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Lateral skull base approaches in the management of benign parapharyngeal space tumors

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ABSTRACT

Objective: To evaluate the role of lateral skull base approaches in the management of benign parapharyngeal space tumors and to propose an algorithm for their surgical approach.
Methods: Retrospective study of patients with benign parapharyngeal space tumors. The clinical features, radiology and preoperative management of skull base neurovasculature, the surgical approaches and overall results were recorded.
Results: 46 patients presented with 48 tumors. 12 were prestyloid and 36 poststyloid. 19 (39.6%) tumors were paragangliomas, 15 (31.25%) were schwannomas and 11 (23%) were pleomorphic adenomas. Preoperative embolization was performed in 19, stenting of the internal carotid artery in 4 and permanent balloon occlusion in 2 patients. 19 tumors were approached by the transcervical, 13 by transcervical–transparotid, 5 by transcervical–transmastoid, 6, 1 and 2 tumors by the infratemporal fossa approach types A, B and D, respectively. Total radical tumor removal was achieved in 46 (96%) of the cases.
Conclusion: Lateral skull base approaches have an advantage over other approaches in the management of benign tumors of the parapharyngeal space due to the fact that they provide excellent exposure with less morbidity. The use of microscope combined with bipolar cautery reduces morbidity. Stenting of internal carotid artery gives a chance for complete tumor removal with arterial preservation.

1. Introduction

Parapharyngeal space tumors (PPST) represent rare pathologies, comprising only 0.5% of all head and neck tumors of which 70–80% are benign. A wide variety of histological tumor types have been described in this location but tumors in this area most often represent salivary gland (40–50%) or neurogenic tumors (20%) [1]. The complex anatomic relationships and proximity of vital neurovascular structures necessitate careful preoperative evaluation and precise surgical techniques [2]. Because approximately 80% of PPS lesions are benign, surgical removal should be contemplated based on patient morbidity [3]. Approaches to the PPS include lateral, transfacial and transoral approaches. In the last few decades lateral skull base surgery has made significant progress with a variety of techniques developed that provide excellent exposure of the lateral and anterior skull base up to the foramen magnum and the cavernous sinus. Lateral approaches to the skull base have evolved from the traditional transcervical approaches to infratemporal approaches with further modifications like the transcondylar–transtubercular extensions and the far lateral approaches. With the advent of excellent neuroradiological techniques it is possible to precisely map the skull base and pin pointedly locate tumors and their extensions. The internal carotid artery (ICA) can be managed by techniques like endovascular stenting and permanent balloon occlusion. In view of this, it is possible to accurately plan the surgical approach to the PPS and remove the tumors without damage to vital neurovascular structures.

In this paper, we review our experience with lateral skull base approaches in the management of benign PPST and propose an

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algorithm for surgical approaches. We also describe our techniques in the management of the ICA.

2. Materials and methods

The records of 55 patients who were diagnosed to have PPST at the Gruppo Otologico, a quaternary referral skull base center in Italy, between January 1996 and December 2012 were retrospectively reviewed. Nine patients with diagnosis of malignant tumors were excluded from the further analysis. We therefore analyzed 46 patients in this series, with 48 PPST as two patients presented with multiple tumors. The signs and symptoms were recorded. All patients underwent preoperative evaluation on the head and neck and skull base region with gadolinium (Gd) enhanced MRI, CT of the neck and temporal bones and four-vessel digital subtraction diagnostic angiography. In relevant cases, bony erosions of the vertical and horizontal portions of the ICA were noted in CT. Encasements of the ICA and involvement of the petrous apices were noted in MRI. Angiography was reviewed to look for the vascular supply to the tumor and signs of involvement of the ICA like irregularities of the wall or stenosis. During angiography, a functional evaluation of the circle of Willis was performed in each case using manual cross compression of the common carotid artery while injecting the contralateral ICA (Matas test) or dominant vertebral artery (Allcock test) looking for rapid and complete filling of the middle cerebral artery in the occluded side [4]. When necessary, a balloon occlusion test (BOT) followed by a permanent balloon occlusion (PBO) was carried out after ascertaining a good cross flow in angiography. Arterial reinforcement with stent was performed as a separate procedure under general anesthesia. The decision regarding the type and number of stents to be used is derived, based on the site and the length of the ICA (cervical, petrous or both) involved by the tumor and on the technical characteristics of the stents. In our experience, the Xpert® (Abbott Vascular, Ireland) and Astron® (Biotronik SE, Berlin, Germany) bare stents are most suitable for reinforcement of both the cervical and petrous portions of the ICA because of their diameter (four or five mm), length (20, 30, or 40 mm), flexibility (during endovascular deployment) and resilience during surgical dissection. We consider that at least 10 mm of tumor-free vessel wall should be reinforced both proximally and distally to the stent to allow safe surgical dissection around the tumor and it may be sometimes necessary to insert two to three stents to achieve this [5,6]. An interval of at least four to six weeks is recommended between stenting and surgery to allow the formation of a stabilized neointimal lining on the luminal surface of the stent [7,8].

Anticoagulation therapy – To reduce the risk of thromboembolic complications, antiplatelet therapy is commenced 5 days before stent insertion using a combination of clopidogrel (75 mg/day) and aspirin (100 mg/day). This regimen is continued for 1–3 months following stent insertion and then reduced to single-drug regimen consisting of only aspirin. Five days before surgery, the antiplatelet agents are stopped and low molecular weight heparin (LMWH) is commenced. Two days after surgery, antiplatelet agents are resumed and LMWH stopped 3 days after. The patient is then placed on life-long antiplatelet therapy.

The following surgical approaches were used based on the compartmentalization of the PPS into upper, middle and lower by Shahinian et al. [9]:

- *Transcervical approach (TCA) for tumors of the lower PPS* – In this approach the posterior belly of the digastric muscle was resected, the extra-temporal facial nerve (FN) was identified, and the styloid was transected to allow a larger and safer exposure into the PPS.
- *Transcervical–transparotid approach (TCTPA) for tumors of the middle PPS* – In addition to the TCA, this procedure included parotidectomy with preservation of the FN.
- *Transcervical–transmastoid approach (TCTMA) for tumors of the upper PPS with a posterior extension* – In this approach the TCA was extended to the postauricular region with a view to open the lateral skull base. In this procedure, the mastoid tip was removed, leaving the VII nerve in its canal. This was followed by an infralabyrinthine dissection to expose the sigmoid sinus and the jugular bulb to control the most inferior part of the tumor.
- *Infratemporal fossa approach-type A (ITFA-A) for tumors of the upper PPS with extension to the vertical tract of the ICA* – In this approach, a permanent anterior transposition of the facial nerve was performed to provide optimal exposure of the jugular foramen and to allow control over the distal parapharyngeal ICA up to the vertical petrous portion and concurrent removal of small intradural tumor extensions.
- *Infratemporal fossa approach-type B (ITFA-B) for tumors of the upper PPS with an antero-medial extension with respect to ICA* – This approach provided access to the vertical and horizontal portions of the petrous ICA, petrous apex and mid to lower clivus. During the exposure, the VII nerve was identified and left in situ without any manipulation.
- *Infratemporal fossa approach-type D (ITFA-D) for tumors of the upper PPS with an anterolateral extension with respect to ICA* – This approach consisted of a preauricular incision with a plane of dissection anterior to the horizontal petrous ICA and the eustachian tube giving access to the nasopharynx, the pterygopalatine fossa and the anterosuperior PPS.

Postoperatively all patients underwent regular imaging follow-up of the tumor with CT and MRI. Ultrasound and angiographic sequences (using both CT and MRI) were performed once a year for at least 2 years for all patients. In the patients with intraluminal stenting of the ICA, follow-up was once a year for the rest of their life.

3. Results

In this series we analyzed 46 patients with 48 PPST. Two patients presented with multiple tumors of which one was an ipsilateral vagal paraganglioma (VP) and carotid body tumor (CBT) and the other was a bilateral CBT. The male to female ratio was 1:1. The mean age of presentation was 48 years. The main clinical features are noted in Table 1. 12 (25%) of the tumors were found to

Table 1
Age, sex and clinical features of benign PPST.

	No.	%
Age and sex		
Male	23	50
Female	23	50
Symptoms		
Neck mass	24	50
Dysphagia	12	25
Hoarseness	9	19
Oropharyngeal swelling	8	17
Tinnitus	4	8
Hearing loss	3	6
Shoulder pain	1	2
Facial hyperesthesia	1	2
Tachycardia and vertigo with neck hyperextension	1	2

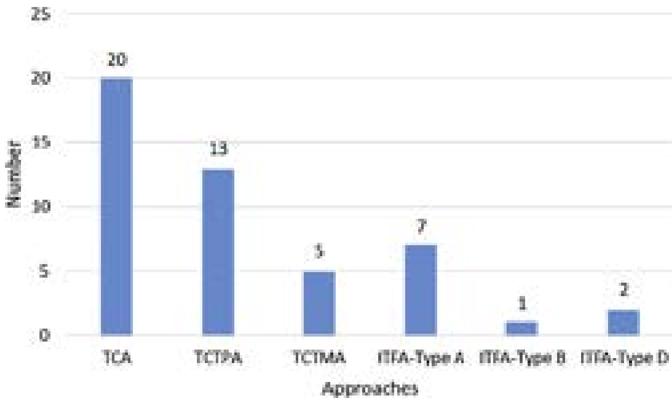

Fig. 1. The number and the surgical approaches used for PPS tumors in our series.

be prestyloid, and 36 (75%) were found to be poststyloid. Intracranial with intradural extensions were seen in two patients and extension into the infratemporal fossa in two cases. Preoperative arterial embolization of the tumor was performed in 19 patients, stenting of the ICA in 4 and PBO in 2 patients.

The TCA was applied in 19 (39.6%) tumors, the TCTPA in 13 (27%) of tumors and the TCTMA was applied in six (12.5%) tumors. The ITFA-A was applied in six (12.5%), ITFA-B in one (2.1%) and the ITFA-D in two (4.2%) tumors (Fig. 1). A tracheostomy was performed in one patient who was operated for synchronous ipsilateral VP and CBT. Total radical tumor removal was achieved in 46 (96%) of the cases. Subtotal removal was achieved in two cases of LCN schwannomas involving the foramen jugulare and the foramen magnum, respectively.

19 (39.6%) tumors were paragangliomas, 15 (31.25%) were schwannomas and 11 (23%) were pleomorphic adenomas (Table 2). In the immediate postoperative period, 31 patients had normal VII nerve function (HB I), one had HB II, five had HB III, two had HB IV, one had HB V and six had HB VI palsies. At the end of 1 year, 34 of them had recovered to HB I and six each to HB II and III (Table 3). Paragangliomas produced the highest LCN palsies, followed by neurogenic tumors (Table 4). Postoperative LCN deficits were highest in ITFA followed by the TCTMA (Table 5).

The mean follow-up was for a period of 4 years (minimum of 4 years and maximum of 15 years). There was one tumor recurrence in a patient with pleomorphic adenoma in whom a revision surgery with ITFA-D diagnosed a carcinoma ex-pleomorphic adenoma. Of the subtotal removals, one of the tumors showed minimal progression on MRI in the 9th year of follow-up and in the second case, the residual tumor has shown no progression in the 5th year of follow-up. We had one patient who developed cerebrospinal fluid (CSF) leak postoperatively which was managed by wound compression and bed rest.

Table 2
Histopathological diagnosis.

Histopathological diagnosis	No.	%
Schwannoma (n = 15)		
CN IX	3	6.25
CN X	3	6.25
LCN	5	10.42
CN XII	1	2.08
Sympathetic trunk	1	2.08
CN V/3	2	4.17
Paraganglioma (n = 19)		
Vagal	12	25
Carotid	7	14.6
Neurofibroma (n = 2)		
CN X	1	2.08
LCN	1	2.08
Salivary gland tumors (n = 12)		
Pleomorphic adenoma of the minor salivary gland	4	8.33
Pleomorphic adenoma of the deep lobe of parotid gland	7	14.58
Myoepithelioma of the deep lobe of parotid gland	1	2.08
Total	48	100

CN IX: glossopharyngeal nerve; CN X: vagus nerve; CN XII: hypoglossal nerve; CN V/3: mandibular nerve; LCN: lower cranial nerves; when it was not possible to distinguish the nerve of origin.

Table 3
Postoperative VII nerve function.

	Cranial nerve function	
	Immediate	After 1 year
CN VII		
HB1	31	34
HB2	1	6
HB3	5	6
HB4	2	–
HB5	1	–
HB6	6	–

CN VII: facial nerve; HB: House–Brackman grading of facial nerve.

3.1. Clinical case 1

A 30-year-old female was presented with a slowly progressing swelling in the left parotid area but with no evidence of cranial nerve dysfunction. HRCT scan and Gd enhanced MRI showed a dumb-bell shaped tumor in the area of the medial skull base and infratemporal fossa. The tumor was centered on the widened foramen ovale (Fig. 2). The ITFA-D with a transparotid approach was performed and tumor was completely removed. VII nerve was found stretched by the tumor but was preserved during the surgery. A small intradural component of the tumor was removed at the same stage and the dural defect was repaired with muscle graft and fibrin glue to prevent CSF into the neck. Histopathology confirmed a diagnosis of schwannoma. The patient suffered HB grade VI facial nerve palsy in the immediate Postoperative period which recovered to HB grade III after 1 year. The last MRI (4 years following the surgery) did not show any evidence of tumor (Fig. 3).

3.2. Clinical case 2

A 41-year-old male was presented with 6 months history of dysphagia and pharyngeal pain. On clinical examination a left

Table 4
LCN deficits in relation to the histopathology of tumor.

	Salivary gland tumors		Neurogenic tumors		Paragangliomas	
	preop	postop	preop	postop	preop	postop
CN IX			4	9	5	8
CN X			2	10	7	12
CN XI				4	1	6
CN XII			1	3		10
Horners syndrome				1		
First bite syndrome		1		1		

CN IX: glossopharyngeal nerve; CN X: vagus nerve; CN XI: spinal accessory nerve; CN XII: hypoglossal nerve.

Table 5
LCN deficits in relation to the different surgical approaches.

	TCA		TCTPA		TCTMA		ITFA-A		ITFA-B		ITFA-D	
	preop	postop	preop	postop	preop	postop	preop	postop	preop	postop	preop	postop
CN IX	3	6	1	1	1	4	4	6				
CN X	3	11	19	0	1	5	4	6		1		
CN XI		2		1		2	1	5				
CN XII		6				1	1	5				
Horners syndrome		1										
First bite syndrome		1		1								

CN IX: glossopharyngeal nerve; CN X: vagus nerve; CN XI: spinal accessory nerve; CN XII: hypoglossal nerve.

oropharyngeal swelling was observed. On CT and MRI, a 5 cm mass was seen arising from the deep lobe of the left parotid (Fig. 4). A TCTPA was applied and the tumor was radically removed with the help of the operating microscope. The postoperative histopathologic examination proved the diagnosis of a pleomorphic adenoma of the deep lobe of the parotid gland. The patient suffered a slightly paresis of the marginal branch of the facial nerve in the immediate postoperative period which recovered in 3 months. On follow-up MRI scans, the patient is totally disease free (Fig. 5).

3.3. Clinical case 3

A 28-year-old female was presented with pulsatile tinnitus and paresis of the right XI nerve. Clinical examination revealed a diffused swelling below the mandible. The MRI showed an enhancing mass in the lower neck (Fig. 6). Tumor was found to be displacing the ICA anterolaterally. The MRI signal characteristics were more in line with the diagnosis of a schwannoma. With a TCA, total removal of the tumor from the IX nerve was accomplished using the operating microscope in a piece-meal fashion. Histopathologic diagnosis confirmed a schwannoma. MRI scans over the last 2 years have confirmed the patient to be disease free (Fig. 7).

3.4. Clinical case 4

A 34-year-old woman was referred to our center with a history of neck mass. The patient showed no symptoms of any cranial nerve deficit on physical examination. On MRI (Fig. 8), two tumors were noted, one on each side. Angio-MRI (Fig. 9A) revealed a hypervascular lesion in the right parapharyngeal space, which displaced the internal carotid artery anteromedially without angiographic sign of adventitial infiltration. The lesion was supplied by the occipital and ascending pharyngeal artery. A similar hypervascularity was visualized in the left side tumor that was supplied by the external carotid artery (Fig. 9B). This confirmed a diagnosis of bilateral vagal paraganglioma. The right sided tumor (Fisch stage I) was found extending into the jugular foramen (arrow) without any sign of bone destruction.

A transcervical approach was used to excise the right vagal paraganglioma (Fig. 10A). The tumor was embolized 48 h before the surgery. The hypoglossal nerve and the spinal accessory nerves which were in close proximity to the tumor were dissected out and anatomically preserved (Fig. 10B). The vagus was resected along with the tumor which was removed en-bloc (Fig. 10C and D). Postoperatively the patient developed hypoglossal nerve palsy in addition to the vagal palsy. There were no other complications. Due to the postoperative nerve palsies, it was decided to irradiate the tumor on the opposite side (Fig. 11).

4. Discussion

The parapharyngeal space is in the shape of an inverted pyramid on a pedestal. The base is formed by the greater wing of the sphenoid at the skull base, including the jugular and

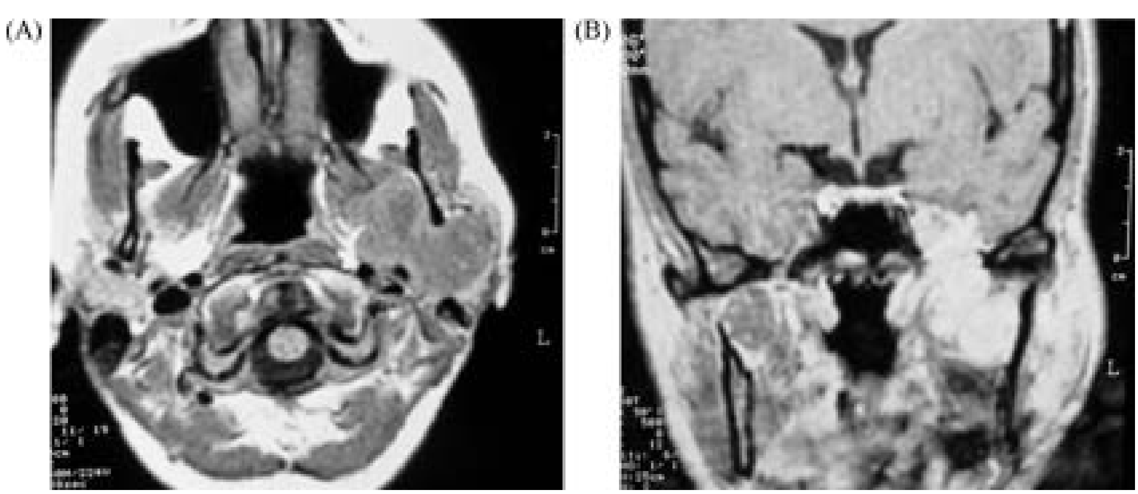

Fig. 2. (A) Preoperative axial T1 MRI showing a schwannoma of the V3 cranial nerve involving the upper PPS. (B) Preoperative coronal T1 MRI with gadolinium contrast showing the involvement of the foramen ovale.

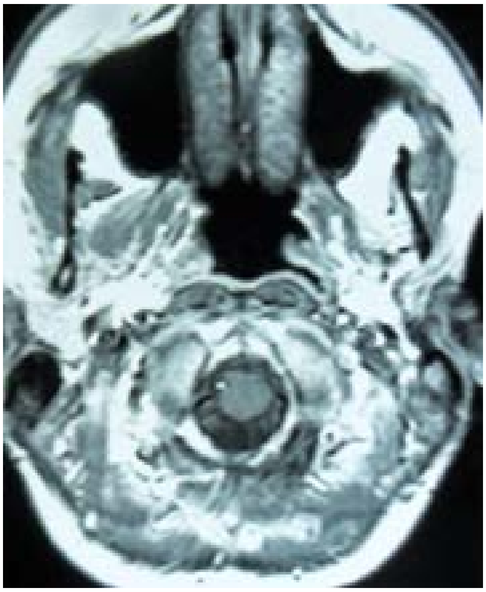

Fig. 3. Postoperative axial T1 MRI with gadolinium contrast showing the area to be tumor free.

hypoglossal foramen and the foramen lacerum (through which the ICA passes across superiorly). The apex is at the level of the greater cornu of the hyoid bone. The medial wall is composed of the superior constrictor muscle. The prevertebral fascia forms the posterior wall. The lateral wall, from an anteroposterior direction, is formed by the medial pterygoid muscle, vertical ramus of the mandible, the deep lobe of the parotid and the posterior belly of the digastric, respectively. Tumors of this area can be approached by three ways: laterally by the skull base approaches, anteriorly by the transfacial approaches or medially by means of the transoral approaches. The lateral skull base approaches being less morbid are more suitable in dealing with benign tumors of the PSS.

Compartmentalization of the PPS – Traditionally, the PPS has been divided into the prestyloid and or poststyloid compartments, but this is of little relevance in planning surgical approaches to this complex area. Shahinian et al. [9] had proposed that the PPS be divided into three compartments; superior (adjacent to the epipharynx), middle (adjacent to the mesopharynx) and inferior (adjacent to the hypopharynx and neck) without actually specifying the levels of division. Kanzaki and Nameki [10] defined six PPS compartments as follows. Using axial CT and/or MRI scans, the PPS was divided into two spaces – anterior and posterior – by a line connecting the styloid process and the tensor veli palatine muscle. However, using coronal views, they subdivided the two into three portions: superior, middle and inferior. They divided the superior and middle portions at the level of the inferior border of the lateral pterygoid muscle, and the middle and inferior portion at the level of the line connecting both sides of the inferior edge of the lateral plate of the pterygoid process. Therefore, by using both axial and coronal CT and/or MRI scans to identify key anatomical landmarks, they were able to subdivide the parapharyngeal space into six compartments. We felt that the lines applied by Kanzaki and Nameki [10] did not appropriately represent the compartments in the PPS, especially the lower division. Our classification of the PPS involves three compartments as suggested by Shahinian et al. [9] and while retaining the upper line proposed by Kanzaki and Nameki [10] separating the upper and middle compartments, the lower line separating the middle and lower compartments is taken as an imaginary line joining the angles of the mandible on both sides (Fig. 12 and Table 6). Using this division, we analyzed the presentation and surgical management of the PPST.

Clinical features – The clinical picture of parapharyngeal space tumors may be diverse and nonspecific, and patients may present with a wide variety of symptoms and signs [3]. As in our series, Chijiwa et al. [11] reported that a neck mass was the most common symptom. Due to the high prevalence of the neurogenic tumors in our series, signs of the LCN dysfunction (e.g. dysphagia and hoarseness) were the next most common symptoms.

Investigations – Neuroradiological imaging methods play pivotal role in the diagnosis and surgical planning of PPS. Both MRI and CT provide excellent imaging of the PPS. These help to differentiate prestyloid from a poststyloid localization of tumor and origin from the deep lobe of parotid. They also provide vital information on potential intracranial and/or intradural spread. Specific imaging characteristics are crucial for diagnosis of selected pathologies (e.g. paragangliomas) and dictate the need for further work up as well as choice of surgical approach [12]. CT is indicated in tumors invading the skull base to better delineate the details of bony erosion and extension. MRI is indicated in most cases and is complimentary to CT. We performed CT and Gd enhanced MRI in all our cases.

Preoperative vascular management – In our series, all vascular tumors underwent endovascular embolization between 2 and 4 days before surgery. Angiographic evaluation is mandatory in all cases of CBTs and VPs. The degree of ICA involvement, anatomical and functional integrity of the circle of Willis, tumor feeding

(A) (B)

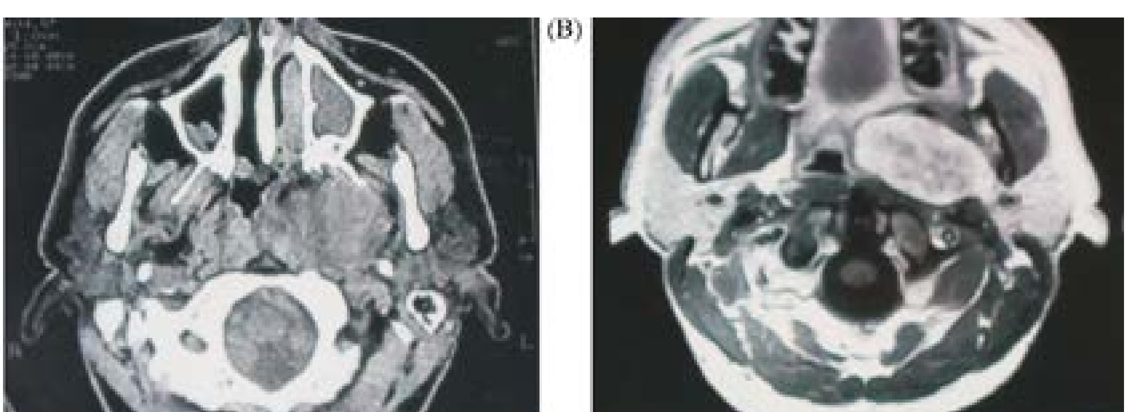

Fig. 4. (A) CT and (B) MRI (T2 axial), a 5 cm tumor occupying the middle compartment of the PPS in continuity with the deep lobe of right parotid gland.

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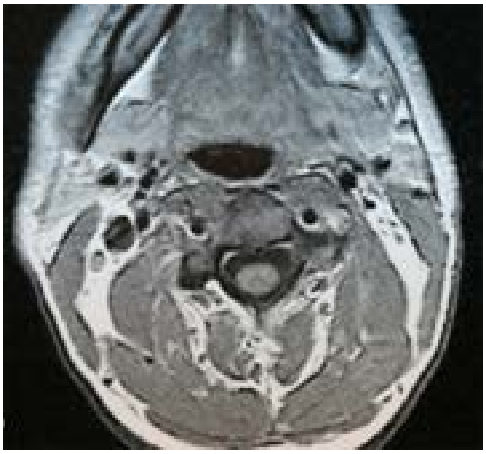

Fig. 5. Postoperative MRI after 6 years showing patient to be disease free.

branches, previous surgeries with vascular manipulation, prior radiotherapy and patients' age and general conditions are all issues that should be considered. Patients can be considered as having high risk of ICA injury if the angiogram shows tumor encasement involving more than half (i.e. 180°) of arterial circumference or the evidence of stenosis or irregularity of vessel walls [13]. The main purpose of preoperative protective stenting of the ICA is to reinforce the arterial wall allowing a safe subadventitial dissection and mobilization of the vessel reducing the risk of arterial damage during tumor removal [5,14].

Surgical approaches and algorithm – Surgical approach for tumor removal should meet two criteria: adequate intraoperative visibility for radical resection and minimal functional and cosmetic sequelae. Our experience has shown that adequate exposure to the PPS is achieved by the lateral skull base approaches like TCA, TCTP, TCTM and the ITFA or their combinations. These approaches not only provide excellent exposure of the PPS and magnification under the microscope but also reduce morbidity. The complete anatomy of the PPS and its contents and the trigeminal nerve with its branches can be controlled adequately by the infratemporal fossa approaches (ITFA) and its variations. Orbito-zygomatic extensions give additional exposure to the middle cranial fossa. The transcondylar–transtubercular extension of the classic ITFA type A is further directed toward giving access to tumors posterior and medial to the jugular bulb [15]. Hence any type of tumor extension can be effectively dealt using the lateral approaches.

The main cited drawback of the lateral approaches is damage to the facial nerve and loss of hearing. However it is important to note that ITFA types B, C and D do not involve mobilization of the facial nerve and it is relocated anteriorly only in ITFA type A. Even in ITFA type A, the postoperative facial nerve palsy that follows in the immediate postoperative period usually recovers to HB grade II or III over 6 months. Conductive hearing loss is a consequence of the ITFA but such patients can be rehabilitated by bone anchored hearing aids. But in comparison, complications of anterior approaches are far more morbid and include facial scar, eustachian tube dysfunction, cheek anesthesia, lower-lid ectropion, oroantral fistulas, destabilization of maxilla and palatal insufficiencies as a consequence of the maxillary swing approach [16–18]. Eustachian tube dysfunction would lead to long term otological consequences like ear discharge, effusion and chronic tympanic perforations [18]. The conductive hearing loss thus obtained would mean that there is no significant benefit with a maxillary swing approach with respect to hearing when compared to a lateral skull base approach. Besides tumor exposure is much better with the lateral approaches.

Since we did not deem it necessary to perform a mandibulotomy in any of our patients, we are strongly of the opinion that it is advisable not to divide the mandible as far as possible. Lip splitting mandibulotomies lead to a facial scar; other mandibulotomies have known to cause malocclusion, loss of mental nerve and paralysis of the mandibular branch of the facial nerve, tracheostomy in 6–27% of the cases and delayed wound healing [3,19,20]. Even the more recent single subcutaneous midline mandibulotomy has the drawback of tooth morbidity and in some cases the application of a tension band or segmental arch bar that is required to prevent rotation of the alveolus [21,22].

Our surgical experience with more than 3500 lateral skull base surgeries have led us to use of the operating microscope routinely during surgeries of the PPS during the most crucial and delicate

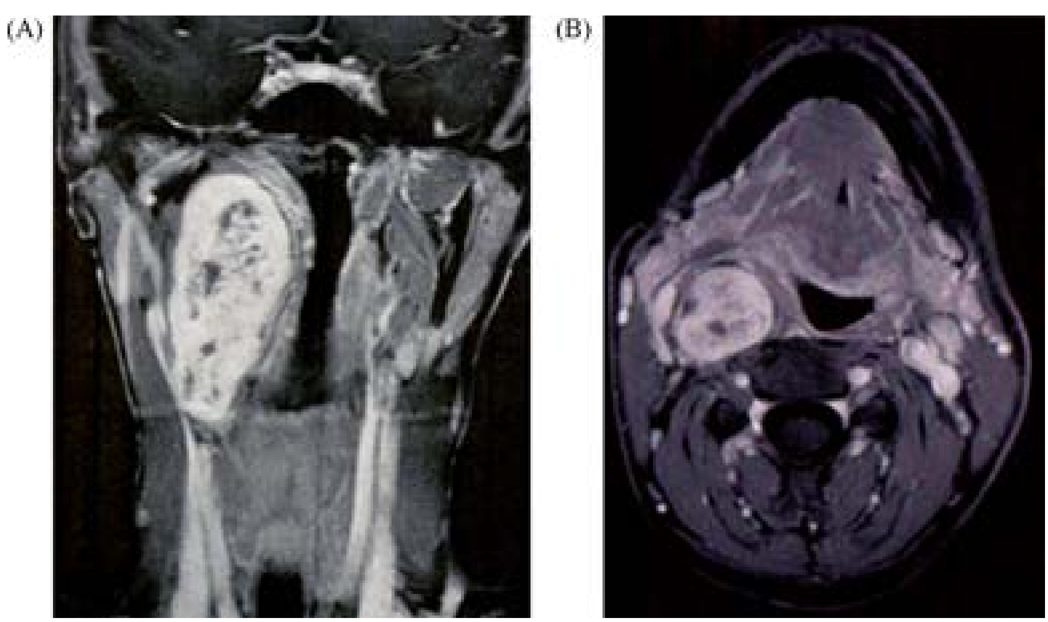

Fig. 6. (A) Preoperative T1 MRI (coronal view) showing tumor in the middle and lower compartments (B) axial view.

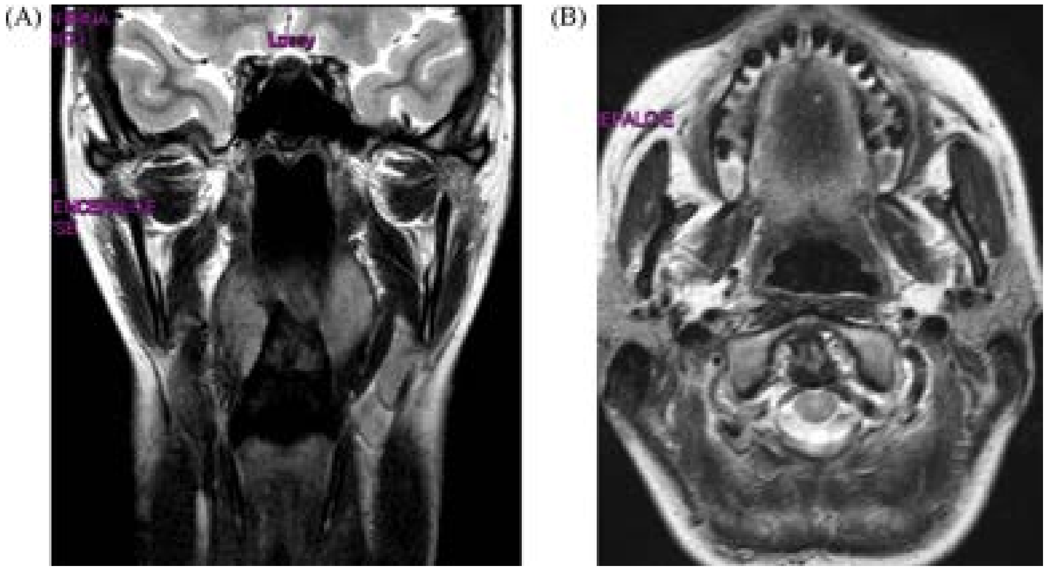

Fig. 7. Postoperative T2 MRI: coronal (A) and axial (B) showing complete tumor removal and patient to be disease free.

steps of the surgery. This, along with the use of a bipolar cautery permits an excellent operative field with minimal bleeding, adequate shrinkage of the tumor by cautery and excellent visualization of important neurovascular structures.

Based on our experience, we developed a useful algorithm (Fig. 13) for lateral approaches to the PPS based on the compartmentalization of PPS described in the discussion earlier. Our algorithm is a broad guide to the surgical approach to PPST, as tumors do not limit themselves to compartments and more often than not, one will encounter those crossing compartments. The algorithm is also limited to benign tumors as the management of malignant tumors being more aggressive, involves other considerations during surgery.

Below we will briefly mention the surgical steps of the lateral skull base procedures. Dealing with skull base tympanojugular paragangliomas is particularly complicated and has been dealt extensively in our previous publications [13,23–30] and is beyond the scope of this paper.

TCA – This approach is suitable for tumors affecting the lower compartment of the PPS. The skin incision begins from the tip of the mastoid going down in the neck in a C fashion into either the upper or lower skin creases depending on the size of the tumor. The sternocleidomastoid muscle, internal jugular vein, internal and external carotid artery and the lower cranial nerves are identified in the neck. The tumor is identified, separated from these structures and dissected out. The morbidity of the approach is minimal and in our series it was limited to transient VII nerve dysfunction of the inferior branch. However in case of vagal paragangliomas, the X nerve will most likely have to be sacrificed. In carotid body tumors, bleeding can be a particular problem even after embolization. However after the introduction of endovascular stenting of the ICA by our team [4,5,13,25,28], the surgery has become much safer and invasion of the ICA is no longer a serious limitation of surgery.

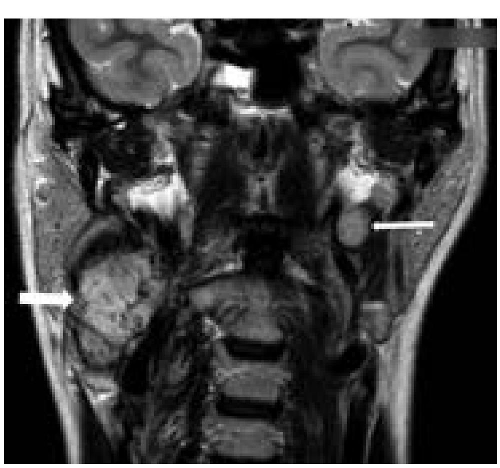

Fig. 8. Two tumors are seen on coronal MRI, the right one (thick arrow) bigger than the left (thin arrow) at the level of the pharynx.

TCTPA – This approach is suitable for tumors of the deep lobe of parotid and for larger tumors affecting the middle compartment of PPS. The incision is the classical parotid incision with extensions if necessary. The facial nerve is identified at the stylomastoid foramen and traced into the parotid. Either a superficial or total parotidectomy is done with preservation of the facial nerve. More medial dissection is performed by identification of the ICA, external carotid artery, internal jugular vein and LCN from the neck to the PPS [6].

TCTMA – This approach is suitable for tumors affecting the upper compartment of the PPS with a posterior extension (extension to the jugular foramen with neither intradural nor carotid artery involvement). It is indicated mainly for selected cases of neurogenic tumors affecting the LCN. There is minimal morbidity associated with the approach with no effect on hearing. The incision is a classical postaural incision with a transcervical extension. A complete mastoidectomy is performed and drilling is continued in the infralabyrinthine area with an aim to isolate the jugular bulb. The sigmoid sinus and the jugular bulb are isolated. Dissection in the neck is carried out to identify the great vessels in the neck and the lower cranial nerves. Proximal and distal controls of the internal jugular vein are achieved and the tumor is isolated and removed by ligating the sigmoid and the internal jugular vein.

ITFA-A – This approach is suitable for tumors of the upper compartment of the PPS when proper management of both high neck and petrous portion of ICA is necessary. Thus it is an optimal approach for PPST extending to the jugular foramen with or without intradural extension (e.g. schwannomas and neurofibromas

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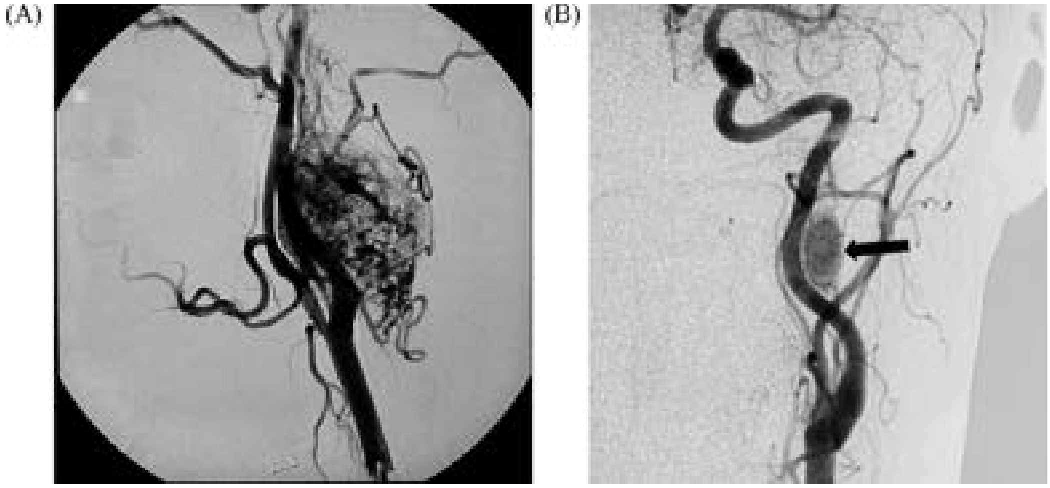

Fig. 9. Angio-MRI of the lesions: (A) A hypervascular lesion in the right parapharyngeal space, which has displaced the internal carotid artery anteromedially without angiographic sign of adventitial infiltration. The lesion is supplied by the occipital and ascending pharyngeal artery. (B) The tumor on the left (arrow) in the contralateral parapharyngeal space is supplied by the external carotid artery.

of the LCN and VP). Incision is an extended postaural incision with a transcervical extension. The external auditory canal is closed as a blind sac. As subtotal petrosectomy is done and the facial nerve is identified from the geniculate ganglion down to the parotid and transposed anteriorly. The sternocleidomastoid and the digastric are detached at the mastoid tip and the great vessels in the neck are identified. The bone around the jugular bulb is completely drilled out and the tumor is exposed after drilling out the tympanic bone anteriorly. Staged tumor removal is highly recommended for tumors with intradural extension with more than 2 cm to avoid CSF leak in the neck. As shown from our results the drawbacks of this approach are due to the rerouting of the facial nerve, with a nerve deficit (HB grade III or II), and closure of the external auditory canal with conductive hearing loss.

ITFA-B – This approach is suitable for tumors of the upper compartment of the PPS with an anteromedial extension in relation to the ICA. This approach provides access to the vertical and horizontal segments of the petrous portion of ICA, petrous apex and mid to low clivus. The main indication for this approach in PPST is petrous ICA encasement.

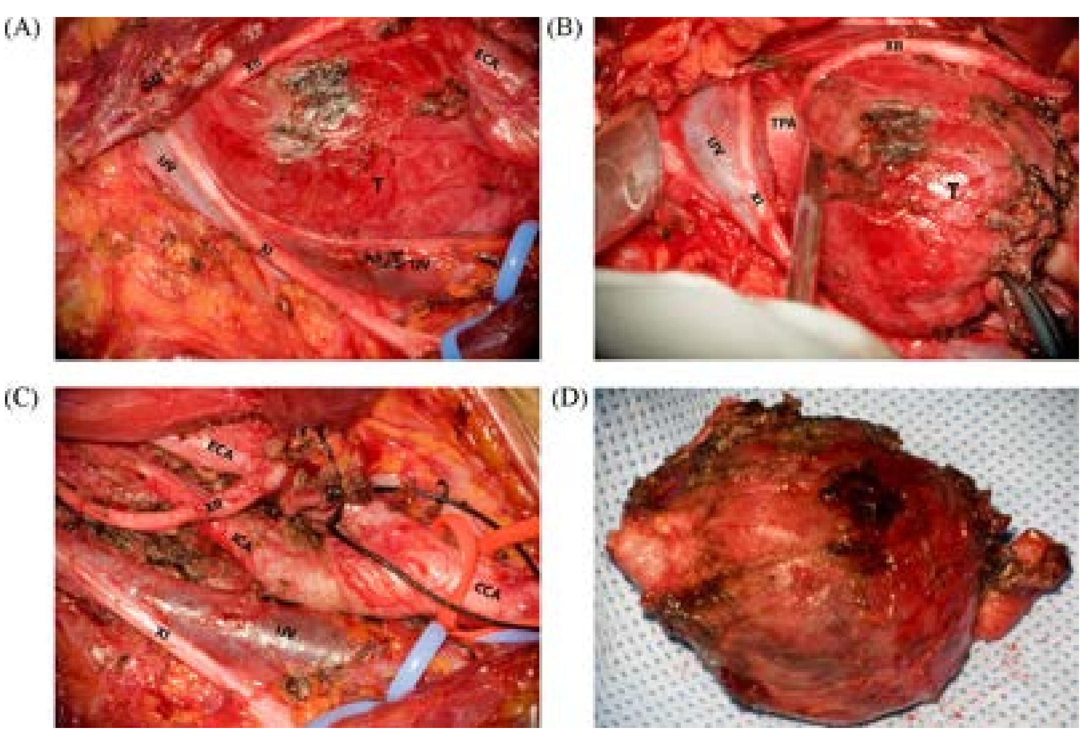

Fig. 10. (A) Transcervical approach for removal of the right vagal paraganglioma. The dissection of the tumor from the external and internal carotid arteries starts from below upwards. The spinal accessory nerve runs posterior to the tumor and is preserved. (B) The superior aspect of the tumor is dissected from the transverse process of the atlas. (C) After complete resection of the tumor. (D) En-bloc resection of the tumor has been accomplished. ECA: external carotid artery; ICA: internal carotid artery; CCA: common carotid artery; XII: hypoglossal nerve; T: tumor; IJV: internal jugular vein; XI: spinal accessory nerve; IJV: internal jugular vein; DM: digastric muscle; TPA: transverse process of the atlas.

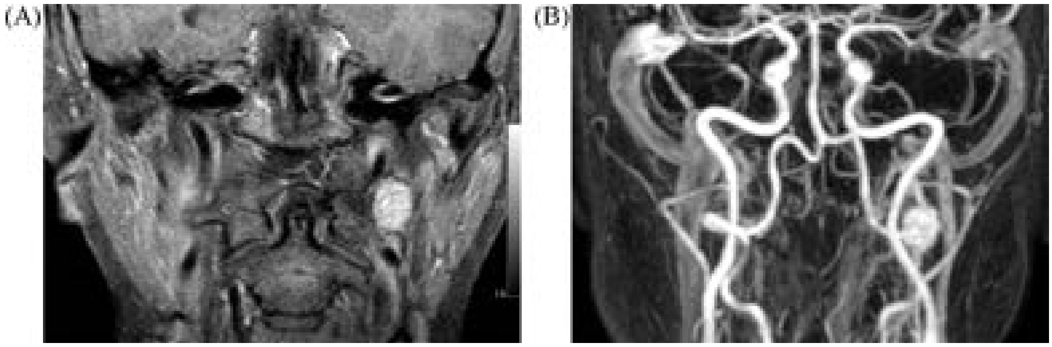

Fig. 11. (A) Postoperative MRI (coronal view) and (B) angiography at the second year of follow-up and 1 year after radiotherapy (for the left vagal paraganglioma) shows complete tumor removal on the right side while the size of the left sided tumor size remains unchanged.

ITFA-D – This approach with a preauricular incision is suitable for tumors of the upper compartment of the PPS with an anterolateral extension in relation to the ICA. This approach represents an extra-labyrinthine approach to the infratemporal fossa, the pterygopalatine fossa, PPS and the orbit. The advantages include sparing of the middle ear and eustachian tube while the disadvantages include limited exposure of the ICA.

LCN sequelae and postoperative complications – Preoperative clinical assessment of the LCN is an important factor to be taken into consideration in the management of PPST. Our results support the observation that histopathology and preoperative LCN function influence the prospect of postoperative LCN preservation. Among PPST, paragangliomas produced the highest LCN palsies due to their aggressive nature and this was followed by neurogenic tumors. Though postoperative LCN deficits were highest in ITFA followed by the TCTMA deficits were mainly due to the size, location and origin of the tumors rather than the procedure itself. For the cases that have evidence of preoperative LCN dysfunction, total resection of the involved LCN is recommended. In our experience, we found that in cases of IX and X LCN palsies contralateral compensation was very good over a period of time and very rarely needed intervention and this was especially true in young patients. We had minimal complications in our series despite the fact that we managed many complex cases. We attribute this to the fact that we perform a thorough preoperative work-up of the patient and routinely use the microscope and the bipolar cautery for dissection.

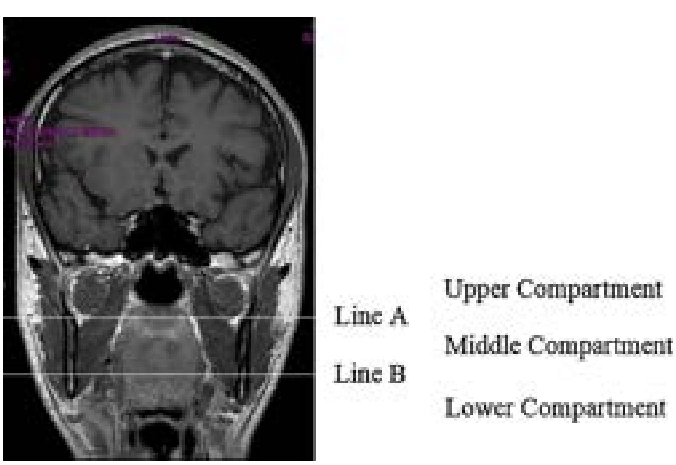

Fig. 12. Compartments of the PPS: upper, middle and lower. Line A drawn at the lower border of the lateral pterygoid muscle. Line B drawn at the angle of mandibles.

Endovascular stenting of the ICA – Patients can be considered as having high risk of ICA injury if (1) encasement reaches more than half (i.e. 180°) of arterial circumference, (2) there is evidence of stenosis or irregularity of vessel walls, (3) previous treatments had been done (radiation therapy or surgery) on the ICA area and in case of (4) multiple ipsilateral lesions, (5) single ipsilateral ICA or (6) recurrent disease medial to the petrous ICA [13].

The main purpose of preoperative protective stenting of the ICA is to reinforce the arterial wall allowing a safe subadventitial dissection during tumor removal [5,14,25]. Simpler manipulation of the vessel even in its intraosseous portion is a derived but not secondary feature; the result is an easier clearance of disease in the pericarotid area. From an oncologic point of view subadventitial dissection is the most appropriate technique when dealing with ICA involvement in HNP and consists in the separation of the muscular layer from the adventitial layer of the vessel. This maneuver may weaken the vessel leading to dilatation and delayed aneurysm formation or even tearing and rupture of the arterial wall. Thickness of the adventitial layer decreases from the cervical to the intrapetrous portion, and at the level of the horizontal segment there is only a thin fibrous layer dividing the media from the periosteoum of the carotid canal. From a surgical and pathological point of view, HNP limited to the neck compartment as CBT and class I and II VP are mainly exposed to ICA injury during tumor removal, while lesions invading the skull base (class III VP and TJP) and involving the intrapetrous ICA require extensive mobilization of the vessel from its bony canal in order to achieve complete clearing of the tumor from the bone medial to the carotid canal. When dealing with tumor encasing the genu or horizontal segment of the petrous ICA (class C3 and C4 TJPs, stage III VPs), subadventitial dissection carries a high risk of intraoperative rupture. The presence of the stent allows a safe subadventitial resection of the tumors and permits mobilization of the vessel reducing the risk of arterial damage.

Table 6
Compartments of the PPS and tumors commonly arising in them.

Compartments of the PPS	Separating radiological landmarks
Upper	Between the skull base and the line joining the lower borders of the lateral pterygoid muscles of both sides
Middle	Between the line joining the lower borders of the lateral pterygoid muscles and the line joining the angle of mandible on both sides
Lower	Between line joining the lower borders of the angle of the mandibles and the plane of the hyoid

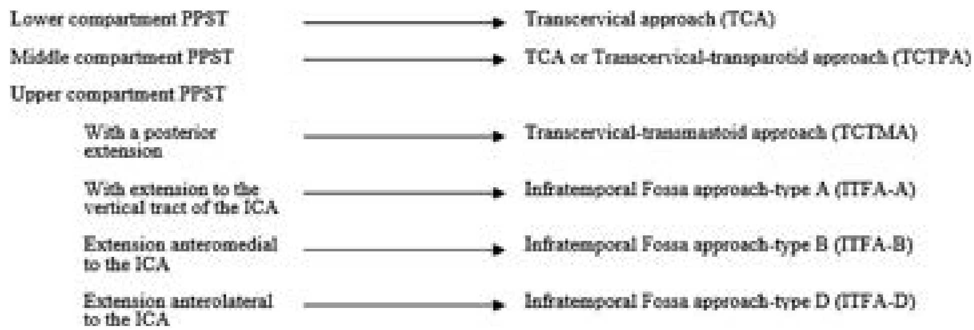

Fig. 13. Surgical algorithm for approach to PPS tumors.

5. Conclusion

PPST are challenging lesions to treat but being mostly benign, the success rate is high. Lateral skull base approaches have an advantage over other approaches in the management of benign tumors of the parapharyngeal space due to the fact that they provide excellent exposure with less morbidity. The TCA is the ideal approach for tumors of the lower compartment of PPS, the TCA/TCTPA for the middle compartment and ITFA and TCTMA for the upper compartment. A thorough preoperative assessment with CT, MRI and angiography is essential. Stenting of the ICA gives a chance for complete tumor removal with arterial preservation in comparison to PBO. A thorough assessment of the LCN is also necessary to plan the management. The use of an operating microscope combined with bipolar cautery in lateral skull base surgeries leads to improved results and decreased postoperative complications.

Conflict of interest

All the authors hereby declare that they have no conflict of interest.

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