preoperative EMB in terms of postoperative neurological deficits, regardless of whether EMB was performed or how much of the tumor was resected. However, in our study, a close relationship was observed between tumor size and postoperative cranial nerve damage. Complications of EMB include occlusion of non-tumoral vessels and EMB of atheromatous material.[21] Borba et al.[22] reported that complete EMB may cause intraoperative nerve dysfunction and neuropathy and should therefore not be applied to all glomus cases. Occlusion of the blood supply may compromise the watershed regions of cranial nerves, leading to transient facial pain or paresis and skin necrosis.

Campbell et al.[23] reported that both surgical resection of glomus tumors and stereotactic radiosurgery can cause CNI, dysphagia, and cerebrospinal fluid leaks. Despite the risk of CNI, stroke, and hemorrhage, surgery remains the gold-standard treatment for glomus caroticum tumors, particularly in patients with small lesions.

Among head and neck paragangliomas, glomus caroticum tumors are rare and slow growing. These tumors are intimately related to vascular

Table 3. Post operative comparison according to Shamblin classification

	Shamblin Class I (n=19)	Shamblin Class II (n=25)	Shamblin Class III (n=8)	p-value
Duration of surgery	75.78±65	110.92±47	160.29±18	0.001
Post operative bleeding (mL)	150±55	290±40	410±60	0.001
Length of hospital stay	2.17±1.34	5.26±4.75	9.07±6.7	0.001
Superior thyroid artery ligation	-	5	8	0.001
External carotid artery ligation	-	-	5	0.001
Post operative hematoma	-	-	3	0.001
Postoperative neurological deficits	-	5	6	0.001
Postoperative cranial nerve deficit	-	3	7	0.001

and neural structures, which may cause compression-related injury. Makeieff et al.[24] reported postoperative nerve injury rates of 19-42.1%, with 0-4% being permanent. In our series, we found a lower postoperative neurological deficit rate (21.2%). Jansen et al.[25] reported that patients with high Shamblin classification have higher postoperative neurological complication rates (30% in Shamblin class III). Similarly, in our study, 37.5% of patients with Shamblin class III experienced postoperative neurological deficits.

There are some limitations to the present study. First, the number of patients in our series may be considered limited compared with other studies. Second, the study had a retrospective design. Third, we were unable to compare postoperative neurological complications between patients with and without preoperative EMB. Fourth, larger, randomized prospective studies are needed to validate our findings. Fifth, although only a single patient actually underwent preoperative EMB, a meaningful benefit-risk analysis cannot be derived from a single case. Finally, long-term follow-up is warranted to confirm these results.

In conclusion, this study demonstrated that advanced Shamblin classification correlates with increased operation time, intraoperative blood loss, and postoperative neurological complications. Although preoperative EMB may help reduce bleeding and shorten the operation, its effect on nerve protection remains uncertain. Surgery remains the mainstay of treatment, especially for smaller and resectable tumors, while adjunctive procedures such as EMB or radiotherapy should be applied selectively based on tumor characteristics.

Ethics

Ethics Committee Approval: The study was conducted in accordance with the Declaration of Helsinki and approved by the İstanbul University-Cerrahpaşa's Ethics Committee (approval number: E-83045809-604.01.01-679490, date: 08.05.2023).

Informed Consent: Written informed consent was obtained from all participants.

Footnotes

Authorship Contributions

Surgical and Medical Practices: B.A., O.O.B., S.B.D., D.G., S.N.Ö., K.B., G.İ.; Concept: B.A., S.B.D.; Design: B.A., S.B.D.; Data Collection or Processing: B.A., Ö.F.S.; Analysis or Interpretation: Ç.T.Ü., O.O.B., S.B.D.; Literature Search: Ç.T.Ü., O.O.B., S.B.D.; Writing: B.A., Ç.T.Ü., S.B.D.

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