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Original Article

Hearing and Facial Function After Surgical Removal of Cholesteatomas Involving Petrous Bone

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Objectives. The purpose of this study was to inspect the clinical characteristics, surgical approaches, functional preservation, and complications of petrous bone cholesteatoma and to propose appropriate surgical approaches based on long-term follow-up cases and previous reports in the literature.

Methods. The medical records of 31 patients who underwent surgery for petrous bone cholesteatoma between 1990 and 2011 at two tertiary referral hospitals were retrospectively analyzed with regard to the classification, type of surgical approach, preservation of facial and auditory function, and recurrence.

Results. Of 31 cases, 16 were supralabyrinthine (class I), 1 was infralabyrinthine-apical (class III), 13 were massive (class IV), and 1 was apical (class V). Facial nerve palsy was found in 35.5% of the cases (11 cases). Hearing was preserved in 11 of 22 patients who had better than a 50-dB hearing level of bone conduction pure tone average preoperatively. Preoperative hearing was preserved in only four of the patients in class I (supralabyrinthine). Facial function was preserved or improved in 29 patients (93.5%).

Conclusion. Complete removal of cholesteatoma of petrous bone can be achieved by choosing the appropriate approach based on location and extent. Facial function was preserved postoperatively in most reviewed cases. Auditory function could not be preserved postoperatively in some cases, but preserving residual hearing levels can be accomplished mostly in supralabyrinthine cholesteatomas with the appropriate surgical approach.

Keywords. *Petrous bone, Cholesteatoma, Classification, Facial nerve, Hearing*

INTRODUCTION

A petrous bone cholesteatoma (PBC) is a rare pathology defined as an epidermoid cyst in the petrous portion of the temporal bone [1]. PBCs can be congenital or acquired; however, the two types are histologically undistinguishable. Congenital cholesteatoma has been suggested to arise from epithelial cell rest within the temporal bone [2], whereas acquired cholesteatoma is the result of medially invasive cholesteatoma of the tympanomastoid region [3]. Because of its complex position of the otic capsule and the possibility of damaging vital intracranial structures (i.e., facial nerve, internal carotid artery, sigmoid sinus, jugular bulb), surgery of PBC is challenging even for the experienced surgeons.

Extension of the PBC to the clivus, sphenoid sinus, or rhinopharynx, although rare, can be extremely difficult to treat. According to Sanna classification, PBC can be subdivided into five classes in relation to the labyrinth: supralabyrinthine, infralabyrinthine, massive, infralabyrinthine-apical, and apical [4]. The development of surgical approaches to treat the skull base and petrous bone, as well as recent advances in radiological imaging

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have changed attitudes towards managing PBC. These new developments have increased the safety of treatment and complete removal of the pathology.

Here, we studied patients with cholesteatoma of the petrous bone and the associated clinical treatment and management. Specifically, we analyzed the clinical aspects of each patient's PBC, the surgical approaches taken to treat the condition, the location of the cholesteatoma, and the final outcome of the chosen treatment. From these data, we aimed to determine a feasible surgical approach to the various classes of PBC that would preserve facial nerve and hearing functions and prevent recurrence.

MATERIALS AND METHODS

Between 1990 and 2011, 31 patients were diagnosed and treated for cholesteatoma of the petrous bone at the Department of Otorhinolaryngology-Head and Neck Surgery of Asan Medical Center and Samsung Medical Center, and their cases were reviewed retrospectively. The study protocol was approved by the Institutional Review Board at each hospital. All patients underwent a thorough otoneurologic evaluation followed by pure tone audiometric evaluation and temporal bone computed tomography (CT). Medical records were collected and analyzed with regard to hearing, facial nerve function, and recurrence.

All lesions were classified according to the method of Sanna et al. [5], based on the topographic location and the extent of the cholesteatoma on the CT scan. Cholesteatomas of the petrous bone were classified into five groups: class I is the supralabyrinthine type located on the geniculate ganglion of the facial nerve; class II is the infralabyrinthine type that arises from the hypotympanic and infralabyrinthine cells; class III is the infralabyrinthine-apical type that originates from the intralabyrinthine compartment internal carotid artery up to the petrous apex; class IV is a massive type that involves the entire otic capsule; and class V is an apical type that arises from the petrous apex.

Treatment and management of the PBC in each case depended on the classification. Facial nerve function was graded preoperatively and postoperatively according to the House-Brackmann grading system [6].

RESULTS

The age of enrolled subjects ranged from 6 to 80 years with a mean age of 37 years. There were 21 males and 10 females. The mean follow-up period for the patients was 35.6 months and ranged from 7 to 176 months in length.

The most common chief complaint was facial palsy, which was observed in nine of the patients, followed by hearing loss in 7 patients, otorrhea in 7, otalgia in 2, vertigo in 2, incidentally found cholesteatoma in 2, tinnitus in 1, and headache in 1 patient. Among 31 patients, 20 patients had combined hearing losses.

According to Sanna classification, 16 of the patients (51.6%) were class I (supralabyrinthine type), 13 (42%) were class IV (massive type), 1 (3.2%) was class III (infralabyrinthine-apical type), and another 1 (3.2%) was class V (apical type). Of the 16 patients in class I, 11 underwent a tympanomastoidectomy and 5 underwent a translabyrinthine approach. One patient in class III underwent a tympanomastoidectomy. Of the 13 patients in class IV, 3 underwent a tympanomastoidectomy, 4 underwent a subtotal petrosectomy, 4 underwent a transcochlear approach, and 2 underwent translabyrinthine approaches. One patient in class V underwent a transcochlear approach (Table 1, Fig. 1). In these cases, there were no cases with encasement of vital structures, such as the internal carotid artery, jugular bulb, sphenoid sinus or nasopharynx. There were two cases (cases 25, 31) which surrounded the clivus. We performed transcochlear approach in both cases and they all showed hearing loss and facial palsy postoperatively.

Preoperatively, 20 of the patients had normal facial function and one of them developed grade II facial palsy after surgery. In this case, we performed facial nerve rerouting to obtain a wide surgical view for the approach. Preoperative facial palsy was noticed in 11 patients and more frequently noticed in class IV; 3 (18.8%) in class I, 7 (53.8%) in class IV, and 1 in class V. Of these 11 patients, postoperative facial function was improved in 6 of them, stable in 4, and worsened in 1 patient (Fig. 2). End-to-end anastomosis was performed in three patients, resulting in improved postoperative facial nerve function in all three (Fig. 2). Postoperative facial function was grade I in 12 out of 16 class I (75.0%) and in 6 out of 13 class IV (46.2%).

Preoperatively, nine of the patients exhibited deafness in the ear that contained the cholesteatoma, and there was residual bone conduction hearing in 22 of the patients. In 11 of the 22 patients with residual bone conduction hearing (4 in class I and 7 in class IV), hearing was sacrificed intraoperatively while removing the cholesteatoma matrix (Fig. 3). Two of the four patients in class I whose hearing was sacrificed underwent a transmastoid approach. In these cases, the cholesteatoma was located in the geniculate ganglion extending inferiorly to make a cochlear fistula. In 11 of the patients (9 in class I, 1 in class III, and 1 in class IV), hearing was better than 50 dB postoperatively. Among these patients, hearing was not worsened in only four patients with class I.

Aside from hearing loss and facial palsy, wound infection occurred in four patients and whirling type vertigo occurred in one patient postoperatively. The instances of wound infection and vertigo were resolved through conservative management.

Recurrence of the cholesteatoma occurred in only 1 out of the 31 cases. In this case, the site of the recurred cholesteatoma was medial to the tympanic membrane, which was completely removed via a transmeatal approach.

Table 1. Surgical approaches used to treat 31 petrous bone cholesteatomas classified according to the Sanna classification

Case	Age (year)	Sex	Class*	Operative procedure	Bone conduction PTA		House Brackmann grade		Complication
					Preoperative	Postoperative	Preoperative	Postoperative	
1	6	M	I	Transmastoid approach	45	35	I	I	-
2	14	M	I	Transmastoid approach	15	30	I	I	-
3	16	M	I	Transmastoid approach	30	15	I	I	-
4	17	F	I	Transmastoid approach	13	11	I	I	-
5	21	M	I	Transmastoid approach	35	50	I	I	-
6	22	F	I	Translabyrinthine approach	Deafness	Deafness	I	I	Wound infection
7	23	F	I	Translabyrinthine approach	Deafness	Deafness	I	I	-
8	24	F	I	Transmastoid approach	50	Deafness	I	I	-
9	28	M	I	Transmastoid approach	7	Deafness	I	II	FP
10	30	M	I	Transmastoid approach	Deafness	Deafness	I	I	-
11	32	F	I	Transmastoid approach	30	50	V	IV	-
12	40	M	I	Translabyrinthine approach	25	Deafness	III	VI	-
13	46	F	I	Transmastoid approach	30	40	I	I	-
14	53	M	I	Translabyrinthine approach	20	Deafness	V	IV	-
15	55	M	I	Transmastoid approach	33	12	I	I	-
16	55	M	I	Translabyrinthine approach	5	50	I	I	Dizziness
17	31	M	III	Transmastoid approach	40	50	I	I	-
18	32	F	IV	Translabyrinthine approach	12	Deafness	V	V	FP
19	23	M	IV	Transcochlea approach	Deafness	Deafness	V	III	-
20	23	M	IV	Subtotal petrosectomy	27	Deafness	I	I	-
21	24	M	IV	Transcochlea approach	10	Deafness	III	II	-
22	33	M	IV	Transmastoid approach	10	Deafness	I	I	-
23	48	F	IV	Subtotal petrosectomy	Deafness	Deafness	I	I	Wound infection
24	53	M	IV	Transmastoid approach	25	50	I	I	-
25	54	M	IV	Transcochlea approach	13	Deafness	III	II	-
26	54	M	IV	Transcochlea approach	Deafness	Deafness	III	II	-
27	55	M	IV	Subtotal petrosectomy	Deafness	Deafness	V	V	-
28	56	M	IV	Translabyrinthine approach	30	Deafness	I	I	-
29	73	F	IV	Subtotal petrosectomy	55	Deafness	I	I	Wound infection
30	80	F	IV	Transmastoid approach	Deafness	Deafness	V	III	Wound infection
31	30	M	V	Transcochlea approach	Deafness	Deafness	V	III	-

PTA, pure tone audiometry; FP, facial palsy.
*I, supralabyrinth; II, infralabyrinth; III, massive; IV, infralabyrinthine-apical; V, apical.

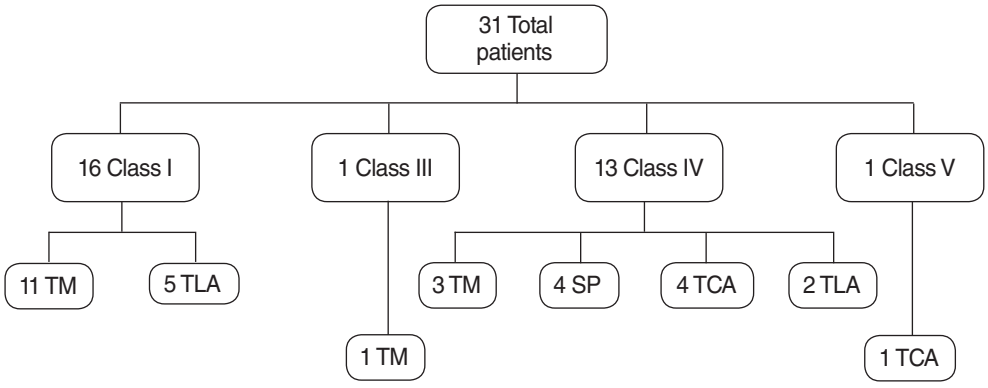

Fig. 1. Surgical approaches used to treat 31 petrous bone cholesteatomas classified according to the Sanna classification. TM, tympanomastoidectomy; TLA, translabyrinthine approach; SP, subtotal petrosectomy; TCA, transcochlear approach.

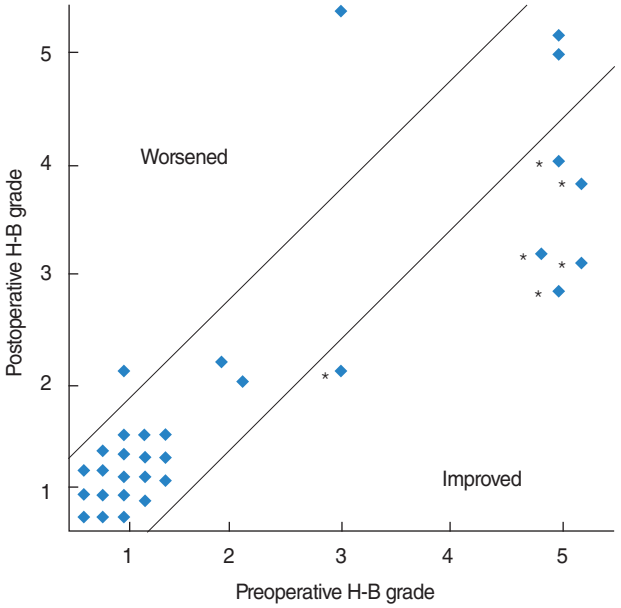

Fig. 2. Comparison of pre- and postoperative facial nerve function according to the House-Brackmann (H-B) grading system. Facial function was improved postoperatively in 6 cases (*) but worsen in 2 cases.

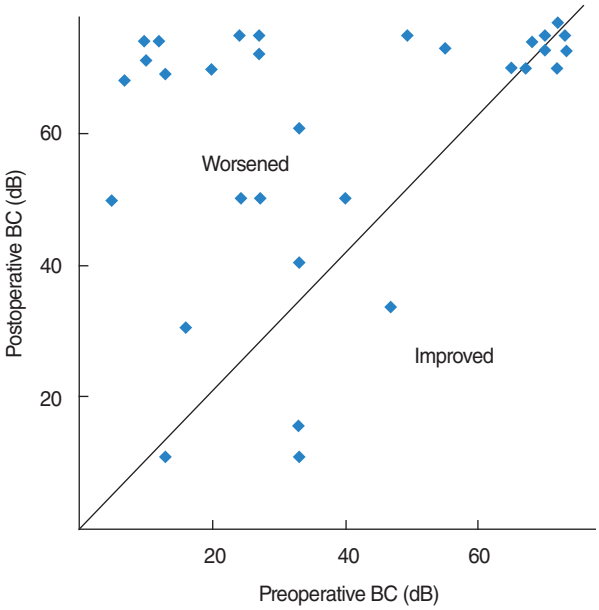

Fig. 3. Comparison of pre- and postoperative hearing levels. Hearing was sacrificed in 11 patients who had residual hearing preoperatively. BC, bone conduction.

DISCUSSION

Diagnosis and treatment of PBC is challenging for surgeons, especially depending on the extent of the lesion. Moffat et al. [7] argued that patients can have symptoms for as long as 20 years. Because cholesteatomas are often invisible during routine otoscopic examinations, diagnosis is often delayed. However, with improvements in CT and magnetic resonance imaging (MRI) technology, and with more reliable means of early detection and determination of the extent of the cholesteatoma, both perioperative and long-term morbidity can be reduced.

Classifying the type of PBC aids in the selection of an appropriate surgical approach. Lateral skull base approaches based on CT and MRI allow for removal of the disease more completely. Recently, diffusion weighted MRI was documented as a more reliable means of identifying cholesteatoma [8] and is a crucial tool for diagnosis and treatment-planning of petrous apex lesions. The ideal surgical approach to PBC must provide a sufficient view of the cholesteatoma, a route for complete resection, and a way to safely control the vital intracranial structures. According to Sanna et al. [5], supralabyrinthine type was most common with massive type being the next most common. This pattern held true in our series as well.

Various techniques have been developed as approaches to treating PBCs. House described a middle cranial fossa approach that removes supralabyrinthine cholesteatoma while maintaining serviceable hearing [9]. If hearing preservation is not feasible, a translabyrinthine approach adequately removes the lesions. Yanagihara et al. [10] mentioned that a translabyrinthine approach with or without a transcochlear approach is considered the basic technique for removing petrous apex cholesteatoma.

We performed 11 transmastoid supralabyrinthine approaches and 5 translabyrinthine approaches in supralabyrinthine cholesteatomas. Of the 11 patients who underwent a transmastoid supralabyrinthine approach in class I, hearing was better than 50 dB in 9 patients. For all surgeons' best efforts for preserving residual hearing level, in 2 patients, hearing was worsened postoperatively.

There are various approaches for massive type (IV) cholesteatomas including subtotal petrosectomy, transcochlear, and infratemporal fossa approaches. The transcochlear approach provides wide access to the petrous apex and clivus [11,12]. The advantages of this approach over the conventional translabyrinthine approaches include wider surgical access and direct visualization and access to the anterior cerebellopontine angle where the facial nerve is usually tenuous and most vulnerable [13]. Of the 12 patients in class IV, hearing could be preserved better than 50 dB in only 1 patient. It seemed to be more difficult to preserve residual hearing in massive type cholesteatoma because of its location and extent. Residual hearing was sacrificed inevitably to provide sufficient access for removing the cholesteatoma matrix completely, which is consistent with reports from other studies. Infratemporal fossa approaches could also access to more anterior structures, including the internal carotid artery [14]. In our series, however, there were no patients whose condition warranted this approach. Finally, a subtotal petrosectomy is appropriate for infralabyrinthine lesions with or without an apical extension.

Also recent advances in minimally invasive surgery with the

use of intraoperative navigation systems allow removing PBC in the petrous apex by an endoscopic transsphenoidal approach with minimal morbidity. Endoscopic surgery or combination of endoscopic approach with a transtemporal or middle fossa approach may be considered for alternative surgical strategy to remove PBC completely according to its location [15].

Facial nerve palsy is an inevitable complication of radical removal of PBCs. Blood supply to the nerve can be compromised when the cholesteatoma involves the geniculate ganglion [16], and sometimes the facial nerve is present as a fibrous band at the geniculate ganglion. We frequently performed decompression of the facial nerve when the nerve was compressed but anatomically intact. When there was no continuity of the facial nerve, we excised the fibrotic segment and performed an end-to-end anastomosis (3 patients) and cable graft (1 patient). All of the patients showed improvement of facial nerve function postoperatively. Because atrophy of the motor end plate occurs after 1 year of damage, the duration of the preoperative facial nerve deficit is the most important factor for determining the final outcome of facial nerve results. Patients with less than 1 year of facial nerve dysfunction can be expected to show significant improvement of facial function [17].

Because PBC is difficult to detect early due to its location, patients with vague otologic symptoms like hearing loss, facial palsy, and vertigo should be considered as being potentially affected by PBC. Complete removal of PBCs is possible by the choosing the appropriate approach based on location and extent.

In conclusion, facial nerve function can be preserved postoperatively in most cases of PBC if the proper approach is performed and if nerve continuity is restored. Although auditory function may be worsened in some patients for total removal including the matirx, preserving the residual hearing level is possible mostly in supralabyrinthine cholesteatomas through the use of appropriate surgical approaches.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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