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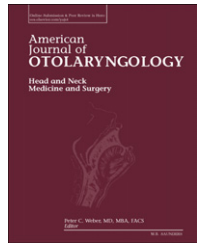

Long term surgical and hearing outcomes in the management of tympanomastoid paragangliomas☆,☆☆,★

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ABSTRACT

Objective: To analyze the long term outcomes after surgery in tympanomastoid paragangliomas.
Study design: Retrospective study.
Methods: The charts of 145 patients with tympanomastoid paragangliomas managed between 1988 and 2013 were reviewed. The clinical features, audiological data, pre- and postoperative notes were noted. The tumors were staged according to the modified Fish and Mattox classification. The surgical approaches for all patients were formulated according to the surgical algorithm developed at our center.
Results: 34 (23.5%), 46 (31.7%), 22 (15.2%), 18 (12.4%) and 25 (17.2%) patients were diagnosed to have TMP class A1, A2, B1, B2 and B3 tumors respectively. Gross tumor resection was achieved in 141 (97.2%) patients. The facial nerve was uncovered in four patients and infiltrated in three. The cochlea was found eroded in seven cases. The mean follow-up was 48.4 months. Recurrence was seen in one patient (0.7%). In the cases where the facial nerve was preserved (n = 143), the nerve function was graded as HB grade 1 in 138 patients (97%). Postoperatively, the mean AC showed an improvement in all categories except in class B2 and B3, which corresponds to the classes that include patients who underwent subtotal petrosectomy.
Conclusion: We report the long term surgical outcomes in tympanomastoid paragangliomas in the largest series published till date. It is possible to completely eradicate all types of tympanomastoid paragangliomas with minimum sequelae by

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choosing the correct surgical approach to achieve adequate exposure for individual tumor classes as described in our classification and algorithm.
Level of evidence: IIb.

1. Introduction

Temporal bone paragangliomas (TBPs) are benign but locally aggressive tumors that arise from various sites in the temporal bone. There are two types: (1) tympanomastoid paraganglioma (TMP), commonly known as 'glomus tympanicum (GT)', which are tumors that originate from the glomus bodies that lie along the Jacobson's nerve and the Arnold's nerve and (2) tympanojugular paraganglioma (TJP) or 'glomus jugulare' which originate from the paraganglia located in the adventitia of the dome of the jugular bulb or those that originate in the hypotympanum with secondary invasion of the jugular bulb [1]. The term 'glomus' itself is a misnomer [2,3] and hence its use must be discontinued and the above terminology must be used to replace 'glomus' consistently while reporting in literature.

With the advances in imaging and refinements in surgical techniques even the most difficult TMPs can be safely eradicated thereby offering a complete cure and making surgery the treatment of choice. The rates of recurrence are very low and hearing preservation can be achieved in almost all cases. The post-operative sequelae and complications are minimal and are comparable to other middle ear surgeries. Barring the one by Forest et al. [4] there have been no other articles that comprehensively described long term outcomes of surgery in TMPs in the last 20 years. In this article we present the long term outcomes in the surgical management of patients with this rare subset of tumors at our center over a 30-year period which is presently also the largest series published in English literature thus far.

2. Materials and methods

The medical records of 145 patients with TMPs who were managed at the Gruppo Otologico, Piacenza, Rome (Italy), between December 1988 and July 2013 were reviewed. Clinical, audiological and radiological data of all the patients were documented and analyzed and tumors staged according to the modified Fish and Mattox classification [5] (Table 1). At our center all patients with TMPs undergo pre-operative HRCT with iodinate contrast medium and an MRI with gadolinium DTPA enhancement when the tumor is found to be close to the jugular bulb or the carotid. Angiography and neuroendocrine testing are not routinely performed for TMPs. The surgical approaches for all patients with TMPs are formulated according to the surgical algorithm as shown in Fig. 1. The surgical techniques have been described elsewhere [1,6,7]. The pre-operative and postoperative facial nerve (FN) function was graded according to the House–Brackmann (HB) grading system [8]. Follow up consisted of clinical evaluation, hearing tests and serial CT scans. Follow up was defined as that period of time from surgery to the most recent office visit or patient contact. Most patients were followed up at our center. Four patients who were lost for follow up or were not followed up at our center were contacted by phone to get details of follow up.

2.1. Statistical analysis

Data were analyzed with a statistical software program (SPSS Statistics for Windows version 20, Chicago, IL). Continuous data were summarized as mean ± interval of confidence at 95% (IC 95%). Categorical data were presented as frequencies and percentages. Preoperative and postoperative hearing results were evaluated according to tumor class and type of surgery performed. p Values below 0.05 were considered significant.

This study has been approved by the institutional review board of the Associazione Italiana Neurotologica (AINOT).

2.2. Results and observations

Of a total of 382 patients with TBPs who were managed at the Gruppo Otologico, a quaternary referral center for otology and skull base surgery in Italy, 145 were diagnosed to have TMPs. The male:female ratio was 15 (10.3%):130 (89.6%). The age, sex and clinical presentation of the study population are presented in Table 2. The median age of the population was 55 years (range 13 years–82 years). 93 (64%) patients presented with pulsatile tinnitus, 118 (81%) with hearing loss, and 22 (15%) with vertigo and 10 (7%) presented with ear discharge and ear

Table 1 – Modified Fisch and Mattox classification of tympanomastoid paragangliomas.

Class	Description
A	Tumors limited entirely to the middle ear
A1	Tumors completely visible on otoscopic examination
A2	Tumor margins are not visible on otoscopy. Tumor may extend anteriorly up to the Eustachian tube and/or to the posterior mesotympanum
B	Tumors limited to the tympanomastoid segment (middle ear cleft) of the temporal bone
B1	Tumors filling the middle ear with extension into the hypotympanum and tympanic sinus
B2	Tumors filling the middle ear with extension into the mastoid and medially to the mastoid segment of the facial nerve
B3	Tumors filling the middle ear with extension into the mastoid with erosion of carotid canal

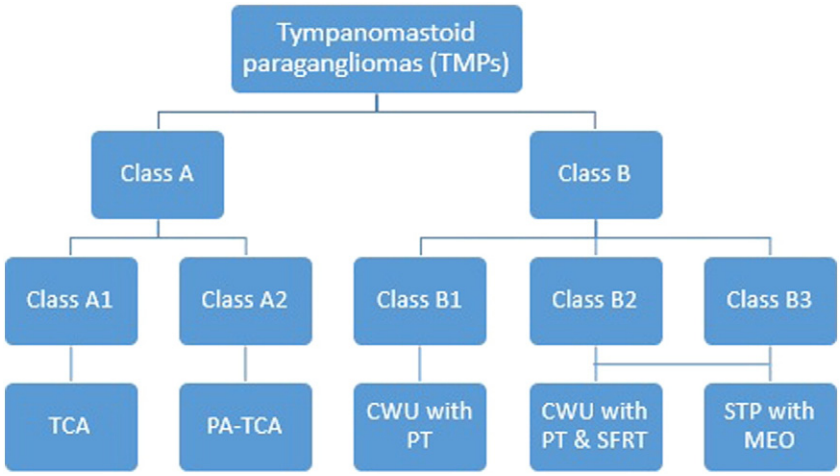

Fig. 1 – Algorithm for the management of TMPs at the Gruppo Otologico.

pain. A pulsatile reddish mass was seen behind an intact tympanic membrane (TM) in 137 (94%) of the patients while the TM was perforated in the remaining 8 (6%) patients. Preoperative facial nerve palsy was seen in 2 (1%) patients. The mean length of symptoms previous to presentation was 36 ± 33.1 months (range, 3–192 months). Two patients presented to us after failure of radiotherapy (RT) and three others presented to us after failure of surgery elsewhere. There were no patients associated with other paragangliomas elsewhere in the body.

2.3. *Tumor class and surgical procedure*

34 (23.5%) patients were diagnosed to have TMP class A1 tumors, 46 (31.7%) to have class A2 tumors, 22 (15.2%) to have class B1, 18 (12.4%) to have class B2 and 25 (17.2%) to have class B3 tumors. All class A1 tumors were approached with a transcanal approach (TCA), class A2 with a postauricular transcanal approach (PA-TCA) and class B1 with a canal wall up (CWU) mastoidectomy with a posterior tympanotomy (PT) (Fig. 2). 10/18 patients with class B2 tumors underwent with a CWU mastoidectomy with a PT and a subfacial recess tympanotomy (SFRT) (Fig. 3). The remaining eight patients underwent a subtotal petrosectomy (STP) with middle ear obliteration (MEO) due to cochlear fistula, inadequate exposure of tumor margins or bleeding. All but one of the patients with class B3 tumors underwent an STP with MEO. In the remaining case, an infratemporal fossa approach (ITFA) type A was performed combined with a transcochlear approach (TCA) for a large class B3 tumor which had infiltrated the facial nerve which was sacrificed and reconstructed using a sural nerve graft. This patient had a previously anacoustic ear. In another patient who underwent an STP, the facial nerve was sacrificed and a facial-hypoglossal anastomosis was done later. One patient who had undergone RT elsewhere for a class B3 tumor also underwent an STP.

2.4. *Intraoperative findings (Table 3)*

Gross tumor resection was achieved in 141 (97.2%) patients. Subtotal resection (tiny tumor bit or >98% tumor removal) was the result in four patients with B2/B3 tumors. Barring the patients in whom an STP with MEO was performed (n = 112), the ossicular chain was preserved intact in 106 (95%) patients. In the remaining 6 (5%) patients, the ossicular chain was reconstructed with autologous incus interposed between the stapes and the malleus in a second stage surgery. The facial nerve was uncovered in four patients and infiltrated in three. The cochlea was found eroded in seven; middle fossa dura and the temporomandibular joint were eroded in two cases each. There was an associated cholesteatoma in three patients and cholesterol granuloma in two patients. In two patients there was an intraoperative CSF leak which was closed using a muscle graft.

2.5. *Follow up and complications*

The follow-up ranged from six to 230 months (mean: 48.4 ± 51.1 months, median: 47.2). A recurrent TMP was seen only in one patient (0.7%) after nine years for whom a revision surgery was performed and the tumor was excised completely. This patient is tumor free after five years of follow up after the second surgery. Postoperative TM perforations were seen in six (4.1%) patients and external auditory canal stenosis in thee (2.1%) patients which were all reconstructed in a second stage. A pearl-like residual cholesteatoma was found in the external auditory canal in one case (0.7%) and easily removed in the outpatient clinic.

In the immediate post-operative period, in the cases where the facial nerve was preserved (n = 143), the nerve function was graded as HB grade 1 in 138 patients (97%), HB grade II in three (2%) and HB grade III in two (1%) had grade III. Of the five facial palsies, the tumor was adherent to an uncovered facial nerve in three cases. At the last follow-up the facial palsies had recovered and all 143 patients had grade I FN function. In the patient in whom the nerve was sacrificed and reconstructed with a sural nerve graft, the nerve function was graded as HB grade III after one year. In the patient in whom a hypoglossal facial anastomosis was done, the nerve function was HB grade IV after 1 year.

2.6. *Hearing results*

Preoperative and postoperative hearing was analyzed according to the modified Fish classification of TMPs. Eleven patients

Table 2 – Age, sex and presenting symptoms of patients with TMPs treated at the Gruppo Otologico.

Class of TMP (n = 145)		Number	Age				Sex		Presenting symptoms				Otoscopy		Facial nerve palsy
			<20 years	20–40 years	40–60 years	>60 years	Male	Female	Pulsatile tinnitus	Hearing loss	Vertigo	Pain, otorrhea	Pulsatile mass behind intact TM	TM perforation/ previous surgery	
A	A1	34 (24%)	–	6 (17%)	21 (62%)	7 (21%)	–	34 (100%)	25 (73.5%)	23 (68%)	5 (15%)	–	34 (100%)	–	–
(n = 80)	A2	46 (32%)	–	8 (17%)	22 (48%)	16 (35%)	5 (11%)	41 (89%)	17 (37%)	33 (72%)	6 (13%)	2 (4%)	45 (98%)	1 (2%)	–
B	B1	22 (15%)	1 (5%)	2 (9%)	14 (63%)	5 (23%)	1 (5%)	21 (96%)	20 (91%)	21 (96%)	5 (23%)	2 (9%)	20 (91%)	2 (9%)	–
(n = 65)	B2	18 (12%)	–	4 (22%)	5 (28%)	9 (50%)	–	18 (100%)	15 (83.3%)	16 (89%)	2 (11%)	2 (11%)	16 (89%)	2 (11%)	1 (6%)
	B3	25 (17%)	–	4 (16%)	9 (36%)	12 (48%)	1 (4%)	24 (96%)	16 (64%)	25 (100%)	4 (16%)	4 (16%)	22 (88%)	3 (12%)	1 (4%)
Total		145 (100%)	1 (1%)	24 (16%)	71 (49%)	49 (34%)	7 (5%)	138 (95%)	93 (64%)	118 (81%)	22 (15%)	10 (7%)	137 (94%)	8 (6%)	2 (1%)

with preoperative anacusia (seven due to cochlear erosion, three due to previous surgery elsewhere and one due to previous RT) were excluded from the hearing analysis. Two patients with incomplete postoperative records were excluded from the postoperative hearing results analysis. It can be observed in Fig. 4 that preoperative hearing worsened with progression of tumor class. Postoperatively, the mean AC showed an improvement in all categories except in class B2 and B3, which corresponds to the classes that include patients who underwent STP. There was no statistically significant difference in the improvement in AC among the classes A1 through B1 ($p = 0.27$, Kruskal–Wallis test).

We also sought to identify the impact of surgical techniques on hearing. For this we classified hearing conservation surgeries into one group and STP into another and compared their effect on hearing. Fig. 5 shows box-plots for pre- and postoperative AC and BC in both groups. Preoperatively, both AC and BC (mean pure tone averages) were significantly better in the hearing conservation surgery group when compared to patients who underwent STP ($p = 0.0001$, U Mann–Whitney test). Postoperatively, AC improved in the hearing conservation surgery group by 7.13 dB (IC 95% 9–5) and deteriorated in the STP by 23.32 dB (IC 95% 18–28) group as a logical consequence of the surgery ($p = 0.0001$ U Mann–Whitney test). However it can be seen that STP caused a mean decrease in AC of only 23.32 dB because this group already had a greatly deteriorated AC as a consequence of the progressive disease. There was no significant difference in BC in both groups after surgery.

3. Discussion

Despite the fact that TMPs tumors are the most common primary neoplasm of the middle ear, they are a diagnostic and therapeutic challenge, but with the right diagnostic and surgical protocols it is possible to achieve excellent results. Regardless of significant advances in the understanding of this subset of tumors there still exists some areas of ambiguity and controversies. The classification of tumors, the clinical and imaging protocols and the significance of surgery versus other forms of treatment are discussed below.

3.1. *Classification*

Different classifications have been proposed to describe TMPs. The most widely used classification is the one proposed by Fisch and Mattox that divided the tumors based on their extensions [9,10]. The other important classification is the one proposed by Glasscock and Jackson that retains the tympanicum-jugular dichotomy [11]. The importance of a classification system is that, it should serve to determine either the prognosis or the treatment of a particular disease process, or preferably both [12]. Both the existing classifications do not provide any prognostic or therapeutic value but focus on the anatomical extensions of the tumors. The possibility of involvement of the internal carotid artery in TMPs, which occurred in 25 (17.2%) of our patients, has not also been addressed in either of the classifications. By modifying the Fisch classification and dividing the tumors

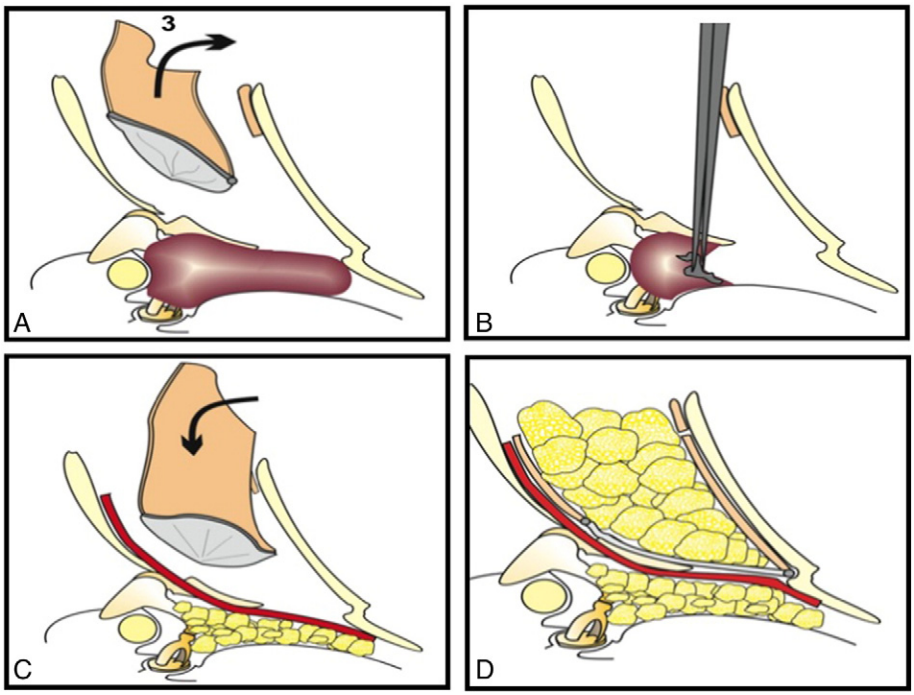

Fig. 2 – The postauricular transcanal approach for removal of class A2 tumors using the 'finger glove' technique; Removal of the skin and TM (A), manipulation and removal of the tumor using a bipolar cautery (B), replacing the skin-TM flap after an underlay tympanic membrane graft (C), gelfoam packing of the middle ear and external auditory canal (D).

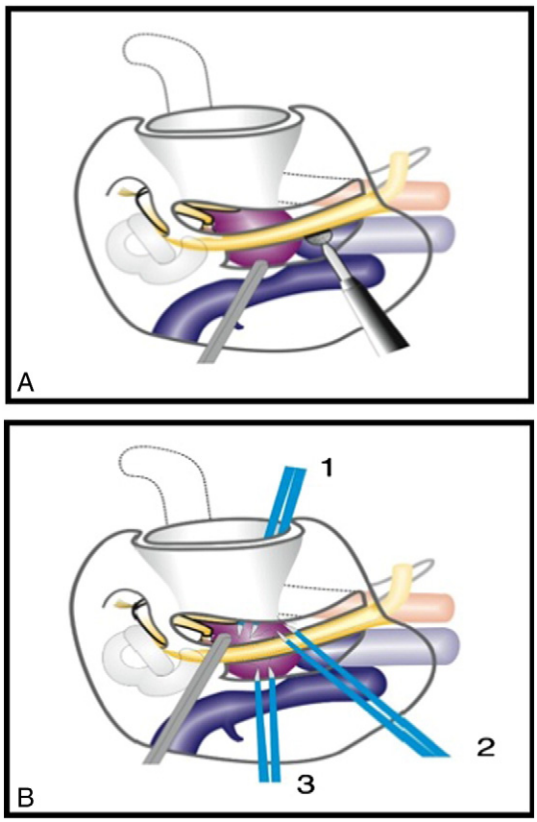

Fig. 3 – Canal wall up procedure with the addition of posterior tympanotomy, and subfacial recess tympanotomy (A). Note how it is possible to tackle the tumor by using bipolar cautery from three angles (B).

into A1, A2, B1, B2 and B3 (Table 1) [1] we retained the structure of the popular Fisch classification and also made it surgically relevant by applying appropriate surgical techniques for each subclass of tumors (Fig. 1). We also identified the problem of carotid involvement in TMPs and classified them into a separate B3 class and proposed STP for this group of patients. Moreover, while the Fisch classification is based entirely on radiology, ours is based on both otoscopy and radiology.

3.2. *Clinical features and imaging protocols*

TBPs affect women five to six times more often than men [11,13] but the reason for this distinct predilection still evades us. A female preponderance of 95% seen in our series of TMPs is perhaps the maximum reported in the literature [4,5,12,14,15]. TBPs are reported to also occur in two peaks, some reporting it at 4th and 5th decades [3] while others at 5th and 6th decades [12]. Though there was no 'double peak' in incidence in our series there was a general upswing between the 4th and the 6th decades. The most common clinical presentation is pulsatile tinnitus and hearing loss as seen in our series. Vertigo is not a consistent symptom and was a presenting feature in only 15% of patients in our series. Otoscopy showed a pulsatile red-pinkish mass behind an intact TM in 94% of the cases. Despite the fact that the incidence of TM perforations increased as the class progressed, 88% of the patients with B3 tumors still had an intact TM. However even in case of a visible mass in the external auditory canal, a biopsy is ill advised. A HRCT of the temporal bone with contrast is an adequate tool for the

Table 3 – Comparison of outcomes of surgery in our series with that of other authors.

	O'Leary MJ et al. [25] 1991, (n = 64)	Jackson CG et al. [23], 1989, (n = 60)	Forest JA et al. [7], 2001, (n = 95)	Our series, 2013 (n = 145)
	No. (%)	No. (%)	No. (%)	No. (%)
Gross total resections (GTR)	61 (95.3%)	54 (90%)	90 (94.7%)	141 (97%)
Recurrence in GTR	0 (0%)	2 (3.7%)	2 (2%)	1 (0.7%)
Management of recurrence in GTR	–	S (n = 1)/W&S (n = 1)	S (n = 1)/W&S (n = 1)	S (n = 1)
Subtotal resections (STR)	3 (4.7%)	6 (10%)	4 (4.2%)	4 (2.8%)
Recurrence in STR	3 (100%)	NA	2 (50%)	0 (0%)
Management of recurrence in STR	S (n = 3)	S (n = 6)	RT (n = 1)/W&S (n = 1)	–
Tympanic membrane perforations	3 (4.7%)	1 (1.7%)	4 (4.2%)	6 (4.1%)
External auditory canal stenosis	0 (0%)	0 (0%)	1 (1%)	3 (2.1%)
External auditory canal cholesteatoma	0 (0%)	0 (0%)	0 (0%)	1 (0.7%)
Middle ear cholesteatoma	1 (1.6%)	1 (1.7%)	1 (1%)	0 (0%)
Temporary facial nerve palsy	0 (0%)	1 (1.7%)	1 (1%)	5 [a] (3.5%)
Permanent facial nerve palsy	1 (1.6%)	0 (0%)	0 (0%)	2 [b] (1.4%)
CVA/hemiplegia due to ICA violation	0 (0%)	1 (1.7%)	1 (1%)	0 (0%)
Intraoperative CSF leaks	0 (0%)	2 (3.3%)	0 (0%)	0 (0%)
Wound infection	0 (0%)	1 (1.7%)	0 (0%)	0 (0%)

S = surgery, W&S = wait and scan, RT = radiotherapy, CVA = cerebro-vascular accident, NA = not available.
[a] Recovered to HB grade 1 in 6 months.
[b] Tumor was found infiltrating the nerve in both cases.

accurate diagnosis of TMPs limited to the mesotympanum. A dynamic CT study of a preselected section showing the tumor mass will differentiate a TMP from other vascular masses such as high jugular bulb [16]. The presence of air or bone between the tumor and the jugular bulb also characterizes the mass as a TMP [1]. Non-enhanced CT can demonstrate TMPs, but the demonstration of a strongly enhancing mass is typical in the diagnosis of a TMP [17,18]. However when the tumor is found to be involving the hypotympanum (B1–B3), it is important to perform an MRI with gadolinium DTPA enhancement to rule out the involvement of the jugular bulb or the carotid and a possible diagnosis of a TJP. The differentiation of a TMP from TJP is of utmost importance for surgical planning with the latter requiring an ITFA [1]. Pre-operative angiography and neuroendocrine testing is not recommended for TMPs.

3.3. *Surgical protocols and outcomes*

In today's era of modern microsurgery and neuroimaging, it is possible to completely eradicate all types of TMPs with minimum or practically no sequelae. It is nevertheless vital to choose the correct surgical approach to achieve adequate exposure for individual tumor classes. Our algorithm for the management of TMPs (Fig. 1) describes precise approaches for specific tumor classes. A detailed description of the surgical approaches and techniques are described elsewhere [1]. Class A1 through B2 can be managed by hearing conservation surgeries. However 44% of patients with B2 tumors in our series ended up with an STP due to difficult surgical conditions like cochlear fistula, inadequate exposure of tumor margins or bleeding. B3 tumors need a more radical approach by way of STP. However, our analysis of hearing results has shown that even in STP, the hearing loss before and after surgery is minimal and acceptable. STP caused a mean decrease in AC of only 23.32 dB because in this group patients already had a greatly deteriorated AC as a consequence of the progressive disease. The average postoperative improvement in ABG in the hearing conservative surgery group was 7.26 dB (range 22.02 dB to 14.76 dB) while in the patients who underwent STP there was a deterioration of ABG by 13.43 dB postoperatively as an expected consequence of the surgery.

The fact that we had just one recurrence (0.7%) in a series of 145 patients which is the largest series reported till date in literature is proof of the fact that TMPs can be comprehensively tackled with the correct clinical, imaging and surgical protocols based on our classification and surgical algorithm. We also had four subtotal resections (4.8%) where a tiny bit of tumor was left behind due to its attachment to vital structures. However none of them showed regrowth. A comparison of our results with other authors is shown in Table 3. Temporary facial palsy was higher in our series due to

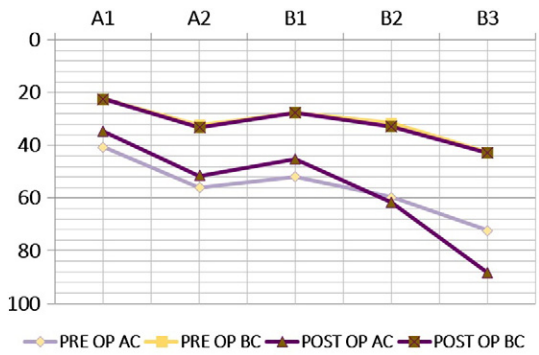

Fig. 4 – Line chart representing the preoperative and postoperative AC and BC for each tumor class.

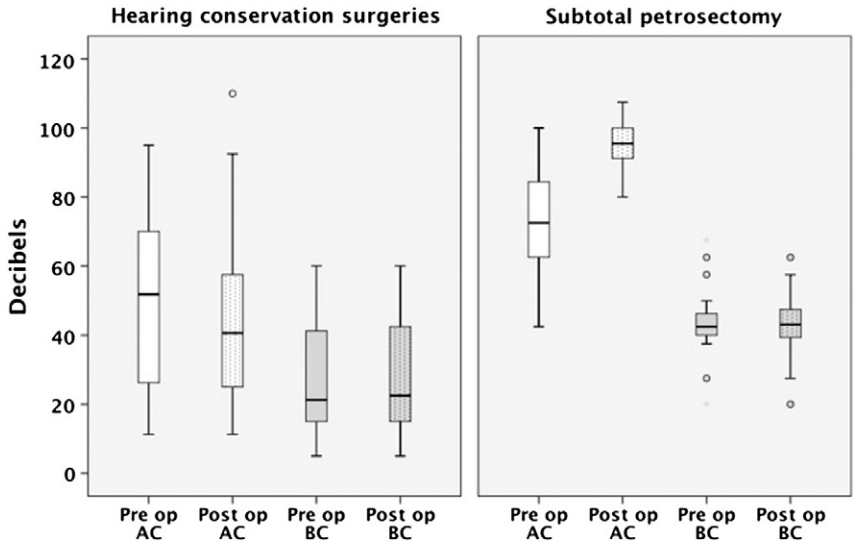

Fig. 5 – Box-plots showing median PTA for AC and BC both pre- and postoperatively according to the surgical approach.

the fact that tumor had uncovered the facial nerve in four of the five patients and infiltrated the nerve in one more patient. In the two patients with permanent facial nerve palsies, the nerve was sacrificed due to tumor infiltration.

3.4. *RT and wait-and-scan as a treatment option*

Though surgery has been the traditional treatment of choice for TMPs, suggestions of radiation as a primary alternative to surgery appear every now and then in literature [19–22]. We firmly believe that radiation has no role in the primary treatment of TMPs and this view has also been emphasized by many authors [10,19,23]. When surgery provides excellent postoperative outcomes as shown in our series, it is impossible to justify radiation in TMPs. Other indications mentioned for radiation or wait-and-scan are in recurrent or residual tumors and in elderly patients [15,24,23]. In our opinion surgery must be the preferred option even in the abovementioned scenarios. In elderly patients it is mostly possible to perform surgery under local anesthesia.

4. Conclusion

We have reported the long term surgical outcomes in TMPs in the largest series published till date. In today's era of modern microsurgery and neuroimaging, it is possible to completely eradicate all types of TMPs with minimum or practically no sequelae. It is vital to choose the correct surgical approach to achieve adequate exposure for individual tumor classes as described in our classification and algorithm. Surgery is the best treatment option for TMPs as it achieves total tumor removal, improved postoperative hearing and low rates of recurrence and complications. RT or wait-and-scan has no role in the treatment of TMPs.

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