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AJNR Am J Neuroradiol 1988, 9 (1) 115-119

<http://www.ajnr.org/content/9/1/115>

This information is current as
of April 20, 2024.

MR of the Normal and Abnormal Internal Auditory Canal

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MR performed with thin, contiguous sections has replaced CT for the study of the cerebellopontine angle and for diagnosis of acoustic neuromas. In our experience large acoustic neuromas are well seen in all pulse sequences. Tumors with small extracanalicular components are seen in the T1- and spin-density-weighted sequences whereas purely intracanalicular lesions are often visualized only in the T1-weighted images. Small acoustic neuromas producing thickening of the nerve are easily recognizable in narrow internal auditory canals but may be missed in large canals because of partial volume averaging.

Since further enhancement of the signal intensity of tumors can be obtained by IV injection of paramagnetic agents, we foresee the use of such agents in the near future in the diagnosis of acoustic neuromas.

Until recently, CT has been the study of choice for assessing the internal auditory canal and diagnosing acoustic neuromas [1]. Extracanalicular lesions larger than 8–10 mm are clearly demonstrated on CT scans obtained after infusion of iodinated contrast media. The diagnosis of intracanalicular and small extracanalicular tumors requires a more invasive approach; namely, the injection in the subarachnoid space by lumbar puncture of gaseous or opaque material.

MR imaging performed with thin, contiguous sections has opened a new approach, which in our view, and that of other authors [2–6], has replaced CT for the diagnosis of cerebellopontine angle tumors. The main advantage of MR is the opportunity it provides to diagnose tumors of any size without ionizing radiation, in a noninvasive manner with multiplanar display. The availability in the near future of paramagnetic agents such as gadolinium DPTA [7, 8] for tumor enhancement will improve the detection of acoustic neuromas and other cerebellopontine tumors.

Materials and Methods

Scans were performed with a 1.5-T GE Signa unit. Coronal and axial sections were obtained using the following spin-echo pulse sequences: coronal 3-mm contiguous T1-weighted sections at 600/25 using a 16-cm field of view, four excitations, and a 256 × 128 matrix. The axial plane was imaged with 3-mm contiguous sections, spin-density weighted at 2000/20 and T2-weighted at 2000/80 using a 24-cm field of view, two excitations, and a 126 × 128 matrix. In five cases the following T1-weighted technique proposed by Enzmann and O'Donohue [9] was used for the coronal images: 3-mm sections with 20% interslice gaps at repetition time (TR) of 800 and echo time (TE) of 25, using six excitations, and a 256 × 256 matrix.

Forty internal auditory canals and cerebellopontine cisterns, from 20 patients referred for an MR scan to rule out supratentorial disease and reported as normal, were reviewed for assessment of the normal appearance. Fifty acoustic neuromas from 48 patients seen from October 1, 1985, through April 1, 1987, are included in this report. The tumor was bilateral in two cases. Patients' ages ranged from 17 to 78; 28 of the patients were women and 20 were men.

Received February 10, 1987; accepted after revision August 9, 1987.

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AJNR 9:115–119, January/February 1988
 0195–6108/88/0901–0115

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Forty-one of the 48 patients have been operated on so far and in all instances an acoustic neuroma was found. In three of the unoperated cases a CT pneumocisternogram was obtained to confirm the presence of the lesion and in four the findings were so obvious that no other examinations were warranted. Two additional patients with only subtle findings of a lesion were not included in this series although they will appear in our discussion.

The internal auditory canal was enlarged on the affected side in 39 cases and normal in 11. The tumor was completely intracanalicular in 13 (26%) cases, intra- and extracanalicular with a cisternal component smaller than 1.5 cm in 21 (42%) cases, and with a cisternal component larger than 1.5 cm in the remaining 16 (32%) cases.

Normal Internal Auditory Canal and Cerebellopontine Cistern

A brief review of the normal anatomy is worthwhile for a proper understanding of the MR findings.

The size of the normal internal auditory canal varies greatly. It may be as small as 2–3 mm in diameter or as wide as 12 mm in diameter, with an average diameter of 5 mm. The size of the neurovascular bundle entering the canal is quite con-

stant, and measures 2–3 mm in diameter. Therefore, the size of the subarachnoid space and the amount of CSF within the canal varies from almost nil to very conspicuous.

The canal is divided into two compartments by a horizontal bony septum, the crista falciformis, which is thicker anteriorly. At the fundus the canal is divided above the crista in the anterior and posterior recesses by a vertical bony bar, the so-called Bill's bar. The facial nerve, which occupies the antero-superior compartment of the internal auditory canal, follows a straight course to reach the opening of the Fallopian canal in the anterior wall of the fundus of the canal. The cochlear nerve also runs straight in the anteroinferior compartment of the canal to approximately 2–3 mm from the fundus, where it makes a sharp turn forward to reach the base of the modiolus (Fig. 1).

The superior and inferior vestibular nerves, which occupy the posterior compartment of the canal, follow a quite different course. Both nerves split in the lateral portion of the canal into several small branches, which reach the various foramina in the cribriform plate dividing the canal from the vestibule and the opening of the singular canal (Fig. 2).

In approximately 30–50% of the cases the anterior inferior

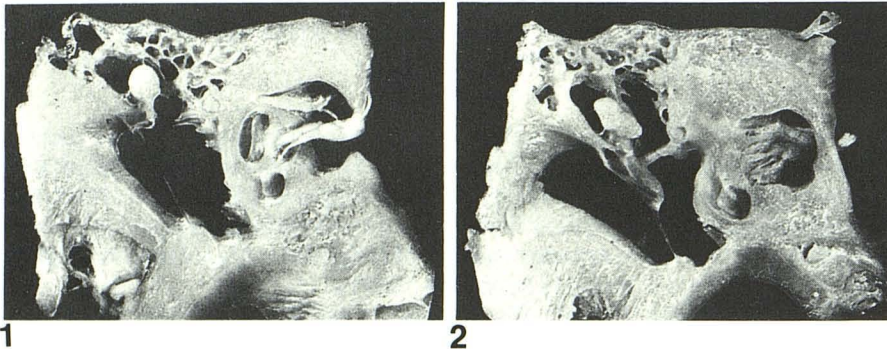


Fig. 1.—Coronal tissue section of normal temporal bone. Section crosses anterior portion of internal auditory canal and exposes facial and cochlear division of acoustic nerves.

Fig. 2.—Coronal tissue section of normal temporal bone 3 mm posterior to Fig. 1. Section crosses posterior portion of internal auditory canal and exposes vestibular nerves. Notice fanning of nerves in lateral portion of internal auditory canal.

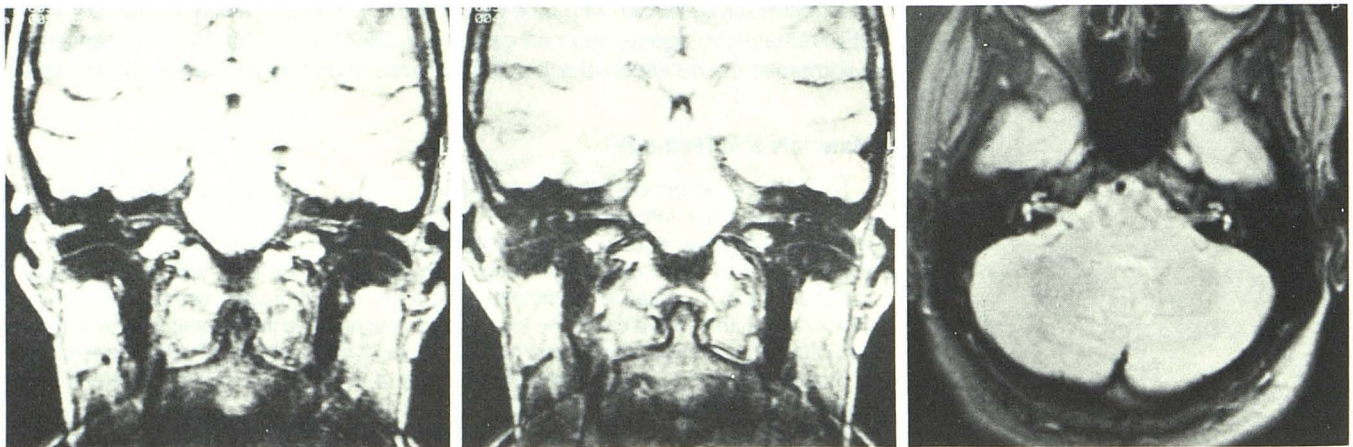


Fig. 3.—Normal internal auditory canal. T1-weighted coronal section at 600/25. Section passes through anterior portion of canal and exposes facial and cochlear nerves separated by the crista falciformis.

Fig. 4.—Normal internal auditory canal. T1-weighted coronal section 3 mm posterior to Fig. 3. Section passes through posterior portion of canal. Notice that vestibular nerves are less distinct than facial and cochlear nerves.

Fig. 5.—Normal internal auditory canals. T2-weighted axial section at 2000/80.

cerebellar artery forms a loop within the internal auditory canal.

The lateral portion of the acoustic nerve is covered by a neurolemmal or myelinated sheath arising from the peripheral ganglia and the medial portion by neuroglial fibers extending peripherally from the brainstem. Most of the acoustic neuromas arise within the internal auditory canal at the junction between the two sheaths.

The cerebellopontine cisterns are also quite variable in size and may be asymmetric not only from patient to patient but also from side to side.

The myelinated intracanalicular portion of the acoustic and facial nerves are seen best on the T1-weighted images; however, the appearance of the nerves varies with the plane of section through the canals. If the section crosses the anterior portion, the facial and cochlear nerves appear as two well-defined linear bands brighter than the fluid within the lateral two-thirds of the canal. The crista falciformis forms a

line of no signal between the two nerves (Fig. 3). If the section crosses the posterior portion of the canal, the nerves are indistinct with areas of higher intensity produced by the fanning of the vestibular nerves (Fig. 4). The crista falciformis, which is quite thin posteriorly, is usually not recognizable. The nonmyelinated proximal or medial portion of the nerve is usually not visualized. The signal intensity of the CSF and the relative signal intensity of brain and nerves to CSF are summarized in Table 1.

On the basis of the previous observation the following conclusions may be drawn: (1) T2-weighted images are best for studying the size of the internal auditory canal, since the contour of the canal is well outlined by the brightness of the CSF. (2) Areas of low intensity within the internal auditory canal and cerebellopontine cistern are produced by bony structures, such as the crista falciformis and Bill's bar, or by blood vessels. (3) T1-weighted images are best for visualizing the myelinated portion of the nerves (Fig. 5). (4) If the canal is large and the ratio between the diameter of the nerves and canal is less than 0.3, the nerves may not be seen because of partial volume effect. (5) A difference in the appearance of the nerves within the two internal auditory canals should not be misinterpreted for a lesion, since the two canals may be sectioned through different compartments due to slight rotation of the patient's head or to anatomic asymmetry between the two sides.

TABLE 1: Signal Intensity of Normal Brain and Acoustic Nerve in Relation to CSF

	T1-Weighted 600/25	Spin Density 2000/20	T2-Weighted 2000/80
CSF	Low-medium	Medium	High
Brain	Brighter than fluid	Brighter than fluid	Less bright than fluid
Nerve	Brighter than fluid	Usually not seen	Not seen

TABLE 2: Signal Intensity of an Acoustic Neuroma in Relation to CSF and Brain

	T1-Weighted 600/25	Spin Density 2000/20	T2-Weighted 2000/80
CSF	More	More	Same or less
Brain	Same as gray matter	Same or slightly more	More

Abnormal Internal Auditory Canal and Cerebellopontine Cistern

The diagnosis of an intracanalicular lesion is based on a differentiation in signal between tumor and CSF. If the lesion originates or extends into the cistern, the diagnosis is based on a differentiation in the signal between tumor, CSF, and brain. If the tumor is large there may be deformity of the adjacent brainstem. A fine, dark line produced by the meninges usually separates the tumor from the brainstem and cerebellum. The signal intensity of an acoustic neuroma in relation to CSF and brain is listed in Table 2.

A review of the 50 tumor cases based on the previously

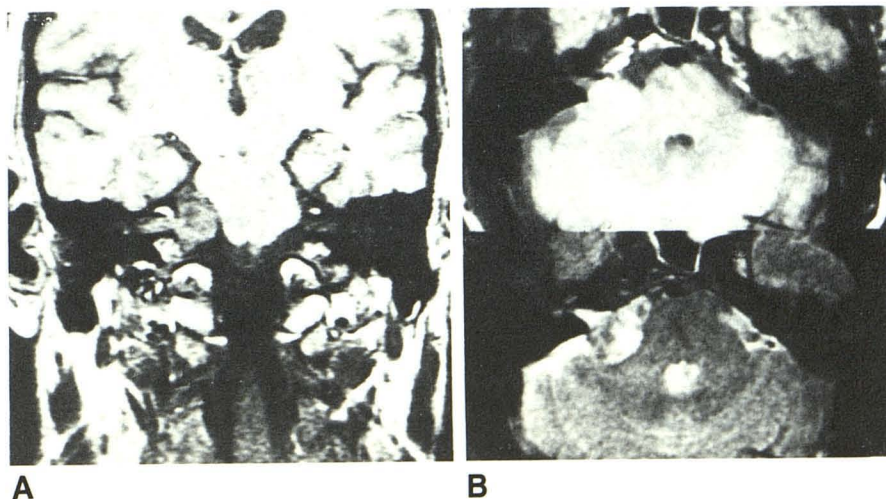


Fig. 6.—Large right acoustic neuroma compressing the brainstem.

A, T1-weighted section.

B, Spin-density-weighted image (*top*), T2-weighted image (*bottom*). Tumor mass is well seen in all sequences. Notice that tumor is inhomogeneous in intensity.

listed diagnostic criteria leads to the following conclusions: (1) Large acoustic neuromas with an extracanalicular component of more than 1.5 cm are well seen in all pulse sequences. Since the CSF has been displaced from the cerebellopontine cistern, the signal intensity of the mass is related to the adjacent brain structures. The tumor is brighter than brain in the T2-weighted images, and the brainstem and cerebellum are compressed, and the fifth cranial nerve is often involved. In the T2-weighted images the tumor is often inhomogeneous in intensity. This inhomogeneity may be caused by the different signal of the Antoni A and Antoni B tissues, which form the bulk of the tumor or by the degeneration that often occurs in the larger lesions [10-12] (Fig. 6). (2) Acoustic neuroma with extracanalicular component of less than 1.5 cm

are best seen in the T1- and spin-density-weighted images. Since the CSF surrounds the cisternal component of the mass, the signal intensity of the lesion is related to both fluid and brain. In the T2-weighted images the mass is often not recognizable, since its signal is isointense to CSF (Fig. 7). (3) Small, intracanalicular neuromas are best seen in the T1-weighted images as areas of higher signal intensity than CSF. Small lesions produce thickening of the nerve. Larger lesions fill a portion of or the entire internal auditory canal (Figs. 8 and 9). In the spin-density- and T2-weighted sequences the lesions are often not seen because their signal is similar to CSF.

We have observed a possible pitfall in the diagnosis of small acoustic neuromas by MR. If the ratio between the

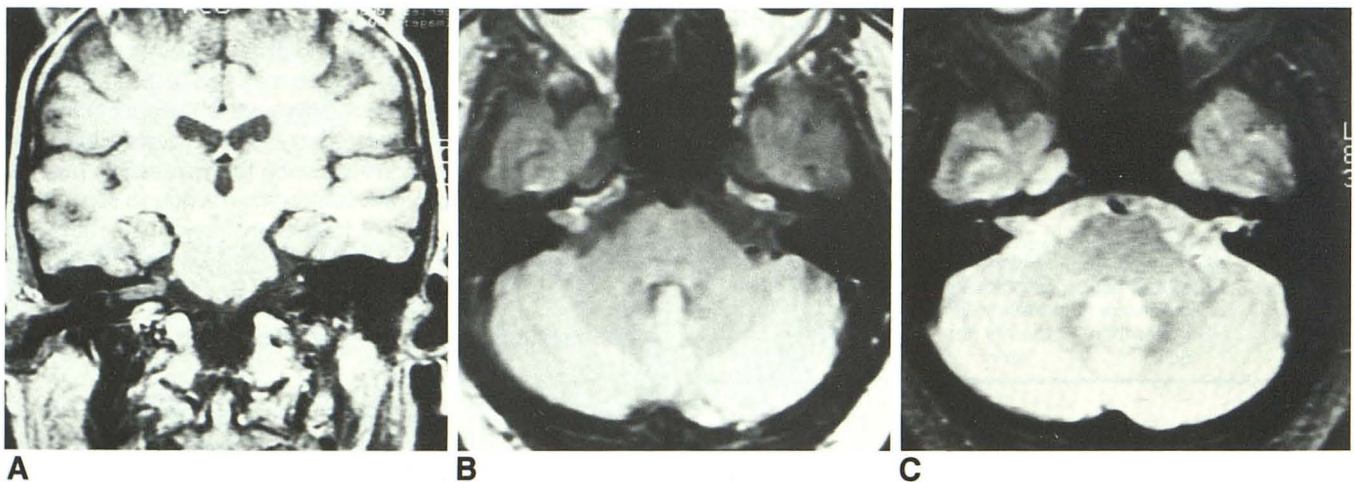


Fig. 7.—Right acoustic neuroma filling internal auditory canal and extending into cerebellopontine cistern. Extracanalicular component of mass measures 1 cm. Tumor is well seen on T1-weighted image (A) and on spin-density-weighted image (B). In T2-weighted section (C) mass is obscured by surrounding CSF.



Fig. 8.—Right acoustic neuroma. T1-weighted coronal section at 600/25. Tumor fills and expands internal auditory canal.



Fig. 9.—Right acoustic neuroma. T1-weighted coronal section at 600/25. Small acoustic neuroma fills and slightly expands lateral portion of internal auditory canal.

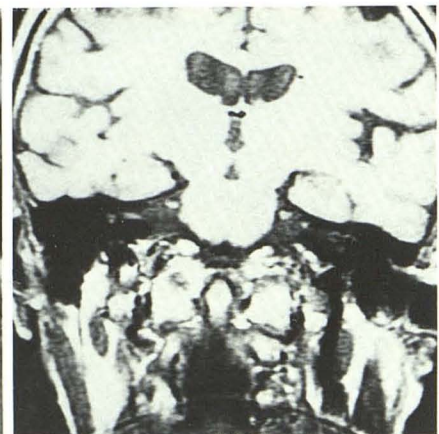


Fig. 10.—T1-weighted coronal image at 600/25 in patient complaining of right sensorineural hearing loss. Notice small area of high signal intensity within right internal auditory canal. There is no expansion of canal or thickening of nerve.

diameter of the tumor and that of the internal auditory canal is less than 0.3, the lesion may be missed because of partial volume averaging.

In two cases not included in this series, a small area of high signal intensity was observed within the intracanalicular portion of the acoustic nerve, which, however, was not thickened (Fig. 10). In both instances the CT pneumocisternogram was negative. Since it is possible that MR may show chemical changes within the nerve before actual thickening of the nerve occurs, we plan to perform follow-up examinations in both cases to rule out an early lesion.

Conclusions

MR allows the diagnosis of acoustic neuromas of varied sizes without subjecting patients to invasive procedures or exposing them to ionizing radiation.

The examination should be performed with the pulse sequences that allow the sharpest contrast or differentiation between the signal intensity of the tumor, CSF, and brain. In comparing the images obtained with our technique and the technique proposed by Enzmann and O'Donohue [9], we concluded that the subtle improvement in signal to noise ratio and definition obtained by using more excitations and a 256×256 matrix did not justify the doubling of the acquisition time from 10 to 20 min. In addition, we believe that the use of contiguous sections is indispensable in the study of a narrow structure such as the internal auditory canal. Small lesions may be missed or inadequately visualized with interslice gaps.

Since further enhancement of the signal intensity of the

tumor can be obtained by IV injection of paramagnetic agents, we foresee the use of such agents in the near future. It is conceivable that incipient tumors may be detected by MR on the basis of chemical changes within the nerve before actual thickening of the nerve occurs.

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