


Carotid body tumor encounters over a two-decade period in an academic hospital

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Abstract

Carotid body tumors (CBTs) are rare and mostly benign. Research outcomes usually arise from single-center data. We conducted this study to present the characteristics and outcomes of patients who underwent surgical resection of CBT at our hospital over the past 20 years. In this retrospective review, the records of CBTs in our hospital were reviewed between 1998 and 2021. All patients who underwent CBT resection were included. The follow-up period was 12 months. A total of 44 CBTs were treated in our hospital. The male-to-female ratio was 1:2.4. Only 4.5% of patients had Shamblin I tumors. Patients with Shamblin II and III tumors were 56.8% and 38.6%, respectively. Duplex scan was used to diagnose CBT in all of the patients. The majority of our patients (97.7%) did not receive any preoperative embolization despite an average tumor size of 4.9 cm. Cranial nerve injuries were observed in 29.5% of cases. Meanwhile, stroke was reported in only two cases (4.5%). No deaths were encountered. Surgery is the definitive treatment for CBT. Size and local extension appear to be the main reasons for adverse events rather than surgical techniques. Our results are consistent with those of previously published studies. Good outcomes are expected in high-volume centers with appropriate preoperative imaging.

Abbreviations: CBTs = carotid body tumors, CT = computed tomography, ECA = external carotid artery, MRI = magnetic resonance imaging.

Keywords: carotid body tumor, CBT, chemodectoma, paraganglioma.

1. Introduction

Carotid body tumor (CBT), also known as carotid body paraganglioma or chemodectoma, is a non-catecholamine-secreting, highly vascularized, and slowly growing tumor of neurovascular origin located in the medial aspect of the carotid artery bifurcation.^[1,2] Paraganglion tissue is derived from the neural crest. Cells from the neural crest migrate during embryogenesis to concentrate around the autonomic ganglia. Glossopharyngeal nerve gives off a branch to the carotid sinus at the carotid bifurcation, thus explaining the origin of these tumors. Both the glossopharyngeal nerve and the ascending pharyngeal artery are embryologically linked to the third branchial arch. This explains the key role of this artery in the vascularization of CBTs. Thus, on contrast imaging, CBT appears as intensely enhancing mass at the carotid bifurcation, splaying the internal and external carotid arteries. Most vascular surgeons rarely encounter cases of CBT throughout their careers. It accounts for <1% of head and neck tumors.^[3] It usually affects females more than males (2:1) and frequently arises in the third or fourth decades of life.^[4,5] The majority of cases present with painless neck swelling and/or symptoms due to the pressure inflicted by the enlarging

tumor on the surrounding structures.^[6] Malignancy occurs only in <10% of cases.^[7] The carotid body functions as a chemoreceptor that senses hypoxia. When hypoxia occurs, signals travel from the carotid body to the respiratory center in the medulla via the glossopharyngeal nerve, resulting in an increased respiratory rate, tidal volume, and sympathetic tone. Despite the rarity of malignancy and slow growth, surgical management remains the definitive treatment in managing these tumors due to the following reasons: some tumors are malignant at presentation; there are no reliable screening measures to follow the cytological progression of the tumor; there is no evidence stating that alleviating hypoxemia will result in regression of the tumor; the risk of tumor resection appears to be minimal due to the improvement in the understanding of the disease, accuracy of preoperative imaging, hypotensive anesthesia, and modern vascular surgical techniques, including arterial revascularization; and lastly, all patients with CBT eventually become symptomatic.^[8–13] However, surgical risks such as cranial nerve injury, stroke, and hemorrhage continue to be major concerns even with experienced surgeons.^[14] The aim of this study is to present the characteristics and outcomes of patients who underwent surgical resection of CBT at our hospital in the past 20 years.

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The data that support the findings of this study are available from a third party, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are available from the authors upon reasonable request and with permission of the third party; The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

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2. Material and Methods

This study was performed after obtaining approval from the King Saud University Institutional Review Board (grant no. E-22-6716) and was conducted in accordance with international research ethics standards. The patients provided written informed consent. In this retrospective study, we included all patients who underwent CBT surgical management at King Saud University Medical City, Riyadh, Saudi Arabia, between April 1998 and August 2021. Cases of CBT were identified based on the patients' clinical history and physical examination. Furthermore, the diagnosis was confirmed via imaging modalities, such as Duplex scan, computed tomography (CT), magnetic resonance imaging (MRI/MRA), and/or angiography. Shamblin classification was identified during surgery. After CBT surgical excision, all tumors were sent for pathological examination to confirm the reliability of the preoperative diagnosis. Patients who were diagnosed with CBT but did not undergo surgical treatment were excluded from the study (n = 4). All surgeries were performed by experienced and board-certified vascular surgeons. Data collected from medical records included demographic features (age and sex), tumor features (laterality, size, and classification), chief complaints, pre-operative investigation, type of surgery and sequelae, and post-operative prognosis. Postoperative data were collected during the 1-year follow-up period. Follow-up visits were conducted at the third month, sixth month, and a year after the surgery, which included the patient's history, physical examination, and Duplex scan of the carotid vessels. Carotid occlusion test was done in selected Shamblin III patients. Those who had large Shamblin III tumors extending higher toward base of the skull which were anticipated to cause more intraoperative difficult dissection or injury to distal internal carotid artery mandating ligation or resulting in delay in introduction and establishment of carotid shunt. No ligation of internal carotid artery was done in our patients. Standard surgical technique was followed (Fig. 1). Early cases had undergone carotid angiogram prior to surgery (before 2006), with the availability of more advanced CT scan machines, carotid angiogram is currently done only during preoperative embolization of carotid occlusion test.

3. Results

Over a period of 23 years, we treated 44 CBT cases in 38 patients. This represents approximately two operations per year. Three of the excluded patients refused surgical intervention and presented with asymptomatic small tumors (Shamblin I). Regarding follow-up visits, all patients (100%) have attended their first visit. Second visit was attended by (86.4%) of the

patients. While only (68.2%) have attended their 1-year follow-up visit. Patients who had complications showed-up to all follow-up visits.

3.1. Age, sex, and tumor features

The mean age of the patients was 44.2 ± 13.6 years (range; 21–68 years old). Females accounted for 70.5% with a male-to-female ratio of 1:2.4. Tumors were found bilaterally in six patients (13.6%). The average size of the tumor was 4.9 ± 1.5 cm, and ranged between 1.5 cm × 1–8.2 cm × 5.3 cm. Based on Shamblin classification, 4.5%, 56.8%, and 38.6% were classified as Shamblin I, Shamblin II, and Shamblin III, respectively (Table 1).

3.2. Presentation

Painless swelling anterior to the sternocleidomastoid muscle at the angle of the mandible was the most common presentation (97.7%). The swelling was pulsating with thrills and bruit was heard in all cases; such swelling usually lasts for years. Only one

Table 1
Demographic data, tumor features, and extent of excision (n = 44).

Variable	Mean (SD, range)/n (%)
Age (yr)	44.2 (13.6, 21–68)
Gender	
Male	13 (29.5)
Female	31 (70.5)
Bilateral tumor	6 (13.6)
Size (cm)	4.9 (1.5, 1–8.2)
Shamblin classification	
I	2 (4.5)
II	25 (56.8)
III	17 (38.6)
Extent of excision	
ECA excision	14 (31.8)
ICA & ECA excision	3 (6.8)
Excision of ECA & ICA with mass, saphenous vein Interposition bypass	7 (15.9)
Excision of the mass and preserving ECA & ICA	26 (59.1)
Shunt used	6 (13.6)

ECA = external carotid artery, ICA = internal carotid artery.

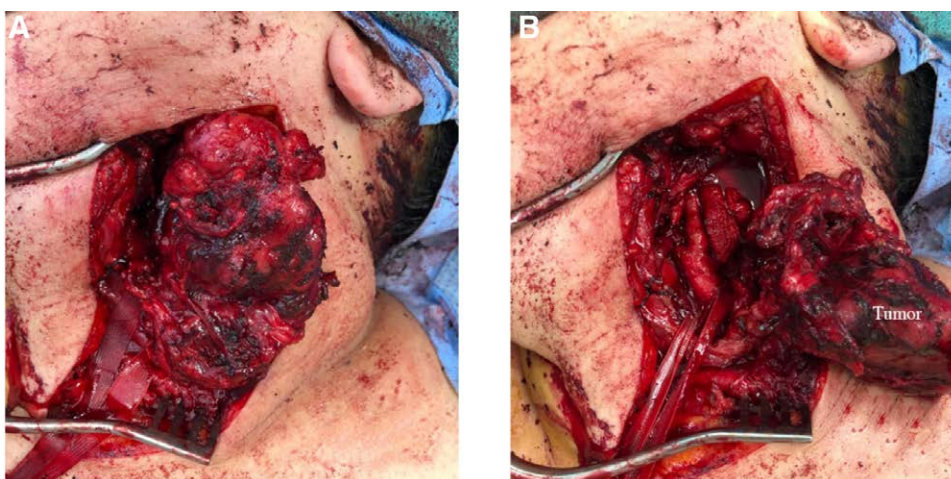


Figure 1. Surgical treatment of CBT. (A and B) During dissection and (C) tumor. CBT = carotid body tumor.

patient (2.7%) who initially did not complain of pain, eventually had painful swelling and larger tumor size over time. Along with swelling, only one patient (2.7%) complained of hoarseness, and one complained of headache (2.7%). None of our patients had a family history of CBT. Lymphadenopathy, odynophagia, dysarthria, upper limb paresthesia, and tongue deviation were not observed at presentation.

3.3. Investigations

As shown in Figure 2, the most frequently used test was carotid Duplex scan (n = 44 cases, 100%), followed by contrast-enhanced CT scan (77.3%). MRI/MRA was needed in 18.2% of cases, while angiography was utilized in 52.3% of patients, mainly to assess carotid distortion and the presence of concomitant atherosclerotic disease. Urine catecholamine levels were evaluated in all patients and the results were within normal limits. Furthermore, the abdominal contrast-enhanced CT results were normal.

3.4. Operative details

Preoperative embolization was performed in one case (2.3%) in 2015 to reduce the incidence of intraoperative bleeding in a patient with large Shamblin III tumor (5.2cm x 2.2cm) who also had a history of massive bleeding and stroke after CBT surgery and ligation of carotid artery in the opposite side done in another center. A preoperative carotid balloon occlusion test was performed in 12 cases (27.3%). Further procedural data are presented in Table 1.

3.5. Postoperative morbidity and prognosis

We did not encounter any short- and long-term CBT-related mortality or recurrence. Stroke was diagnosed in two patients after the CBT surgery (4.5%), one of them underwent preoperative

embolization. Both have recovered during the last follow-up visit. No complications were observed in patients underwent carotid occlusion test. We did not encounter any surgical wound infections. Numbness of the lateral neck in eight (18.1%). Cranial nerve injuries were frequently reported postoperatively. Hoarseness was observed in five patients (11.4%), dysphagia in six (13.6%), and ptosis in one (2.3%). At follow-up visits, all affected patients (100%) regained their cranial nerve function at the third month postoperative visit (Table 2).

4. Discussion

The carotid body is the richest tissue of the paraganglia in the head and neck and is usually found in the carotid space. Due to the rarity and anatomical location of CBTs, they are difficult to diagnose and treat.^[4] They can either be sporadic or familial. The familial type can be anticipated in patients with a family history of paraganglioma, and it is due to the absence of the succinate dehydrogenase gene in the long arm of chromosome 11, which leads to a decline in succinate dehydrogenase production and subsequently, hypoxia, carotid body hyperplasia, and tumor development.^[11,15] The same result was found in patients with chronic hypoxia, chronic obstructive pulmonary

Table 2
Postoperative outcomes and prognoses (n = 44).

Morbidity	N (%)
Stroke	2 (4.5)
Recurrent laryngeal nerve	5 (11.4)
Glossopharyngeal nerve	6 (13.6)
Horner's syndrome	1 (2.3)
Hypoglossal nerve	1 (2.3)
Sensory changes (lateral neck numbness/pain/tingling sensation)	8 (18.1)

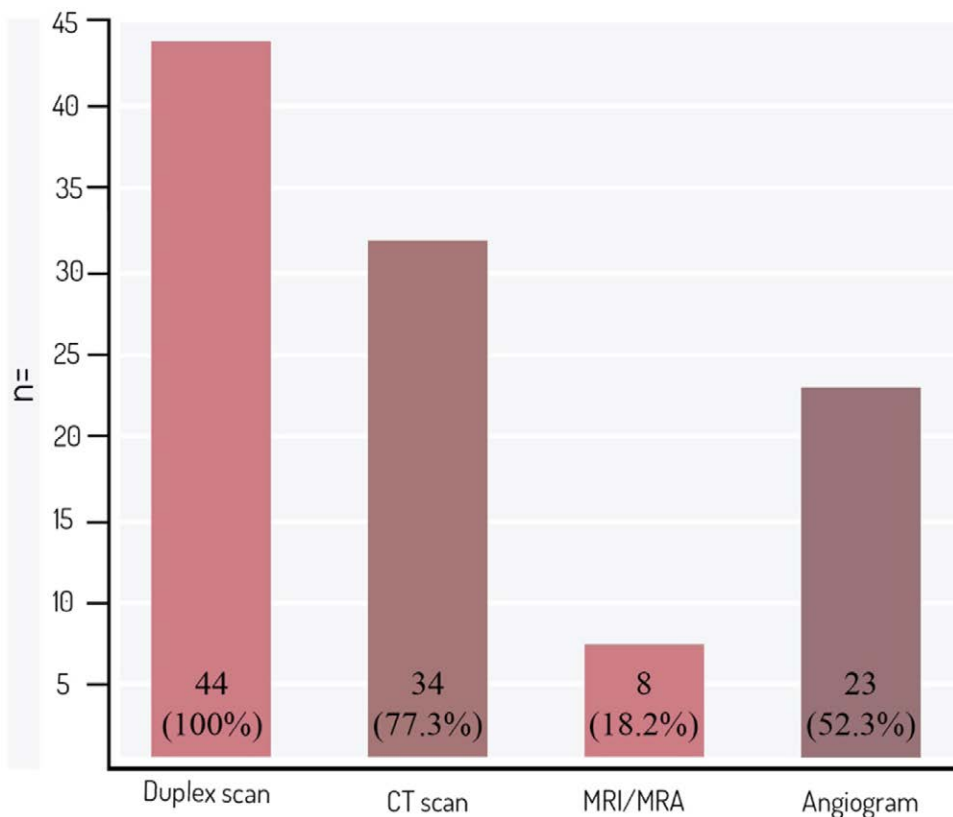


Figure 2. Preoperative investigations.

disease, and those who live in high altitudes.^[16] However, the cause remains unknown in the sporadic type. Our patients' average age was approximately equal to that of patients in the earlier CBT series.^[4] The male-to-female ratio was 1:2.4, which is consistent with the international range.^[4] A study was published for a high-altitude cohort of patients who reported a higher ratio (1:8.3), stating that areas of high altitude had a higher female population than males, which might influence their results.^[16] Another study in Morocco reported the opposite (2.3:1), and might be explained by the study setting, as it was conducted in a military hospital.^[17] Bilateral tumor usually represent 9.6% of cases and are more common in familial than sporadic tumors (33% vs 5%, respectively).^[4,16] We reported bilateral CBT in 13.6% of patients, which is within the range of previously published papers.^[4,18] Surprisingly, based on family history, we did not find any familial type of CBT. This incidence is higher than that reported in previous studies.^[16,19] However, Kruger et al reported a higher incidence of bilateral tumors in sporadic types than in familial types (72% vs 28%).^[18] The possible cause of this phenomenon remains unclear.

The lack of guidelines for the management and investigation of CBTs has made it difficult to formulate the appropriate treatment strategy for these tumors. Several radiological investigations have been conducted to diagnose CBT. Duplex scan is an ideal screening tool, as it outlines the shape, dimensions, vascularity, and carotid artery dislodgment (Fig. 3a).^[10,20] Conventional angiography remains the gold standard for CBT diagnosis, and it is still the initial modality performed based on our experience. However, with the improvement of high-resolution cross-sectional imaging, we shifted to CT and MRI/MRA for preoperative planning, which is consistent with recent trends.^[21,22] CT and MRI/MRA were used mainly to delineate the relationship between the tumor and surrounding structures, to determine cranial extension and to identify the relationship between the tumor and the internal jugular vein and carotid artery (Fig. 3b, c, and d).

Preoperative embolization and radiotherapy have been mentioned in literature to be treatment options, but surgery, despite its risks, still serves as the mainstay treatment for this condition.^[4,23,24] Apart from its complexity and surgical cost, preoperative embolization is not beneficial to patients as it can induce inflammatory changes and carotid artery damage, which can lead to ischemic stroke.^[23,24] Furthermore, it increases the risk for intraoperative bleeding, which is a known cause of numerous complications.^[25] Only one patient in the present study underwent embolization, and he eventually developed stroke. Radiotherapy can decrease tumor size or cease tumor growth, which is reasonable for those who cannot undergo

surgery due to operative or anesthetic risks.^[20] The primary goal of surgery is to excise the tumor completely and avoid any neurovascular injury. External carotid artery excision has been suggested in many studies to minimize bleeding and operative time.^[9,26] Despite having many patients with large tumors, we were able to preserve the external carotid artery in 59.1% of cases. Larger CBTs result in a higher incidence of adverse outcomes.^[4] Mortality increases from 1% to 3% in CBT sizes exceeding 5 cm.^[10] Even with the decrease in morbidity after surgical excision, cranial nerve injuries have remained at the same incidence rate for the past 50 years.^[4,23] The incidence of cranial nerve injuries range between 11% and 49%, and we fall in the middle of this range (29.5%), which is comparable to the rate reported in a systematic review (25.4%).^[4,10] All of the reported cranial nerve deficits in this study were temporary, while other researchers have encountered (6%–18%) permanent deficits. Neurological outcomes are likely related to the pathology and local extension of the tumor rather than the surgical technique.^[8,27,28] There was no report of bleeding complications such as neck hematoma in our study, compared to the 5.2% that was reported earlier.^[4] The presence of a vascular surgeon in the operating room can minimize vascular injuries.^[22] A multicenter review of 33 vascular centers has demonstrated that vascular surgeons are the best fit for CBT resection due to the lower complication rates.^[10] Overall, hospitals with higher volumes have better outcomes.^[29] We compared our three main parameters (cranial nerve injuries, stroke, and death) with those of contemporary studies with 44 ± 15 resected CBTs (Table 3).

This study was limited by its retrospective nature and sample size due to the rarity of the tumor. We highly encourage the performance of further clinical trials and formulation of appropriate guidelines for CBT management and investigations in the future.

5. Conclusion

In conclusion, most CBTs are benign and present as a slowly growing painless neck mass. Duplex scan is excellent in screening for CBTs and should be supplemented with other imaging modalities for appropriate surgical planning. Surgery is the definitive treatment for CBT. Advanced imaging coupled with surgery in high-volume centers provide the best outcomes. Our outcomes are comparable to those of the international studies. Size and local extension of the tumor appear to be the main factors determining the risk for adverse neurological effects. We demonstrated that surgical treatment without preoperative embolization is safe and effective even in large tumors.

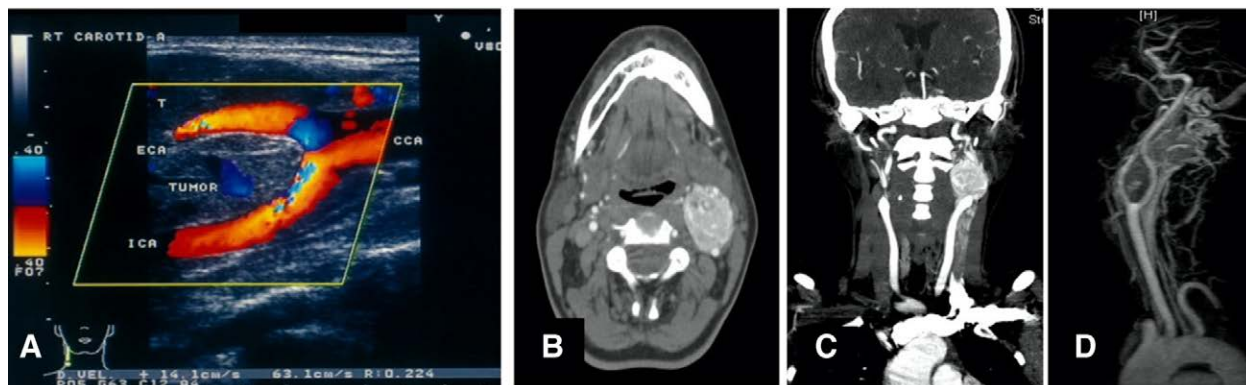


Figure 3. Illustration of different imaging modalities to diagnose CBTs. (A) Duplex scan showing a hypoechoic mass at the carotid bifurcation, (B and C) Non-contrast CT images showing a mass with soft tissue density, (D) enhanced MR angiography imaging showing a mass enhancement with splaying of the internal and external carotid arteries. CBTs = carotid body tumors. CT = computed tomography.

Table 3
Summary of characteristics of CBTs of contemporary studies with 29 to 59 tumors resected.

Study	Yr	No. of tumors resected	Age (mean) (range) (yr)	Shamblin classification			Cranial nerve injury (%)	Stroke (%)	Death (%)
				I	II	III			
Altoijry et al	2021	44	44.2 (21–68)	4.5%	56.8%	38.6%	29.5%	4.5%	0%
Dorobisz et al ^[30]	2016	47	45 (34–56)	33%	53%	14%	18%	6.4%	0%
Lamblin et al ^[31]	2011	54	49 (38.2–57.7)	31.2%	46.3%	22.2%	47.6%	5.6%	0%
Metheetraitur et al ^[21]	2015	38	36.9 (15–59)	22.5%	35%	42.5%	20%	5%	0%
Fruhmann et al ^[15]	2013	50	54.5 (17–80)	20.6%	44.4%	34.9%	20.6%	2%	0%
Torrealba et al ^[32]	2016	30	45.5 (18–75)	16.7%	63.3%	20%	23%	0%	0%
Lozano et al ^[33]	2020	50	60.3 (33–78)			18%	16.3%	2%	6%
Zhang et al ^[34]	2018	29	46	27.6%	55.2%	17.2%	27.6%	0%	0%

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