AJNR

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*AJNR Am J Neuroradiol* 1997, 18 (10) 1834-1838
http://www.ajnr.org/content/18/10/1834.citation

# Rule Out Eighth Nerve Tumor: Contrast-Enhanced T1-Weighted or High-Resolution T2-Weighted MR?

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The question is whether noncontrast high-resolution T2-weighted magnetic resonance (MR) imaging can replace contrast-enhanced T1-weighted imaging as the primary approach to imaging a patient with a possible eighth nerve tumor. The contrast-enhanced T1-weighted sequence is extremely reliable. A high-resolution T2-weighted sequence without contrast material is potentially more cost-effective, but is it adequate to the task?

Radiologic imaging operates along a technological continuum in which the state of the art changes almost yearly. For example, the approach to imaging a suspected acoustic neuroma has progressed dramatically in the last few

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**Index terms:** Nerves, vestibulocochlear (VIII); Magnetic resonance; Special reports

AJNR 18:1834–1838, Nov 1997 0195-6108/97/1810–1834 

decades. Attempts to show subtle findings that only suggested the presence of a lesion have given way to actual visualization of the smallest of tumors deep within the internal auditory canal. Indeed, even the official name of the lesion has changed from *acoustic neuroma* to *vestibular schwannoma*.

Although much has changed in this area of imaging, the basic goal has not. While we are certainly interested in visualizing and thus diagnosing these small eighth nerve lesions, the true goal is not to find an abnormality but to prove that a particular patient does *not* have a tumor. For example, a patient presents with tinnitus or a sensorineural hearing loss. Many potential causes of such symptoms are considered, but the acoustic neuroma (vestibular schwannoma) is one that the otologist must exclude. The acoustic neuroma is treatable, and potentially significant harm can result from one that is untreated. Removing an acoustic neuroma almost never improves hearing; indeed, what hearing remains may be destroyed by surgery. However, the growth of such a lesion may lead to further, more devastating problems. An enlarging lesion can cause pressure on the brain stem or other cranial nerves. The best chance for removing a tumor without complication occurs when the lesion is small. For instance, facial paralysis is more commonly a by-product of surgery for large tumors than for small ones (1). Earlier diagnosis is obviously preferred for these reasons. The referring physician sends a patient for imaging to make sure that there is no tumor before a treatment strategy is chosen.

Our imaging strategy must be designed to rule out a tumor. The perfect or ideal test will detect every tumor and miss none. The morbidity of the test is a factor, and cost must be figured into the equation. In addition, the ideal test would never give a false-positive result; that is, never indicate disease where there is none. However, as long as the radiologist and the neurootologist are aware of potential false-positive findings, the situation can be carefully controlled. The patient with a small lesion or a suggestive but not absolutely diagnostic finding may be followed up perhaps until the doubt is resolved. The false-negative study, in which a lesion is missed, is more significant, as a patient with this result may exit the medical system, inappropriately confident that a tumor has been excluded (2). If the patient returns later with continued or progressive symptoms, the once small tumor may have enlarged, bringing increased surgical risk.

Certainly, imaging of the internal auditory canal and potential eighth nerve abnormalities has progressed significantly, as has the technology of imaging in general. Twenty-five years ago, a discussion of optimal imaging of a suspected eighth nerve tumor might have centered on a comparison between angiography and pneumoencephalography. Morbidity was a very real issue. Twenty years ago, tomography was used as a screening examination to look for canal asymmetries that suggested tumor. In inconclusive cases, or when the index of suspicion was high, positive contrast cisternography was done with plain radiography or tomography actually to show the margins of the tumor (3, 4). Alternatively, the test would show the normal nerves within the canal and thus exclude a lesion. Fifteen years ago, most tumors were diagnosed with intravenous contrast-enhanced computed tomography (CT). Equivocal cases were further imaged with CT air cisternography (5–7). Ten years ago, high-resolution CT would be compared with noncontrast MR imaging (8, 9). Then came contrast material, and MR imaging reigned supreme (10–12). Contrast-enhanced MR images show all or almost all vestibular schwannomas. Dr Huckman continually cautions authors and reviewers to avoid claims of priority and to never say never. Accepting the risk of incurring his wrath, I must say that I am unaware of any case of acoustic neuroma missed by a contrast-enhanced MR examination in which sections were thin enough that the canal was well seen. Of course, we might not be aware of such a case, since a positive MR study is almost always required before surgery is considered.

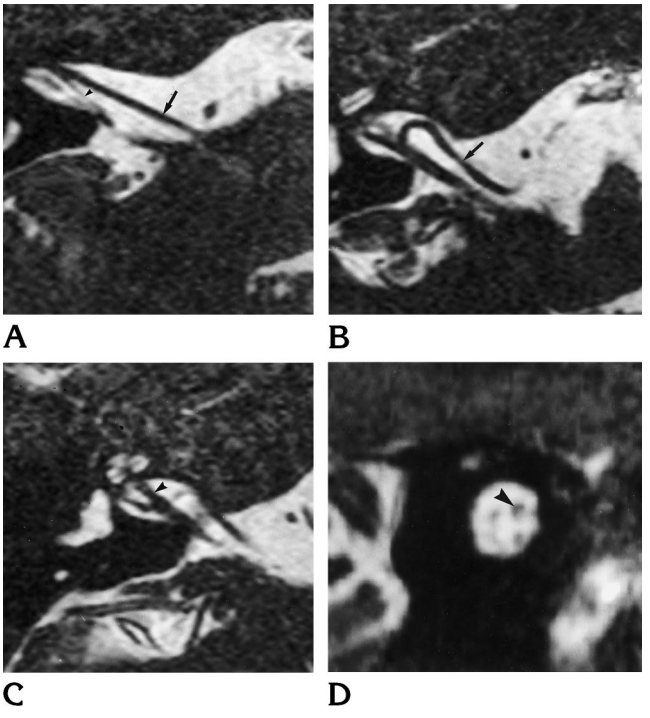


Fig 1. Normal findings. Noncontrast high-resolution T2-weighted (12.3/5.9/2 [repetition time/echo time/excitations]) MR examination obtained with 3-D Fourier transform constructive interference in the steady state (CISS). Flip angle was 70°, imaging matrix was 230 × 512.

*A*, Axial image through upper internal auditory canal shows the facial nerve (*arrow*) and the superior vestibular nerve. A thin filament (*arrowhead*) may represent the vestibulofacial anastomosis (a portion of the intermediate nerve of Wrisberg).

*B*, Slightly lower axial image shows a loop of the anteroinferior cerebellar artery (*arrow*) as well as a portion of the vestibular nerve.

*C*, A lower section shows the cochlear nerve (*arrowhead*) and the inferior vestibular nerve.

*D*, Sagittal reformatted image through the medial internal auditory canal shows facial nerve (*arrowhead*), cochlear nerve, and inferior and superior vestibular nerves.

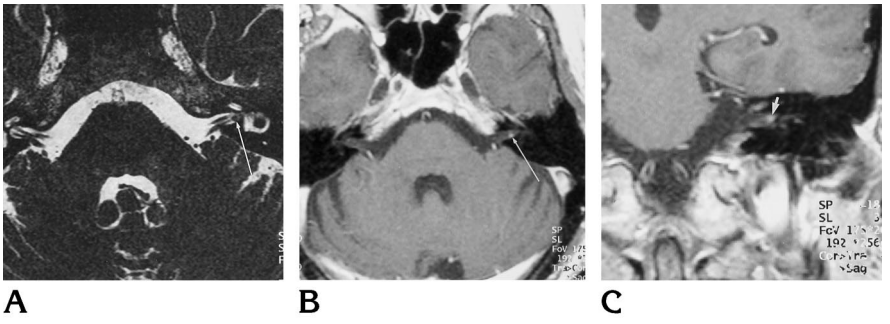


Fig 2. Probable small acoustic neuroma.

*A*, Three-dimensional Fourier transform CISS sequence shows a small, nodular filling defect (*arrow*) in the fundus of the left internal auditory canal.

*B*, Axial contrast-enhanced T1-weighted (500/20/2) spin-echo image (matrix, 192 × 256) shows a small area of enhancement (*arrow*) conforming to the location of the abnormality. The diagnosis is not absolute, and this patient would be followed up to see if there were an increase in the size of the lesion.

*C*, Coronal T1-weighted image shows the small area of enhancement (*arrow*) in the upper internal auditory canal.

The contrast-enhanced T1-weighted MR examination is not perfect. Although it approaches 100% sensitivity, false-positive findings have been known to occur. Inflammatory abnormalities or even small, vascular structures can closely mimic small tumors. While false-positive results are a problem, they are much less significant than missing a tumor. Moreover, this limitation can be easily addressed. Small, questionable abnormalities are monitored to see whether the lesion regresses, grows, or remains stable. Although acoustic neuromas do grow, they tend to grow slowly. The morbidity of an MR examination is so low that it may be repeated to establish a time line and to see if the lesion has enlarged. The crucial concern is to enter the patient into the system. Certainly, if the patient with negative imaging findings is followed closely by the referring otolaryngologist, progression of symptoms or worsening of various audiometric test parameters may necessitate imaging. However, a patient with a negative imaging examination who is assured that there is no tumor is likely to disappear from direct medical scrutiny.

Is the contrast-enhanced MR examination the perfect test? One would think that with a sensitivity approaching if not reaching 100%, the question regarding optimal imaging would have been put to rest: that the ideal test had been realized. However, there are always alternatives. Can the test be made more simple or less expensive? Do we need to use contrast material, which represents an additional cost? Could we provide a lower-cost but equally effective imaging examination? Currently, otologists screen patients by using such measurements as speech discrimination scores and brain stem evoked responses (13). In an effort to avoid the cost of MR imaging, less expensive but less accurate tests are used. Can imaging compete by providing a high-accuracy, low-cost alternative (14)? Another imaging approach takes the field to answer the challenge. Recently, gradient-echo and fast spin-echo sequences stressing T2 information and providing high resolution have been used to examine the eighth nerve (14–23) (Fig 1). Although the type of signal information acquired varies, both approaches produce an image that has the appearance of a cisternogram. Brain and nerves appear very dark, and are clearly delineated against the cerebrospinal fluid (CSF). This high-resolution noncontrast strategy should be less expensive, but is this an appropriate substitution?

Perhaps the history of imaging acoustic neuromas can help us find the answer. Until there was contrast material, the standard of reference for a negative study was demonstration of normal-sized nerves from the pontomedullary junction to the fundus of the internal auditory canal. If the nerves were seen as linear, normal-sized filaments with no visible enlargement or mass, then the examination was confidently called "normal." If contrast material penetrated the internal meatus, the radiologist was fairly certain there was no tumor, but the confidence of the exclusion was much higher if the normal nerves were actually visible. In a CT air cisternogram, the radiologist would tap on the patient's head, trying to break up an air bubble and to achieve better filling of the canal with better demonstration of the nerves inside.

Demonstration of normal nerves within the internal auditory canal represents appropriate evidence that there is no tumor. A tumor must distort the normal contour of the nerve. Can noncontrast MR imaging adequately show the nerves and thus save the cost of a contrast-enhanced study? Actually, this was done in the early days of MR imaging before contrast material, when the alternative was air CT cisternography (H. D. Curtin, E. Kanal, L. Burk, R. Latchaw, G. Wolfe, "1.5 Tesla MR Imaging in Acoustic Neuroma," presented at the annual meeting of the Radiological Society of North America, Chicago, Ill, November 1985). With the use of an extremely long repetition time and long echo time, the CSF appeared very bright, producing an MR cisternogram. Several excitations were needed to achieve adequate signal with high resolution, so the sequence might take 15 minutes or even longer. Any motion ruined the effectiveness. With contrast material, work on this technique slowed but did not disappear. Now with high-resolution fast spin-echo or 3-D gradient-echo sequences, such images can be generated in a fraction of the time.

To be competitive with contrast-enhanced examinations, these alternative high-resolution T2-weighted sequences must allow the radiologist to find all tumors; al-

ternatively, the criteria for declaring this type of study "normal" (definitely no tumor) must be extremely rigorous. First, the technique must be able to reliably identify all nerves within the internal auditory canal (Fig 1). Second, all tumors must be of demonstrably lower signal than CSF, otherwise the lesion may be lost in the high signal of the normal fluid spaces in the cerebellopontine angle cistern or the internal auditory canal (Fig 2). Third (and probably most important), even if a tumor is not clearly demonstrated, images must be sufficiently ambiguous to prompt the radiologist to proceed to a contrast-enhanced examination (Fig 2). Alternatively, depending on the degree of uncertainty, a repeat examination may be scheduled. However, the ambiguous examination cannot be called "normal" or read as "no tumor seen."

Several reports have indicated that these sequences can show the nerves within the canal (14–19, 21, 22). The use of thin sections and, at times, reformatted images show the normal nerves from the brain stem to their exit points from the lateral fundus of the internal auditory canal. The second condition, that all tumors be dark enough to stand out against the bright CSF, raises a question. Acoustic neuromas have frequently been described as "bright" on T2-weighted sequences. However, this description usually results from comparing signal with brain rather than CSF. With MR cisternography, gray and white matter and, it is hoped, even small tumors converge to a very low signal, and the CSF is extremely bright. In a series of 50 eighth nerve tumors imaged with fast spin-echo techniques, all were dark relative to the bright CSF (16).

So the main criteria necessary to allow these new sequences to identify tumors are met. But does this strategy work? In the studies that have looked at significant numbers of patients, the contrast-enhanced studies identified all the tumors, and the new techniques missed either no tumors or a few small tumors (16, 17, 20). Is this acceptable? In clinical practice, this may be adequate as long as the radiologist is aware of the issue and as long as those false-negative studies are at least ambiguous. There must be some degree of uncertainty that will lead the radiologist to perform a contrast-enhanced examination. This is true whether the study constitutes a replacement for the routine contrast-enhanced examination or is used as a lower cost screening tool. In an investigation by Stuckey et al (18), interpreters rated each MR examination in terms of reader confidence in excluding tumor. Calling a study "normal" required demonstration of the seventh and eighth nerves. Those studies in which the nerves could not be adequately delineated were called "indeterminate" and the patients would go on to receive contrast material, if the noncontrast sequence was being used as a screen. Similarly, in a study by Fukui et al (16), some small tumors could not be clearly diagnosed from the noncontrast T2-weighted examination. However, in each of these cases, there was some ambiguity. The contents of the canal were not completely defined and nerves were not completely seen. Again, the noncontrast study could be identified as indeterminate and the patient referred for a contrast-enhanced study. This becomes the key concept if these noncontrast sequences are to be used as the primary strategy. If sensitivity is to approach that of the contrast-enhanced T1-weighted sequence, then strict criteria for calling a test "negative" must be applied. The high-resolution noncontrast study must depict all nerves within the canal before the examination is called "definitely negative" and the patient assured that a tumor has been excluded. If all nerves are not completely seen, the patient is examined again with contrast material or scheduled for a repeat examination after an appropriate interval. It is probable that this strategy can achieve the same sensitivity as that of giving contrast material to every patient.

The information on the noncontrast examination should be optimized. In our institution, the greatest anatomic area of concern is at the lip of the internal auditory canal. The nerves exit the internal auditory canal in the inferior portion, passing close to or bending slightly over the inferior lip of the internal auditory meatus. Here the nerves merge together, and clear separation is more difficult. The canal often has a slight ridge or rise at the inferior aspect of the medial opening. The nerves are in proximity to or in contact with the bone at this location. Any susceptibility effect from the bone/CSF interface can add to the obscuration of this area. The glial/Schwann cell junction occurs near here, so this is a likely region for occurrence of an eighth nerve tumor. However, if the nerves can be followed across this area and identified as normal, then the study has reliably excluded an acoustic neuroma. If there is ambiguity in identifying the nerves, sagittal reformation of the data can help.

So where are we? We have two excellent methodologies. Higher resolution will only improve both. Either would have been considered the ideal examination only a few years ago. A study could be done with a large group of patients in which if the nerves are seen well, the examination is called negative, if the nerves are seen incompletely, the examination is called ambiguous, and if a tumor is seen, the examination is called positive. This strategy could then be evaluated by comparing the findings with those from a contrast-enhanced study as the standard of reference.

The logistics of such a study would be difficult. Also, this would not be a true comparison of techniques, since one of the tests would be the standard of reference. Instead, the study would simply be an attempt to define the number of acoustic neuromas (if any) missed by the high-resolution T2-weighted sequence using the strict criteria indicated. A very large patient group would be needed, considering the low number of positive cases compared with the number of examinations performed to rule out an acoustic neuroma and considering that only small tumors are likely to be missed by noncontrast imaging. This type of study would, however, determine if, indeed, the high-resolution T2-weighted study could actually compete. How often does the study confidently exclude a tumor? How many studies are considered ambiguous? The problem of false-positive contrast-enhanced examinations must be considered before the final conclusions are orga-

nized. The true cost analysis would balance the savings in contrast material costs against any added processing time required or the inconvenience of having the patient return for contrast-enhanced examinations in ambiguous cases. The percentage of patients eventually referred for contrast-enhanced studies would be one key to the acceptability of this imaging strategy. If the contrast-enhanced study can be done at the same time, the equation changes yet again. This might be difficult if reformatted images are required to see the nerves optimally and to make a determination while the patient is waiting.

There are other factors to be considered. Contrast material does show other abnormalities. The nerve may enhance without size distortion in diseases such as sarcoid, lymphoma, and leukemia, to name a few. The labyrinth may enhance in labyrinthitis. Are we comparing the cost of a single-sequence high-resolution T2-weighted screening examination with a complete study with and without contrast material and with images obtained through the entire head? Would it be appropriate to do a single-sequence contrast-enhanced T1-weighted study as a screen? These considerations must be kept in mind. The referring clinician must realize the limitations of the noncontrast examination and use this approach only when the clinical question has been reduced to whether or not there is a tumor. Imaging is then done only to exclude the eighth nerve tumor.

In summary, either test can be effective in excluding acoustic neuroma/vestibular schwannoma. The contrast study is easy to do and very easy to interpret. Normal is normal, and a tumor is hard to miss. If an experienced radiologist can cautiously examine the nerves and maintain a low threshold for taking the next step to proceeding to a contrast-enhanced study, then, in my opinion, pending the results of a larger study, the unenhanced T2-weighted MR examination is a reliable alternative.

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