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Internal Auditory Canal Involvement of Acoustic Neuromas: Surgical Correlates to Magnetic Resonance Imaging Findings

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Objective: Factors that play a role in the selection of surgical approach for acoustic neuromas include patient health and age, size of tumor, hearing status, and location of tumor in the internal auditory canal (IAC) and the cerebellopontine angle. Deep extension into the IAC makes hearing preservation extremely difficult when a retrosigmoid craniotomy is used, and the best approach is a middle fossa subtemporal route. Modern gadolinium-enhanced magnetic resonance imaging (MRI) can be inaccurate in identifying the presence of tumor laterally in the IAC. This may affect the selection of a surgical approach.
Study Design: This study was a retrospective case review.
Setting: Patients were accrued from a tertiary referral otologic practice.
Patients: From 1997 through 2000, the authors identified six patients who had undergone acoustic neuroma surgery, had adequate imaging and intraoperative data, and demonstrated a lack of correlation between MRI and intraoperative findings of the lateral IAC.
Intervention: The interventions were preoperative MRI of the IAC and surgical resection of an acoustic neuroma.
Main Outcome Measure: Comparison of MRI and intraoperative findings of the lateral IAC were the main outcome measures.
Results: Six patients demonstrated a lack of correlation between MRI and intraoperative findings of the lateral IAC.
Conclusions: Gadolinium-enhanced T1-weighted MRI findings of the depth of penetration into the lateral aspect of the IAC do not always correlate with intraoperative findings and thus may have implications in the selection of surgical approaches to acoustic neuromas. **Key Words:** Acoustic neuroma—Internal auditory canal—Magnetic resonance imaging.
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With advances in imaging technology, the acoustic neuroma surgeon is now better able to preoperatively gauge the location and size of a tumor. This information, the age, the health, and the hearing of a given patient can help in the decision-making process regarding selection of the surgical approach. Gadolinium-enhanced magnetic resonance imaging (MRI) is accurate in defining the cerebellopontine angle (CPA) component of an acoustic neuroma, but there are questions regarding the accuracy of defining the component in the internal auditory canal (IAC). Lateral extension into the region of the fundus can be particularly problematic for retrosigmoid approaches when hearing is present and hearing conservation is being attempted. This study presents recent examples of misinformation regarding IAC involvement obtained on present-day MRI scans.

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MATERIALS AND METHODS

The senior author performed 74 skull base surgical procedures from January 1997 through February 2000. Of these, 45 were for primary acoustic neuroma procedures. In this group, 28 patients had adequate imaging and intraoperative data for inclusion in this retrospective study. The surgical procedures were performed at the New York Weill Cornell Center of New York Presbyterian Hospital and Memorial Sloan Kettering Cancer Center. T1-weighted gadolinium-enhanced axial and coronal MRI images that specifically included adequate images of the IAC were reviewed. The magnet strength, Tr, Te, slice thickness, slice overlap, and date of examination were recorded. On MRI images, the IAC length and the tumor length were measured by a senior neuroradiologist (L.A.H.), who was blinded to the surgical findings. The medial portion of the IAC was defined according to a standard method, as described by Telischi et al. (1), which measures from the midpoint of a line joining the level of the uneroded posterior petrous face bone anterior and posterior to the porus. Measurements were taken from the porus acusticus to the most lateral extent of tumor within the IAC. The procedures for these tumors included translabyrinthine craniotomies, retrosigmoid craniotomies, and middle fossa subtemporal craniotomies. The degree and lateral extent of IAC involvement at surgery were determined visually by the senior author (S.H.S.).

RESULTS

Six patients had IAC MRI findings inconsistent with the surgical findings and are included in this analysis. All patients were men. Their ages averaged 50.2 years (range 40–54 years). All patients underwent coronal and axial MRI scans with T1 weighting (Table 1). Five of six patients underwent a scan by a 1.5-Tesla machine. The sixth patient underwent a scan by a low-field magnet that yielded a clear and adequate result for interpretation. Axial slice thicknesses ranged from 3 to 6 mm, and interslice gaps ranged from 0 to 3 mm in thickness. Coronal slice thickness ranged from 2 to 4 mm, and interslice gaps ranged from 0 to 3 mm in thickness. All of these parameters for MRI scanning reflect present-day valid techniques and do not inherently compromise the quality of the data.

The intervals between the date of the MRI scan and the date of surgery averaged 33 days (range 1–49 days) (Table 2). The CPA component of the tumor averaged 20.3 mm (range 15–25 mm) (Table 2).

The measured IAC lengths on axial MRI scans ranged from 11 to 17 mm, and the involvement of the IAC with tumor ranged from 33% to 59% (Table 3). A representative axial MRI scan from patient 6 can be seen in Figure 1A. The involvement of the IAC with tumor observed at surgery was 100% in all patients. In these six patients, the axial MRI findings did not accurately predict the IAC findings at surgery.

The measured IAC lengths on coronal MRI scans ranged from 12 to 17 mm, and the IAC involvement with tumor ranged from 38% to 71% (Table 4). A representative coronal MRI scan from patient 6 can be seen in Figure 1B. The IAC involvement with tumor observed at surgery was 100% in all patients. In these six patients, the coronal MRI findings did not accurately predict the IAC findings at surgery.

Both the axial and coronal data show an absence of involvement of the lateral third of the IAC in five of the six patients, whereas at surgery tumor filled the IAC in all of these patients. The sixth patient had 71% involvement of the IAC, and so minimally involved the lateral third on MRI.

TABLE 1. *Magnetic resonance imaging parameters used in the evaluation of patient group*

Patient no.	Tesla	Coronals Thickness (mm)	Coronals Gap (mm)	Axials Thickness (mm)	Axials Gap (mm)
1	N/A	4	3	6	3
2	1.5	3	1	3	1
3	1.5	3	0.3	3	3
4	1.5	2	0	5	0
5	1.5	4	0.5	3	0.5
6	1.5	3	0	3	0
Range	1.5	2–4	0–3	3–6	0–3

TABLE 2. *Imaging surgery time interval and size of cerebellopontine angle (CPA) portion of tumor in patient group*

Patient no.	Imaging surgery time interval (days)	Size of CPA portion of tumor (mm)
1	29	25
2	1	15
3	21	25
4	8	16
5	48	25
6	49	16
Range	1–49	15–25
Average	26	20.3

DISCUSSION

The ability to identify patients with acoustic neuromas has paralleled advances in diagnostic technology. In the early part of the 20th century, when technology had yet to make a significant impact on the identification of acoustic neuromas, Cushing and his neurologic and neurosurgical colleagues relied on an understanding of the symptom progression caused by acoustic tumor compression of the IAC contents, CPA, and posterior fossa structures to lead to a tumor diagnosis (2). With reliable audiometry and imaging techniques unavailable, all 30 patients in Cushing's 1917 monograph *Tumors of the Nervus Acusticus* sought treatment late and had large tumors. Decades later, site of lesion, retrocochlear audiologic testing, brainstem auditory evoked response testing, air contrast computed tomography, and intravenous contrast computed tomography increased the clinician's ability to accurately and efficiently diagnose acoustic neuromas. Yet, each of these modalities pale in comparison with the resolution, reliability, and relative comfort of MRI. Magnetic resonance imaging with intravenous gadolinium has the ability to identify 2- to 3-mm acoustic neuromas and, along with an improved awareness and suspicion of acoustic neuromas as a di-

TABLE 3. *Axial magnetic resonance imaging (MRI) and surgical findings of the internal auditory canal (IAC)*

Patient no.	IAC length (mm)	% IAC with tumor	Tumor involvement/ MRI (by ⅓ IAC) Medial ⅓	Middle ⅓	Lateral ⅓	% IAC at surgery
1	17	59	x	x		Entire
2	11	36	x	x		Entire
3	12	58	x	x		Entire
4	13	38	x	x		Entire
5	12	33	x			Entire
6	11	45	x	x		Entire
Range	11–17	33–59				
Average	12.7	45				

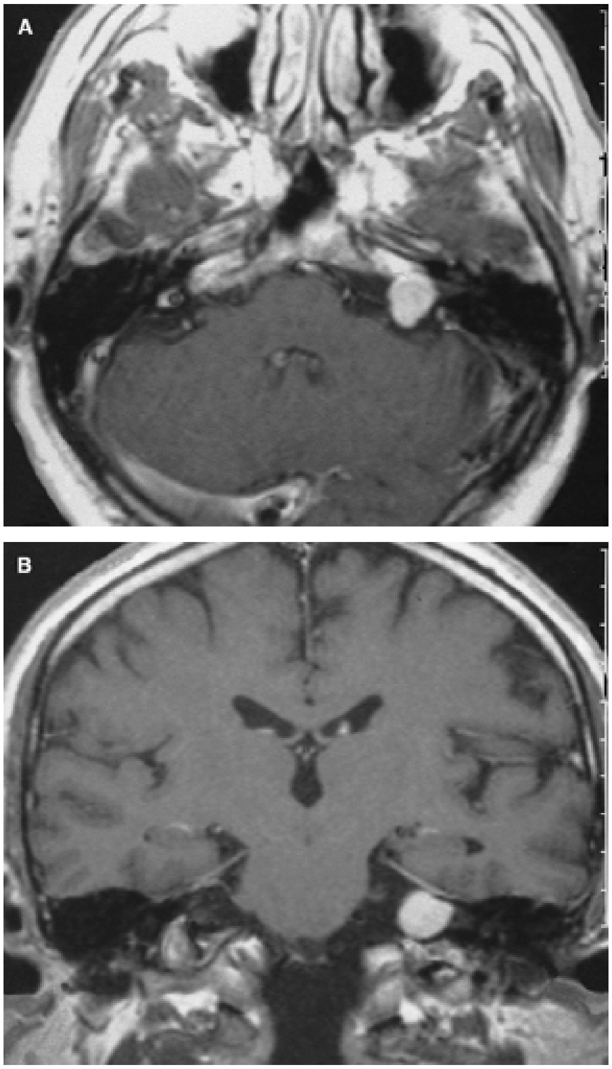

FIG. 1. T1-weighted gadolinium-enhanced axial magnetic resonance imaging of Patient 6, axial (**A**) and coronal (**B**). Note the lack of enhancement in the lateral aspect of the internal auditory canal (IAC). At surgery, tumor was found to occupy the entire IAC.

agnostic entity by physicians in general, has led to earlier diagnosis of symptomatic patients (3).

Early diagnosis is an essential first step toward the goal of improved surgical outcomes, which ultimately depend on several factors, probably the most important of which are the surgeon's technical skill and judgment. Tumor characteristics, however, predict outcomes as well. These predictors include the variable anatomical relationship of the tumor with related normal anatomy, tumor adherence to related normal anatomy, tumor location, and tumor size. Although it would be desirable for the present-day MRI scanner to be able to define these predictors preoperatively, this is not a reality. For example, a recent study of over 1000 patients operated on for acoustic neuromas defined the variable relationship of the facial nerve with the CPA portion of acoustic neuromas at surgery (4). In this study, the facial nerve was most often on the ventral or superior surface of the tumor in the CPA but at times was found inferior or dorsal to the tumor. Today's MRI capabilities are not yet sophisticated enough to warn the surgeon of these unusual tumor–nerve relationships.

Acoustic neuroma surgeons are all too familiar with the variability in adherence of the facial nerve to the CPA portion of the tumor. It is thought that the adherence may represent a focal chronic arachnoiditis. But again, present-day MRI is not able distinguish patients with dense facial nerve adhesions from patients who at surgery are found to have unencumbered surgical planes between the facial nerve and the tumor. There is a clear relationship between facial nerve outcome and tumor size: larger tumors have worse facial nerve postoperative function and hearing preservation (5).

Acoustic neuromas are thought to arise from the junction of peripheral and central myelin at the Obermeier-Redlich zone of the cochleovestibular nerve in the IAC (6). Characteristically, acoustic neuromas fill the IAC before prolapsing into the CPA. Accordingly, the usual MRI picture of an acoustic neuroma is that of a brightly enhancing homogenous smooth lesion, filling and widening the IAC and extending into the CPA. Variants such as cystic tumors are well recognized (7,8).

Present-day MRI is thought to be able to accurately define both the intracanalicular and the CPA portions of acoustic neuromas, but it has become apparent in several cases that the absence of gadolinium enhancement in the lateral portion of the IAC did not correlate with absence of tumor in this location at surgery. This finding has implications on the choice of surgical approach and on functional outcomes.

While there is no universal agreement on indications for surgical approaches to acoustic neuromas, the indications used at the Weill College of Medicine of Cornell University are based on well-accepted reasoning and probably represent a reasonable consensus of many acoustic neuroma surgeons.

The audiologic criteria used in determining whether a hearing conservation approach is indicated is controversial, but many surgeons still rely on the 50/50 rule of

TABLE 4. *Coronal magnetic resonance imaging (MRI) and surgical findings of the internal auditory canal (IAC)*

Patient no.	IAC length (mm)	% IAC with tumor	Tumor involvement/MRI (by ⅓ IAC): Medial ⅓	Middle ⅓	Lateral ⅓	% IAC at surgery
1	15	60	x	x		Entire
2	13	46	x	x		Entire
3	17	71	x	x	x	Entire
4	12	67	x	x		Entire
5	13	38	x	x		Entire
6	12	42	x	x		Entire
Range	12–17	38–71				
Average	13.7	54				

speech discrimination and speech reception threshold (9). Regardless, once a hearing conservation approach has been selected, the decision then involves the selection of the subtemporal middle fossa (MF) or the retrosigmoid (RS) approach. Recent data have shown improved hearing preservation rates when the MF approach is used. In some large series, hearing preservation has been achieved in up to 70% of patients (9,10). The MF has the distinct advantage of excellent exposure of the entire IAC, including the most lateral portion, the fundus, without entering the otic capsule structures and causing a profound sensorineural hearing loss. One disadvantage of the MF approach is that the facial nerve is more vulnerable to injury because of its superficial relationship to the intracanalicular portion of the tumor. A second disadvantage is limited access to the posterior fossa. The posterior fossa is accessed by wide drilling of the petrous temporal bone at the level of the porus acusticus and by division of the superior petrosal sinus and tentorium. The risks of division of the sinus and of temporal lobe retraction are small but real, as is the threat of posterior fossa hemorrhage that cannot be adequately controlled through a limited opening.

The RS approach on the other hand, offers a wide approach to the posterior fossa, but only approximately the medial two thirds of the IAC can be exposed by drilling without entering the posterior semicircular canal (11). Entrance into the posterior semicircular canal risks a complete sensorineural hearing loss. Entering the otic capsule can be circumvented by avoiding drilling the lateral one third of the IAC and fundus, but then this region can be accessed only by indirect methods, such as blind dissection or the use of angled endoscopes. Indirect access risks the loss of not just hearing but facial function as well. For this reason, the MF approach is best for tumors involving the entire IAC and that have a small angle component, and the RS approach is best for tumors not involving the lateral one third of the IAC when hearing is present. Therefore, involvement of the lateral one third of the IAC by tumor can have a profound effect on deciding which hearing conservation approach should be used.

Despite the touted accuracy of the ability of MRI to identify small acoustic neuromas, several cases have been identified in which tumor was present in the lateral IAC and fundus at surgery, even though the preoperative MRI scan showed a lack of enhancement in that region. To date, this has been best described by Telischi et al., who prospectively examined the relationship between the preoperative MRI scans of 82 patients with acoustic neuromas and their operative findings (1). These authors found 4 patients who had MRI scans that did not show involvement of the lateral third of the IAC, but who at surgery did have involvement of the lateral third of the IAC. In their study, the ability of an MRI scan that does not show involvement of the lateral third of the IAC to correctly correlate with an absence of involvement of the lateral third of the IAC at surgery was only 76%.

The MRI techniques reported in this study are valid and current and do not affect the accuracy of the data; rather, the findings on MRI in these 6 patients simply do not show gadolinium enhancement at all sites in the IAC on T1-weighted studies where tumor was, in fact, present. While this study has insufficient data to permit conjecture with regard to the incidence of inaccurate IAC imaging, it is the largest series of a cases in which this finding is present.

As noted earlier, MRI accuracy has implications in the selection of surgical approaches when hearing preservation is being considered. A RS approach is most appropriate if the lateral one third of the IAC and fundus is free of tumor. If it is not free of tumor, then additional drilling of the lateral IAC will lead to penetration into the posterior semicircular canal and a profound sensorineural hearing loss, accomplishing essentially a non–hearing preservation translabyrinthine approach.

It is not clear why the absence of gadolinium enhancement on MRI in the distal IAC and fundus may still be associated with the presence of tumor, but several explanations could be invoked. First, there may be something unusual with the tumor in this region. For example, if the tumor is necrotic, it may not enhance well with the intravenous paramagnetic dye, although it should still appear different from a distal IAC filled with normal cerebrospinal fluid. An adequate understanding of these issues is not presently available for acoustic neuromas. Alternatively, the sensitivity of the MRI study is less accurate than was originally presumed. Recent studies have compared fast-spin T2 sequences with traditional T1 gadolinium-enhanced images in their ability to diagnose intracanalicular lesions (12,13). The T2 sequences can often identify the neural structures of the IAC, can define space-occupying lesions by the absence of the bright cerebrospinal fluid signal, and in some ways are superior to gadolinium studies. In the cost-cutting environment of managed care, these T2 studies are especially attractive because expensive gadolinium paramagnetic dye is unnecessary. It is also unclear why so many of these tumors have been identified in our study in only the past 3 years and why all patients in our series were male.

Ultimately, the acoustic neuroma surgeon should not be surprised to find tumor in the lateral IAC in the absence of gadolinium enhancement, and should make surgical plans accordingly.

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