Petrous Apex Lesions

Abstract—The purpose of this article is to detail our experience in treating 69 patients over the past 6 years with pathologic processes involving the petrous apex. These included 25 (36%) primary petrous apex lesions, 40 (58%) lesions that involved the petrous apex by direct invasion from an adjacent region, and four (6%) lesions that were the result of metastatic spread from a distant site. Although lesions of the petrous apex are uncommon, they may present significant morbidity to the patient. The symptoms elicited by these lesions are usually vague and nonlocalizing in the early stages but may progress to include multiple cranial neuropathies. Successful results are contingent on early diagnosis, which requires a high index of suspicion and use of appropriate imaging modalities. Thorough preoperative assessment with use of computed tomography, magnetic resonance imaging, and carotid arteriography is essential to plan the surgical approach. We present this collection of patients in order to aid in the further preoperative characterization of the differences in primary and secondary lesions of the petrous apex. (*Skull Base Surgery*, 4(1):10–14, 1994)

Petrous apex lesions were believed to be relatively uncommon; however, the reported numbers of these lesions are apparently increasing due to improved diagnostic imaging modalities.^{1–3} These imaging modalities, specifically computed tomography (CT) and magnetic resonance imaging (MRI), are providing accurate anatomic localization of these lesions, and in many cases even suggest specific tissue diagnoses. Infective, inflammatory, and neoplastic conditions are all known to affect the petrous apex.^{4–6}

The petrous apex is situated within the temporal bone and lies between the inner ear and the clivus. Anatomically, it may be further divided into two compartments by the orientation of the internal auditory canal. The larger more anterior portion, which is medial to the cochlea, is more frequently involved by disease processes. The smaller more posterior portion lies between the semicircular canals and the internal auditory canal and is clinically less significant. The petrous apex exhibits a varying degree of pneumatization along with bone marrow content, and it is estimated to be pneumatized in approximately one third of adults.³ The anatomic relationships of this region remain quite complex.

The purpose of this article is to review our experience with 69 patients treated over the last 6 years. During

diagnostic evaluation with CT or MRI, these patients were found to have pathologic processes with significant involvement of the petrous apex. We hope to improve on the characterizations of primary and secondary processes of the petrous apex based on preoperative information, that is, clinical and radiographic findings.

MATERIALS AND METHODS

This article was formulated by a retrospective review of patients treated for lesions of the petrous apex from 1986 to 1992. Patients were included in this study if, on evaluation, a pathologic process was found on an imaging procedure (either CT or MRI) that demonstrated significant involvement of the petrous apex and the patient subsequently underwent a surgical procedure that resulted in a diagnosis.

Data obtained from the chart review included information related to prior ear disease, prior ear surgeries, presenting symptoms, physical findings, and preoperative testing, that is, audiometry, auditory evoked brainstem responses, arteriography, and radiographic imaging. Additionally, the lesions were categorized with regard to extent of disease, type of lesion (primary, secondary inva-

sive, or secondary metastatic), and final diagnosis. Statistical analysis was performed comparing the type of lesion using Student's *t* test, chi-square contingency tables, Fischer's exact test, and one-way analysis of variance where appropriate.

RESULTS

There were 69 patients included in this study. Twenty-five patients were found to have primary petrous apex lesions (PPAL), 40 patients had invasive secondary petrous apex lesions (ISPAL), and four patients had metastatic secondary petrous apex lesions (MSPAL). The PPAL included 13 cholesterol granulomas (52%), five congenital cholesteatomas (20%), four mucocoeles (16%), and three eosinophilic granulomas (12%). The ISPAL included 11 acoustic neuromas (27.5%), six glomus tumors (15%), six meningiomas (15%), five cases of osteomyelitis (12.5%), four squamous cell carcinomas (10%), three sphenoid sinus mucocoeles (7.5%), three chordomas (7.5%), one trigeminal neuroma (2.5%), and one nasopharyngeal carcinoma (2.5%). The MSPAL included three renal cell carcinomas (75%) and one follicular carcinoma of the thyroid (25%).

The age range of patients was 14 to 77 years with an average of 37 years, and included 33 males (48%), and 36 females (52%). There was no significant predilection for gender or race when comparing PPAL, ISPAL, and MSPAL. However, the average age of the patients with PPAL was 30 years (range, 14 to 63) compared with 40 (range, 14 to 77) for ISPAL and 55 (range, 41 to 68) for MSPAL ($p < 0.005$).

Eighteen (26%) of these 69 patients had a past medical history of ear disease that involved the ear ipsilateral to the petrous apex lesion. Eight of 25 patients (32%) with PPAL had a prior history of ear disease that was exclusively otitis media or chronic otitis media. Nine of 40 patients (22.5%) with ISPAL had a past medical history of ear disease but only one (2.5%) had chronic otitis media, five (12.5%) had a history of sensorineural hearing loss,

and one patients each had a history of otitis externa, otosclerosis, and squamous cell carcinoma of the ear. Prior ear surgery was performed in 7 of the 18 cases with previous ear disease. Five of these procedures were performed on PPAL and consisted of myringotomy with placement of a ventilation tube in four cases and myringotomy alone in one case. The other two procedures were performed on patients with ISPAL and included a stapedectomy and a sleeve resection of the external auditory canal. No patient with MSPAL had undergone previous ear surgery.

Presenting symptoms, otoscopic findings, and cranial nerve deficits found on presentation are displayed in Tables 1, 2, and 3, respectively. The most common presenting symptom was hearing loss, followed by tinnitus, vertigo, and headache. The most common otoscopic finding was a normal examination followed by serous effusion, granulation, and swelling of the external auditory canal. There were no statistically significant differences in presenting symptoms or otoscopic findings between groups. Fifty-four patients had cranial nerve deficits on initial evaluation. The trigeminal nerve was the most common cranial nerve deficit. There was a statistically significant difference in the incidence of involvement of cranial nerves V, VI, IX, and XI between groups. There were no significant differences for the incidence of cranial nerves VII and XII. No patient had involvement of cranial nerves II, III, or IV.

An audiogram was performed in 66 of 69 patients (96%), and the most common finding was that of a sensorineural hearing loss found in 46 patients (70%) (Table 4). A mixed hearing loss was found in 14 patients (21%), and normal hearing was noted in the remaining six patients (9%). A statistically significant difference was found between PPAL and ISPAL for type of hearing loss ($p < 0.02$). None of the patients in this study presented solely with a conductive hearing loss.

Auditory evoked brainstem response (AEBR) and electronystagmography (ENG) were obtained sporadically and there were no significant intergroup differences

Table 1. Presenting Symptoms of Patients with a Petrous Apex Lesion

Symptom	PPAL (n = 25)	ISPAL (n = 40)	SPAL (n = 4)	Total (n = 69)
Hearing loss	22 (88%)	29 (73%)	4 (100%)	55 (80%)
Tinnitus	13 (52%)	13 (33%)	0	26 (38%)
Vertigo	10 (40%)	10 (25%)	0	20 (29%)
Headache	7 (28%)	12 (30%)	1 (25%)	20 (29%)
Diplopia	1 (4%)	9 (23%)	0	10 (14%)
Otalgia	0	6 (15%)	0	6 (9%)
VII paralysis	3 (12%)	3 (8%)	0	6 (9%)
Dysphagia	0	6 (15%)	0	6 (9%)
Hoarseness	0	6 (15%)	0	6 (9%)
Facial hypesthesia	3 (12%)	2 (5%)	0	5 (7%)
Ataxia	0	5 (13%)	0	5 (7%)
Otorrhea	0	3 (8%)	0	3 (4%)
Ketoacidosis	0	2 (5%)	0	2 (3%)

Table 2. Otoloscopic Findings

Findings	PPAL	ISPAL	MSPAL	Total
Normal	21 (84%)	26 (65%)	4 (100%)	51 (74%)
Effusion	3 (12%)	2 (5%)	0	5 (7%)
Retraction	1 (4%)	0	0	1 (1%)
Tumor	0	2 (5%)	0	2 (3%)
Granulation	0	6 (15%)	0	6 (9%)
Brown's sign	0	3 (8%)	0	3 (4%)
Otorrhea	0	1 (3%)	0	1 (1%)

Table 3. Cranial Neuropathies in Patients with a Petrous Apex Lesion

Cranial Nerve	PPAL (n = 25)	ISPAL (n = 40)	MSPAL (n = 4)	Total (n = 69)
V	4 (16%)	21 (53%)	0	25 (36%)
VI	1 (4%)	14 (35%)	0	15 (22%)
VII	3 (12%)	6 (15%)	0	9 (13%)
IX	0	7 (18%)	0	7 (10%)
X	0	8 (20%)	0	8 (12%)
XI	0	5 (13%)	0	5 (7%)
XII	0	2 (5%)	0	2 (3%)

Table 4. Hearing Loss at Presentation

Type	PPAL	ISPAL	MSPAL	Total
Sensorineural	14 (56%)	28 (70%)	4 (100%)	46 (67%)
Conductive	0	0	0	0
Mixed	10 (40%)	4 (10%)	0	14 (20%)
Normal	1 (4%)	5 (13%)	0	6 (9%)

with regard to outcome. AEBR was obtained in 27 patients included in the study. All were considered abnormal with the exception of one patient with a cholesterol granuloma. ENG was obtained in only 14 patients. Twelve were abnormal, one result was unknown, and one case was normal. The only normal ENG also occurred in a patient with a cholesterol granuloma.

The extent of disease spread is listed in Table 5. PPAL most commonly was contained within the petrous bone (76%), whereas very few had intracranial spread (8%). By

Table 5. Disease Extension Beyond the Petrous Apex

Extent	PPAL	ISPAL	MSPAL	Total
Intrapetrous	19 (76%)	4 (10%)	2 (50%)	25 (36%)
Intracranial	2 (8%)	23 (58%)	2 (50%)	27 (39%)
External auditory canal	0	10 (25%)	0	10 (14%)
Nasopharynx	4 (16%)	2 (5%)	0	6 (9%)
Neck	0	3 (8%)	0	3 (4%)
Sphenoid sinus	0	2 (5%)	1 (25%)	3 (4%)

contrast, ISPAL had spread intracranially in the majority of cases (58%), whereas 10% remained within the petrous bone. Additionally, the sphenoid sinus, neck, and external auditory canal were involved by ISPAL in a handful of cases, but no PPAL was involved in these regions. MSPAL presented with only petrous involvement in half of the cases, with intracranial spread in half of the cases, and with sphenoid sinus involvement in only one case. These differences in disease spread were found to be statistically significant ($p < 0.005$) between all three groups.

Characteristics of preoperative radiologic imaging were subjectively evaluated. The results were generally consistent with attributes detailed in Table 6. However, it must be noted that not all of the lesions were typical in their radiologic characteristics.

DISCUSSION

Presenting Symptoms

As lesions of the petrous apex progress in size, surrounding structures are compressed, leading to more obvious symptomatology. In this series the most common presenting symptoms included hearing loss, tinnitus, vertigo, and headache (Table 1). Progression of these lesions anteriorly primarily produced involvement of cranial nerves V and VI. Extension of disease posteriorly produced dysfunction of cranial nerve VII in six patients; however, involvement of this nerve was less common except in advanced lesions. Cranial nerves IX, X, and XI were primarily compressed at the level of the jugular foramen. In this study and other reports, solid tumors apparently produced cranial nerve dysfunction more commonly than cystic lesions. Thirty-seven of the 69 patients (54%) presented with single or multiple cranial neuropathies. The most commonly involved cranial nerves were V, VI, and VII (Table 3).

Presenting signs and symptoms could not be used as a means to distinguish definitively whether a lesion was a PPAL, ISPAL, or MSPAL. However, there were some factors that may certainly aid in this distinction. These include age, past medical history of chronic otitis media, type of cranial nerve deficit, and type of hearing loss. The average age of patients with PPAL were the youngest (30 years), those with MSPAL were the oldest (55 years), and those with ISPAL were intermediate in age (40 years). A past medical history of chronic otitis media was fairly common (32%) among patients with PPAL but was almost nonexistent in the other groups. The trigeminal nerve overall was the most commonly involved cranial nerve (36%), but proved to be much more common in ISPAL (53%) than the other groups (16% in PPAL, 0% in MSPAL). Additionally, deficits of cranial nerves VI, IX, X, XI, and XII were almost exclusively found in ISPAL lesions. This could certainly be accounted for by the aggressively invasive nature of this particular collection of ISPAL lesions.

Table 6. Imaging Characteristics of Petrous Apex Lesions

Pathology	MRI (T_1)	MRI (T_2)	Enhancement
T scan: smooth margins, lesion isodense with brain			
1. Cholesteatoma	Low-medium	High	None
2. Cholesterol granuloma	High	High	None
CT scan: irregular margins, lesion nonisodense with brain			
1. Mesenchymal tumors, meningiomas, or metastatic lesions	Low-medium	High	Strong
2. Bone marrow	High	Low	None

Lastly, sensorineural hearing loss was found more commonly in ISPAL lesions (70% in ISPAL, 56% in PPAL) and mixed hearing losses were found more commonly in PPAL (40% in PPAL, 10% in ISPAL).

RADIOLOGIC EVALUATION

The radiologic evaluations of petrous apex lesions often incorporates CT, MRI, angiography, and nuclear scanning techniques in a manner that, it is hoped, optimizes diagnostic yield and provides details required for treating planning. Thin-section CT scanning with contrast remains the initial study of choice for these lesions, since it provides the best visualization of the relevant bony surgical landmarks.^{3,7} Furthermore, CT and MRI in many cases are complimentary.⁸ Table 6 demonstrates how one might diagnose a petrous apex lesions through use of CT and MRI with gadolinium enhancement. Although classic descriptions of radiologic appearance on CT and MRI are helpful, not all lesions follow these guidelines. Long-term follow-up of these patients is best accomplished by the use of MRI, which may display very early recurrences.^{1,2} The detection of a recurrence is difficult when using CT, since it relies on bone destruction to identify tumor growth. It is also important to remember that there are several normal variants that may simulate pathologic conditions in the petrous apex and these include asymmetrical bone marrow deposition or the presence of giant air cells.^{3,9,10} Bone marrow is sometimes mistaken for a pathologic process due to the high signal intensity on T_1 images. This can be easily distinguished from other lesions by the low signal intensity on T_2 images and lack of enhancement following gadolinium. Angiography becomes important in the preoperative assessment of patients suspected of having vascular tumors, and it can aid in the diagnosis by demonstration of a tumor blush.¹ Also, it helps delineate the course of the internal carotid artery, which is almost invariably displaced laterally by the tumor. Nuclear scanning techniques are particularly useful in those patients suspected of having osteomyelitic processes involving the skull base.

PATHOLOGY

A classification scheme originally reported by Gacek⁴ in 1975 includes *primary lesions* of the petrous apex and *secondary lesions*, which are additionally divided into invasive and metastatic categories. Twenty-five patients in this study had primary lesions of the petrous apex, which included 13 cholesterol granulomas, five congenital cholesteatomas, four primary mucocles, and three eosinophilic granulomas. Secondary invasive lesions were found in 40 patients and included the diagnosis of acoustic neuroma in 11, glomus tumors in six, meningioma in six, osteomyelitis in five, squamous cell carcinoma of the ear and temporal bone in four, sphenoid sinus mucocle in three, clivus chordoma in three, and nasopharyngeal carcinoma in two. The petrous apex is one of the more common sites for distant metastases in the skull base.¹¹ These lesions most commonly originate from hematogenous spread of breast, lung, kidney, and prostate tumors. Secondary metastatic lesions in this study included four cases: three patients with renal cell carcinoma and one with follicular thyroid carcinoma.

Disease extension is detailed in Table 5, and the percentages add up to greater than 100% because a few patients had more than one site of extension. The most common regions for extension included the intrapetrous and immediate intracranial areas. Disease extension was characteristically less remarkable for PPAL compared with ISPAL.

SURGICAL APPROACH

Surgical access (when indicated) required consideration of the following criteria: (1) preoperative cochlear function, (2) the relationship of the tumor to the jugular bulb, (3) the relationship of the horizontal segment of the internal carotid artery to the tumor, and finally (4) whether or not primary or secondary disease was suspected.^{3,7,10,12} Other factors considered in choosing surgical access were the ability to provide adequate exposure for complete

excision or exteriorization of disease, along with the ability to preserve facial nerve and other cranial nerve functions, avoidance of injury to the brainstem, and proper wound closure without cerebrospinal fluid leak. Patients in this study requiring a surgical procedure most commonly included access utilizing suboccipital, infralabyrinthine, or transphenoidal approaches.

SUMMARY

Although classic descriptions of petrous apex lesions are useful, there is no radiographic definition of these lesions that is absolute. Thin section CT scanning with contrast is the preferred mode of initial imaging. However, MRI is superior to CT scanning in evaluating tumor recurrences, particularly in a soft tissue-obiterated cavity. Arteriography was used to lesser degrees in this study with the advent of MRI, but it remains useful in all patients with suspected vascular pathologic conditions. Petrous apex lesions, primarily as a result of MRI, are apparently becoming more frequently recognized. There is no one clinical presentation that typifies all lesions. Preoperative findings that are most helpful in the distinction of PPAL, ISPAL, and MSPAL include age, history of chronic otitis media, type of cranial nerve deficit, type of hearing loss, and radiologic characteristics.

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