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Research Article

Impact of Radiological Predictors on Surgical Management and Outcomes of Carotid Body Tumour Resection

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Abstract

Background: Carotid body tumours (CBTs) are rare, highly vascular tumours that arise from the paraganglion cells of the carotid body chemoreceptor organ, located near the carotid arteries bifurcation. CBTs cause a slow-growing mass in the neck region. This work aimed to plan a radiological-based surgical approach, assess for predictive factors of vascular reconstruction, the technique and types of vascular graft implemented and analyse outcomes following surgical intervention.

Methods: This retrospective, observational cohort study was conducted on 20 patients over 15 years who underwent resection of CBTs and were further categorised into whether they underwent vascular reconstruction or not. Radiological predictors were evaluated including the tumour size, location, vascularity, and proximity to adjacent structures. Data was analysed intraoperatively and postoperatively to investigate for complications.

Results: The majority of our patients were Male with an average age of 40, presenting with neck swelling. A total of 85% of patients were classed as 3 on the Shamblin Classification indicating extensive disease. The mean operation duration of the studied cases was 5.35±1.46hours and the mean blood loss was 1320±1044.59 mL. There were 3 (15%) cases that required vascular reconstruction of internal carotid artery using grafts and 2 (10%) cases were successfully controlled by primary vessel repair. We encountered high rates of intraoperative and postoperative complications confounded by the complex anatomical and physiological nature of the tumour.

Conclusions: Pre-operative imaging can help identify the location and extent of the tumour, which can guide the selection of surgical approach to reduce the risk of complications. Despite adequate planning, our study highlights the need for thorough patient education directed towards intra- and postoperative complications and morbidity. Emphasis should be placed on appropriate patient selection.

***Keywords:** Radiological, Predictors, Carotid Body Tumor, Resection, Vascular Reconstruction.*

Introduction

Nearly every physical problem is accompanied by a disturbance of breathing. Hans Weller M.D [1].

Breathing is a process that must remain uninterrupted throughout life from birth to death for us humans to stay alive [2]. Our body is in constant need of oxygen, and it automatically regulates the rate and pattern at which we breathe in oxygen to maintain the constantly changing energy demands of our organs [3]. It is worth noting that the sensitivity and physiology of the peripheral chemoreceptor changes throughout the lifespan [4].

The carotid body is a bilateral sensory organ that is highly sensitive to levels of arterial PO_2, PCO_2, and pH [5].

Cells of the carotid body translate chemical changes into electrical and biochemical signals transferred to the respiratory centres in the central nervous system via the glossopharyngeal nerve, leading to physiologic cardiovascular vasomotor activity and respiratory regulatory response [6].

Carotid body tumours (CBTs) are rare, highly vascular tumours that arise from the paraganglion cells of the carotid body chemoreceptor organ, located near the carotid arteries bifurcation. CBTs cause a slow-growing mass in the neck region [7].

Their most common mode of presentation is a longstanding painless, pulsatile, slow-growing mass in the neck region below the angle of the mandible. The most important step in the proper diagnosis of this condition is a proper clinical examination with the simple but paramount basics of inspection and palpation of suspicious neck lumps [8].

Although 95% of CBTs are benign, they can be locally aggressive and turn malignant in approximately 10% of cases. They have a tendency to turn into malignant tumours in approximately 10% of all cases [9].

Surgical excision presents a challenge because of the frequent complications and difficulties caused by their high vascularity, proximity and possible infiltration of the carotid bifurcation, compression of cranial nerves in the neck, and extension to the skull base [10].

To predict the difficulties encountered during resection, their comparison to pre-op imaging, and the outcomes of surgery performed at our institution was made by reviewing our experience of this rare disease over the past 10 years. [11]

This work aimed to plan surgical approach based on radiological findings, analyse for indications of vascular reconstruction and the technique and types of vascular graft and lastly, assess outcomes following surgical intervention and the scope of pre-operative embolization.

Materials and Methods

This retrospective, observational study was carried out on a total of 20 patients over the course of 15 years within the Surgical Oncology Department at Cairo University who underwent resection of CBTs. The study was conducted looking at these patients from January 2007 to November 2022 after approval from the Ethical Committee at the National Cancer Institute, Cairo, Egypt. Informed written consent was obtained from the patients analysed. The study included patients who underwent CBT resections irrespective of whether they underwent vascular reconstruction or not and whether they received preoperative embolization or not. Patients with a histopathological diagnosis other than CBTs were excluded from the study.

Patient data were collected from medical records, including demographics, pre-operative imaging, intraoperative details, and post-operative follow-up. Radiological predictors that were evaluated included the tumour size, location, vascularity, and proximity to adjacent structures. Demographic and clinical data were fully anonymised and collected into an electronic database. Statistical analysis was conducted using SPSS v26 (IBM Inc., Chicago, IL, USA). Quantitative variables were presented as mean and standard deviation (SD). Qualitative variables were presented as frequency and percentage (%).

The primary outcome parameters of this study were to plan a radiological based surgical approach and to assess vascular reconstruction indications, techniques, and types of vascular graft. The secondary outcome parameters were to analyse outcomes following surgical intervention and evaluate the importance of pre-operative embolization.

Results

The mean age of studied cases was 39.45 (±12.23 SD) with a range (22-58), according to sex there were 13 (65%) female patients and 7 (35%) male. Only 3 (15%) patients were identified as smokers. Stratifying based on comorbidities, 1 patient (5%) has Diabetes Mellitus, 2 patients (10%) suffered with hypertension and 1 (5%) with Rheumatoid Arthritis.

Based on their presenting complaint, 17 patients (85 %) presented with asymptomatic neck masses, 1 (5%) with a deviation of the tongue, 1 (5%) with a sore throat and 1 (5%) was discovered accidentally during medical check-ups. The mean size of CBT (largest dimension in cm) was 5.1 cm (± 1.77 SD) with a range (2-9.5). During the analysis there were 2 patients (10%) with bilateral masses, 6 (30%) with a left-sided mass, 12 (60%) with a right-sided mass and 1 (5%) had a positive balloon occlusion test.

Table 1: Demographic data, medical history, complaint, Pre-op imaging and laterality measurements of the studied patients.

		N=20
Age (years)		39.45 ± 12.23
Sex	**Male**	13(65.0%)
	Female	7(35.0%)
Smoking		3(15.0%)
Medical history	**DM**	1(5.0%)
	HTN	2(10.0%)
	Rheumatoid arthritis	1(5.0%)
Initial Complaint	**Neck Swelling**	17(85.0%)
	Sore throat	1(5.0%)
	Tongue deviation	1(5.0%)
	Asymptomatic	1(5.0%)
Pre-op imaging and Laterality measurements		
Size (Largest dimension (Cm))		5.1 ± 1.77
Side	**Bilateral**	2(10.0%)0
	Left	6(30.0%)
	Right	12(60.0%)

Data are presented as mean ± SD or frequency (%). DM: diabetes mellitus, HTN: hypertension.

According to the Shamblin classification as shown in Table 2, there were 17 cases (85%) of class 3, 2 cases (10%) of class 2 and only 1 case (5%) of class 1. The mean operation duration of the studied cases was 5.35±1.46hours and the mean blood loss was 1320±1044.59 mL. There were 11 cases (55%) who sustained permanent iatrogenic injuries: 8 (40%) had vagal nerve sacrifice, 3(15%) had hypoglossal nerve injury. It is worth noting that there was only 1(5%) case that required mandibular subluxation to allow easier access to the tumor.

Table 2: Shamblin classification, operative duration, estimated blood loss and significant intra-op events among studied cases.

		N=20
Shamblin classification	**Class 1**	1(5.0%)
	Class 2	2(10.0%)
	Class 3	17(85.0%)
	Operative Duration	5.35 ± 1.46
	Estimated blood loss	1320 ± 1044.59
Significant intra-op events	**Vagal Nerve Injury**	8(40.0%)
	Hypoglossal Nerve Injury	4(20.0%)
	Vascular Reconstruction	3(15.0%)
	Mandibulotomy / Mandible subluxation	1(5.0%)

Data are presented as mean ± SD or frequency (%).

There were 3(15%) cases that required vascular reconstruction of internal carotid artery using grafts and 2(10%) cases were successfully controlled by primary vessel repair. All cases that required vascular reconstruction were performed using natural grafts. Intra-operative shunting was used in 2(10%) cases during control and restoration of carotid circulation. Ligation without reconstruction was done in 2(10%) cases that had complete ligation of internal carotid arteries and 1(5%) case that required ligation of the common carotid artery.

Table 3: Types of grafts used during vascular reconstruction and major vessel ligation without reconstruction.

		N=20
Types of grafts used	**Natural graft**	3(15.0%)
	Synthetic graft	0(0.0%)
Major vessel ligation without reconstruction	**CCA ligation**	1(5.0%)
	ICA Ligation	2(10.0%)
	ECA ligation	4(20.0%)
	IJV ligation	2(10.0%)

Data are presented as frequency (%). CCA: common carotid artery, ICA: internal carotid artery, ECA: Transcervical endometrial cryoablation, IJV: internal jugular vein.

Post-operative complications were monitored and recorded, we found that there were 5(25%) cases of dysphagia, 5 patients (25%) developed a change of voice, 2 patients (10%) experienced a deviation of the tongue on protrusion, 1 case (5%) of regurgitation during swallowing, 2 patients (10%) experienced dental pain, 1(5%) with significant hemorrhage, 1(5%) with wound dehiscence, 1(5%) with stroke and 1(5%) with CBT recurrence.

Table 4: Post operation complications among the study population.

	N=20
Dysphagia	5(25.0%)
Change of voice	5(25.0%)
Deviated tongue on protrusion	2(10.0%)
Dental/TMJ pain	2(10.0%)
Regurgitation during swallowing	1(5.0%)
Hemorrhage	1(5.0%)
Wound dehiscence	1(5.0%)
Stroke	1(5.0%)
Recurrence	1(5.0%)

Data are presented as frequency (%). TMJ: temporomandibular joint.

Discussion

Based on radiological analysis of the patients who required vascular reconstruction (3 Patients) during carotid body tumour resection, there were multiple common factors contributing to the need for vascular reconstruction, including a tumour size > 3cm, local invasion, advanced-stage of the tumours, high vascularity and higher Shamblin classification (stage 3). All patients were classified as Shamblin class 3, which is known to be associated with a higher risk of vascular involvement which in turn requires a more extensive surgical resection. According to the preoperative CT scan, patient 1 had a hypervascular lesion that measured 4.3 cm at the bifurcation of the right common carotid artery, which was supplied by a hypertrophied right external carotid artery. The mass encased both the right internal and external carotid arteries and infiltrated a portion of the internal carotid artery wall. As a result, resection and reconstruction were necessary, and the right common facial vein was used as a graft.

Additionally, primary repair of the external carotid artery was performed using prolene 8/0. Following surgery, this patient experienced a right frontotemporal infarction in the area of the middle cerebral artery (MCA) territory. (Figure 1, A)

Patient 2 had a 3 x 2 x 5 cm left upper neck carotid space-avidly enhancing mass lesion, which encased the left ICA and partially encased the left ECA, resulting in a left vagus injury and postoperative haemorrhage. The patient required a shunt, an external jugular vein graft, and a patent graft with good flow after completing anastomosis. (Figure 1, B)

Based on the preoperative ultrasound and CT scan conducted outside NCI, Patient 3 had a well-defined mass located between submandibular and parotid regions, with no clear line of cleavage and extended downwards, engulfing the carotid artery with high vascularity. Multiple bilateral sub-centimetre and intra-parotid lymph nodes were also observed, with a preserved nodal pattern. The CT scan revealed an oblong vascular tumour measuring 6 x 2.5 x 2 cm located at the carotid bifurcation, which extended upwards, displacing both the internal and external carotid arteries without affecting the lumen diameters. The tumour terminated at the skull base, necessitating a left saphenous vein interposition graft during the surgery. (Figure 1, C)

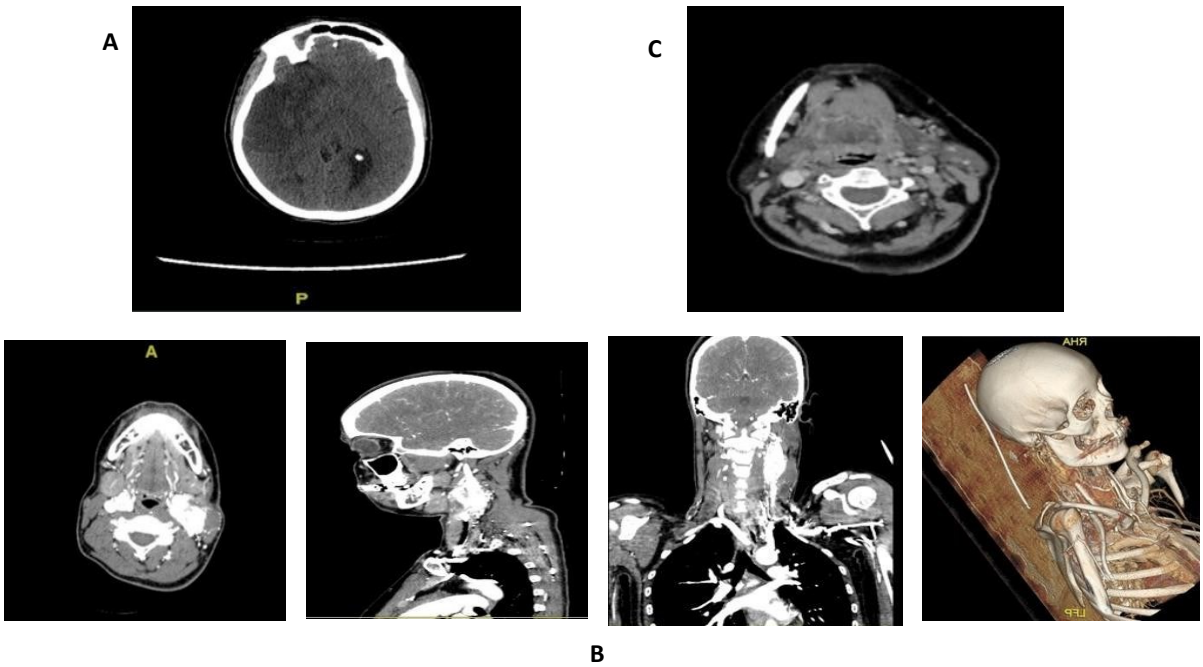

Figure 1: *(A) Right frontotemporal infarction detected post-operatively in Patient No.1, (B) Preoperative imaging in Patient No.2 and (C) Post-op Patient 3.*

CBTs are rare neoplasms that can be challenging to manage surgically. Advances in radiological imaging techniques have enabled more accurate pre-operative evaluation of CBTs, providing valuable insights into the extent of surgical resection required and the risk of complications. This study aimed to investigate the impact of radiological predictors on surgical management and the outcome of CBT resection [12].

The most common complaint among the studied cases was asymptomatic neck swelling, which is also consistent with previous reports [13]. By the time of diagnosis our study identified the average mass size being 5.1cm ± 1.77, with the majority of our patients being affected unilaterally on the right (60% of our patients). Only 1(5%) case required a pre-op balloon occlusion test and the majority of patients (85%) of cases were advanced and identified as class 3 on the Shamblin classification. The advanced nature of the tumours and complexity was reflected by the prolonged duration of surgery whereby our mean operative duration was 5.35 hours with a range from 4-9 hours in total, average blood loss of 1320 mL with a range from 200-4000 mL and the complications encountered intra- and postoperatively.

There were 11 cases (55%) with iatrogenic injuries and 1 case (5%) required mandibular subluxation to allow easier access to the tumor, 2 (10%) had multiple surgeries, 8 (40%) had vagal nerve sacrifice, 3 (15%) had hypoglossal nerve injury, 4 (20%) required vascular reconstruction of carotid arteries, 2 (10%) had primary carotid vessel repair, 2 (10%) underwent ligation of internal carotid arteries.

In terms of post-operative complications, 5 cases (25%) developed dysphagia, 5(25%) had a change of voice, 2 (10%) had tongue deviation on protrusion, 1(5%) had regurgitation during swallowing, 1 (5%) had dental pain, 1 (5%) had hemorrhage, 1(5%) had wound dehiscence, and 1 (5%) had a stroke.

Dysphagia and hoarseness of voice were the most common adverse events, which is consistent with previous reports as described by Kim et al. [14] and Patel et al. [15]. Other less common complications included deviated tongue on protrusion, regurgitation during swallowing, and wound dehiscence. The need for vascular reconstruction in 15% of cases is noteworthy and suggests that these procedures can be technically challenging and require a high level of expertise. This is consistent with previous studies that have reported a high incidence of iatrogenic injuries and the need for vascular reconstruction during surgery for CBTs [15].

Our study revealed that large tumour size, significant involvement of the surrounding vascular structures, increased vascularity of the tumour, and Shamblin class 3 were common features that contributed to the need for vascular reconstruction during carotid body tumour resection. Radiological factors that may indicate the need for vascular reconstruction during CBT surgery include Tumor size: Larger CBTs are more likely to involve the adjacent blood vessels and require vascular reconstruction during surgery. Tumor location: CBTs located near the bifurcation of the common carotid artery or adjacent to the internal or external carotid arteries are more likely to require vascular reconstruction. Tumor invasion: CBTs that invade the arterial wall are more likely to require vascular reconstruction. Degree of stenosis: CBTs can cause narrowing or obstruction of the adjacent blood vessels, leading to reduced blood flow and ischemia. The degree of stenosis can help to determine the extent of vascular reconstruction needed. Following surgery, 90% of our patients were transferred to the ICU. The average length of stay in the ICU was 3 days, with a range of 2 to 5 days. Patients also spent an average of 3.7 days in the surgical ward, with a range of 2 to 8 days. Patients who required vascular reconstruction had a longer overall hospital stay, ranging from 5 to 10 additional days compared to those who did not require reconstruction.

Conclusion

Our retrospective, observational cohort study assessed the hospital course for 20 patients with a diagnosis of carotid body tumours. Despite the slow-growing, benign nature of most Carotid Body Tumours, they are often diagnosed relatively late on with the majority of patients presenting with an asymptomatic neck mass which poses a higher chance of the tumour reaching a large size with local invasion, increasing vascularity and being scored as a higher Shamblin class thereby perpetuating the chances of vascular reconstruction. Pre-operative imaging can help identify the location and extent of the tumour, which can guide the selection of surgical approach to reduce the risk of complications. However, as shown in this study the complication rates and morbidity remain high primarily due to the difficulties encountered intraoperatively from complex, advanced carotid body tumours. Therefore, emphasis should be placed on thoroughly discussing all risks with patients pre-operatively guiding in appropriate patient selection.

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Author Contributions

All authors have accepted responsibility for the entire content of this manuscript and consented to its submission to the journal, reviewed all the results and approved the final version of the manuscript.

Abdelrahman Mohamed and Mahul Patel are joint first authors of this publication.

Data Availability Statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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