

Air-CT Cisternography and Canalography for Small Acoustic Neuromas

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Disenchantment with the limitations, and in some cases the morbidity, of currently used radiologic techniques for the demonstration or exclusion of small acoustic neuromas prompted development of an examination using small amounts of intrathecal air and computed tomography (CT). A prospective study was designed to evaluate air CT cisternography/canalography, wherein patients with the clinical symptoms of acoustic neuroma but with negative enhanced CT, were evaluated by metrizamide CT cisternography followed by air CT cisternography/canalography. Pantopaque cisternography was then performed as a control procedure. Four patients had surgically proven tumors. In 13 others, accumulated evidence indicated no tumors were present. Results suggest that air-CT cisternography is superior to all other diagnostic methods in defining small acoustic neuromas, and may exclude an intracanalicular lesion without the potential hazards of Pantopaque cisternography or high concentration metrizamide tomocisternography. With air-CT cisternography, there were no errors in this series.

Routine thin-section contrast-enhanced CT may be unsuccessful in demonstrating small acoustic neuromas [1-3]. This is usually so with lesions of less than 10 mm diameter in cisternal size and is constant with tumors smaller than 5 mm. Conventional CT metrizamide cisternography will demonstrate a cerebellopontine angle cisternal mass smaller than can be seen by enhanced CT, but cannot exclude a purely intracanalicular lesion or reliably demonstrate tumors that extend to the porus acusticus without a significant cisternal component [2].

Currently, Pantopaque cisternography is the only widely used radiologic diagnostic study that can exclude an intracanalicular acoustic neuroma, and conversely, it may demonstrate such a lesion [4-6]. However, a significant proportion of Pantopaque examinations are inconclusive, and false-positive studies are not uncommon [4-6]. In addition, intracranial use of Pantopaque carries a risk of adhesive arachnoiditis [7-11]. In response to the limitations and risks of Pantopaque and metrizamide cisternography (M-CTC), an alternative approach to the diagnosis of small acoustic neuromas has been developed at our institution utilizing the CT scanner with air as a subarachnoid contrast material (air-CTC). A prospective study was devised to evaluate the efficacy of air-CTC and to compare this new technique with metrizamide CT cisternography and Pantopaque cisternography in patients with a clinical suspicion of acoustic neuroma in whom 5 mm section enhanced CT scans were negative.

Materials and Method

Seventeen patients with audiologic and clinical suspicion of an acoustic neuroma were studied by air-CTC and combinations of M-CTC and Pantopaque cisternography. Two patients in whom M-CTC, air-CTC, and polytomocisternography [12] demonstrated a surgically verified eighth nerve tumor, were not subjected to Pantopaque cisternography. Two

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TABLE 1: Composite of Diagnostic Modalities Performed on 17 Patients

Modality	Normal Canal	Tumor	Total Patients Studied
Polytomography	15	2	17
Enhanced CT	16	1	17
Pantopaque	12	3*	15
Metrizamide CT cisternography	12†	3‡	15
Air-CT cisternography/canalography	13	4	17

Note.—Air-CT cisternography/canalography (Air-CTC) was accurate in all cases.

* One error.

† Filling or nonfilling could not be determined in any case.

‡ Tumor not seen in one case; canal did not fill.

different patients with histories of previous allergic reaction to iodinated contrast material were not studied by M-CTC (table 1). All 17 patients had undergone routine CT with and without iodinated contrast material by drip infusion. Fifteen patients received 42 g iodine in 6–8 min; the two patients excluded from M-CTC both developed a hypersensitivity reaction after the intravenous administration of 20 g iodine. All 17 patients were also examined by thin-section pluridirectional tomography (Polytome) prior to CT. In four patients, tumors were surgically verified. In the remaining 13, radiographic evidence suggested that tumors were not present.

All patients underwent lumbar puncture under fluoroscopic control using a catheter myelographic needle [13]. In 15, 6 ml of 190 mg I/ml of metrizamide was introduced into the subarachnoid space. The catheter was left in place, taped to the back, and covered with a sterile dressing. The patient was placed prone, tilted into a 30° head-down position for 5 min, and subsequently transferred to a stretcher and moved into the CT unit. Using an EMI 5005, consecutive 5 mm slices were obtained through the posterior fossa with particular attention to the region of the porus acusticus, where the slices were overlapped by 2–3mm depending on canal size. Images were reconstructed in both the 160 × 160 matrix and the 320 × 320 matrix.

At the completion of the metrizamide CT cisternography, the patient was elevated to a sitting position with a 45° tilt of the body to the horizontal with the side to be studied superior. The head was tilted an additional 45° so that the sagittal plane was horizontal. Air (3–4 cm³) and Pantopaque (2 ml) were introduced through the spinal catheter which was then removed. The patient was then laid flat on the gantry table in a decubitus position with the side to be examined uppermost. Consecutive cuts were repeated at 5 mm intervals within the posterior fossa as before, with particular attention to the porus acusticus and the internal auditory canal. Viewing and imaging were carried out at conventional window widths and levels, and also at wide window settings (800 H) and low settings (–500 H to –300 H) to best demonstrate the neurovascular bundle coursing through the air-filled cerebellopontine cistern from the brain stem to the porus acusticus. At completion of the air-CT cisternogram and canalogram (air-CTC), the patient was transferred to a biplane myelographic room for a routine low volume Pantopaque cisternogram.

Films were interpreted by two radiologists (I.I.K., R.S.P.) in the usual clinical manner with prior studies available. Also, cases were reviewed later by an additional radiologist (R.T.B.) as well as the other two.

Results

Table 1 is a composite of diagnostic methods performed on the 17 patients in our series. Of the 17, 16 had a normal contrast-enhanced CT scan. The sole exception demonstrated an enhancing cerebellopontine angle cistern mass

about 2 cm in diameter. Conventional polytomography demonstrated the clinically suspected internal auditory canal was asymmetrically larger than the contralateral canal in all patients, but was diagnostically larger (a difference in the height of the canal greater than 1.5 mm) in only two patients, both of whom had tumors. The high incidence of asymmetry is selective, for this finding is one of several criteria on which a decision for further studies is based. In one patient, oblique polytomography demonstrated a 4 mm cisternal tumor based in the porus acusticus.

Metrizamide CT cisternography, performed on 15 patients, was indicative of a lesion in three, although a mass was only seen in two. A difference in density between the contrast-filled cistern and the internal auditory canal, indicative of nonfilling was observed in one case with a markedly enlarged internal auditory canal, but the tumor itself was not visualized even though it bulged into the cistern. Whether metrizamide filled the internal auditory canal could not be determined in our 12 normal patients (figs. 1 and 2) or in two positive cases that had this examination. An erroneous appearance suggested nonfilling of the canal (figs. 1B and 2B) as well as apparent filling in the presence of a lesion (figs. 3A and 4A).

Air-CTC clearly demonstrated a normal cistern and air within the internal auditory canal in 13 patients (figs. 1C and 2C). Air-CTC demonstrated nonfilling of the internal auditory canal and a cisternal or porus mass in all four positive cases (figs. 3B, 4B, and 5B). Filling or nonfilling of the internal auditory canal by air is so strikingly imaged by CT that there were no doubts of the result achieved. Variation of window settings demonstrated linear structures within the cerebellopontine angle cistern converging from the brain stem to the porus acusticus (fig. 2D). These structures are presumed to represent elements of the neurovascular bundle, probably the VII and VIII cranial nerves. The neurovascular bundle was observed in 10 of 13 normal patients. It was seen in one of four positive cases, with the VII and VIII cranial nerves separated, presumably by the tumor (fig 5C).

A longer and larger linear structure was noted on a higher CT cut, 2–4 mm superior to the cut that best demonstrated the porus acusticus and the internal auditory canal (fig 6). The level of the CT slice, site of origin from the brain stem, and course of this structure suggests it is the VI cranial nerve. This structure was visualized only in three of 17 cases since the air-CTC was frequently terminated on completion of visualization of the internal auditory canal.

Pantopaque cisternography, performed in 15 patients, demonstrated a cisternal filling defect and nonfilling of the internal auditory canal in the two patients studied with tumors. Pantopaque filled the internal auditory canal in 12 of 13 patients in whom tumors were excluded. In one patient nonfilling of the internal auditory canal by Pantopaque occurred on two separate occasions, although air-CTC clearly showed a normally filled, though small canal. There were no discrepancies in interpretation among the three radiologists who reviewed the material.

Discussion

Since the advent of CT, acoustic neuromas larger than 1.5 cm have been detected with a high degree of accuracy,

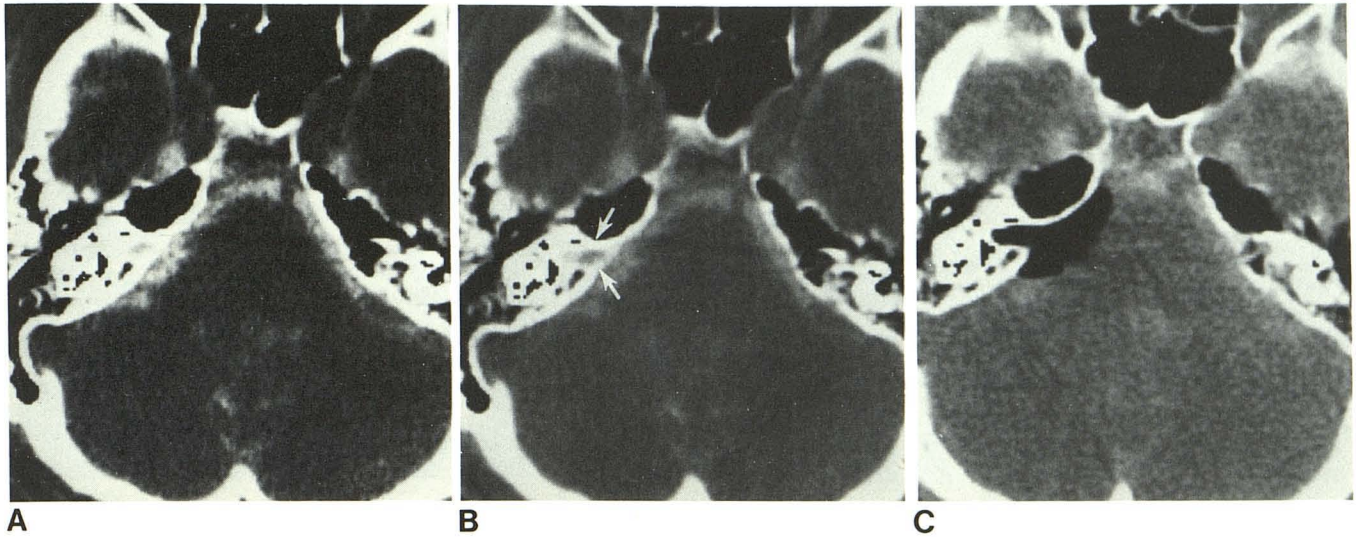


Fig. 1.—Normal CT cisternograms. Large internal auditory canal. **A**, Metrizamide cisternogram. Contrast opacification of cerebellopontine angle cistern and prepontine cistern. **B**, Wider window setting. Density differential between contrast-filled cerebellopontine angle cistern and internal auditory canal (*arrows*) erroneously suggests intracanalicular neuroma. **C**, Air CT cisternogram. Air within both cerebellopontine angle cistern and entire bulbous internal auditory canal, thus excluding acoustic neuroma.

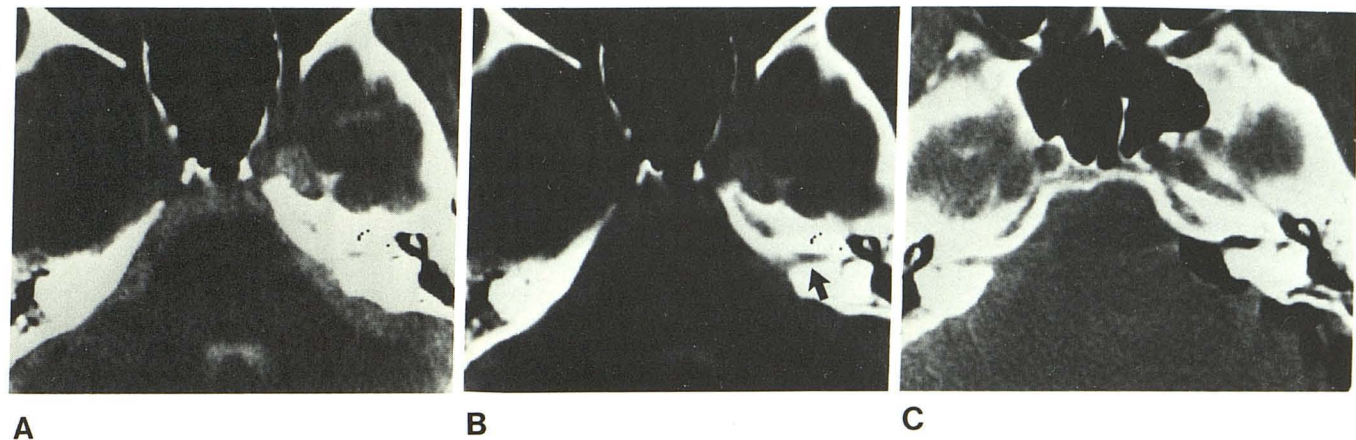


Fig. 2.—Normal CT cisternogram. Small internal auditory canal. **A**, Metrizamide CT cisternogram. Cerebellopontine angle cisterns cleared bilaterally. **B**, Wider window setting, same cut as **A**. Apparent density difference between contrast-filled cerebellopontine angle cistern and internal auditory canal (*arrow*). **C**, Air CT cisternogram. Air completely fills internal auditory canal and cerebellopontine angle cistern thus excluding acoustic neuroma. **D**, Variation of window settings (window width 800 H; level, - 700 H) at same cut as **C**. Two linear densities within air-filled cerebellopontine angle cistern coursing to adjacent porus acusticus. These densities probably represent VII (*arrowhead*) and VIII (*arrow*) cranial nerves.

D

particularly when overlapping, thin section, intravenous contrast-enhanced CT scans are done [1]. However, as tumor size diminishes below 1 cm and lesions are limited to the internal auditory canal and porus acusticus or extend only

slightly into the cistern, CT has been incapable of demonstrating the pathology [1-3].

With the acceptance of metrizamide for routine use, this situation has been partly resolved, since metrizamide-CTC

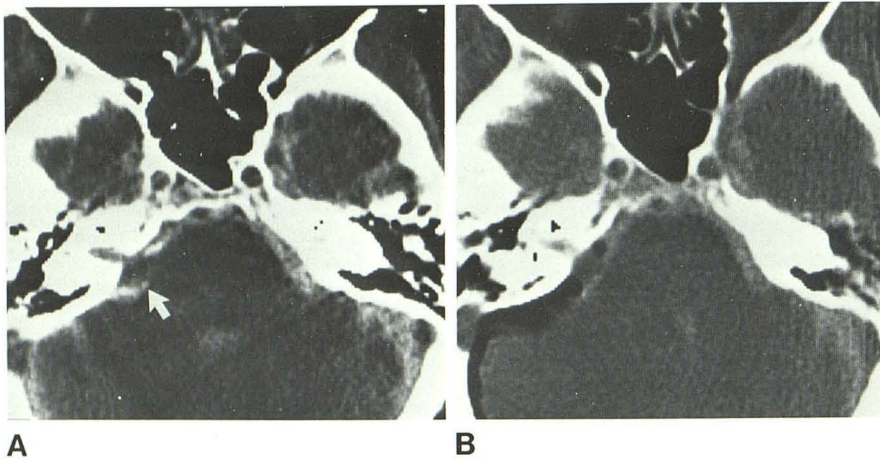


Fig. 3.—Small cerebellopontine angle acoustic neuroma. **A**, Metrizamide CT cisternogram. Tumor as filling defect within cerebellopontine angle adjacent to internal auditory canal. Metrizamide between tumor and brainstem documents lack of attachment (*arrow*). **B**, Air CT cisternogram. Non-filling of internal auditory canal. Cerebellopontine angle tumor shown clearly. However, no air caps tumor medially; attachment to brainstem cannot be excluded.

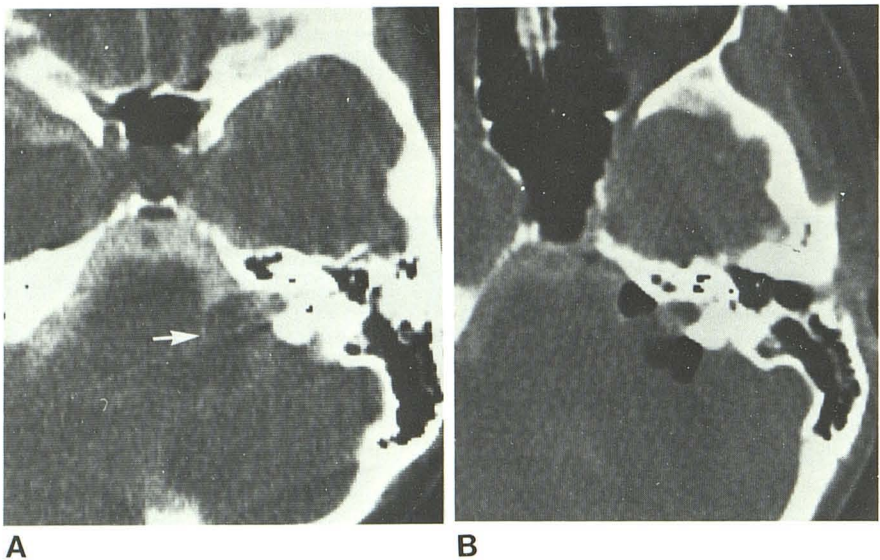


Fig. 4.—2 cm cerebellopontine angle acoustic neuroma. **A**, Metrizamide CT cisternogram. Enlargement of internal auditory canal; cerebellopontine angle mass widens cistern and compresses lateral aspect of brainstem (*arrow*). Tumor size correlated well with tumor found at surgery. Canal appears filled with metrizamide. **B**, Air CT cisternogram. Nonfilling of internal auditory canal and cerebellopontine angle part of mass. No air medial to tumor. Brainstem compression not well appreciated. Tumor appears smaller (in error) than on metrizamide cisternogram.

will demonstrate small lesions which encroach on the cerebellopontine angle cistern [1, 2] (figs. 3A and 4A). However, current CT techniques preclude reliable visualization of metrizamide in the internal auditory canal except when the canal is quite large [2] (figs. 1B and 2B). In small, normal, or even moderately enlarged canals, either a density is not appreciated or it cannot prove that such a change is not due to a partial-volume effect produced by inclusion of adjacent bone in the slice. Thus M-CTC is incapable of excluding or diagnosing a small acoustic neuroma limited to the canal or to the porus acusticus. If M-CTC cannot exclude an acoustic neuroma, it seems inappropriate to subject patients to this study when Pantopaque cisternography and air-CTC can provide such diagnostic accuracy.

On the other hand, the canal can be shown with metrizamide if polytomography is used. A few milliliters of contrast material (metrizamide, 300 mg I/ml) introduced by C1-C2 puncture as devised by Valk [14] has clearly demonstrated the internal auditory canal and the neurovascular bundle

surrounded by contrast material. While the volume of contrast material used is small, few data are available regarding the untoward effects of surrounding the VII and VIII nerves with high concentration, positive contrast material which is certainly more toxic than air. The C1-C2 puncture is probably not quite as safe as lumbar puncture, fewer examiners are skilled at performing it, and the radiation dose from complex motion tomography is greater than from CT.

Pantopaque is at best a compromise contrast material because the potential hazard of adhesive arachnoiditis is increased by high volume Pantopaque cisternography. The low volume technique, used by most investigators since the advent of CT, results in a high (> 25%) incidence of nondiagnostic examinations and not infrequent false positive studies [4-6]. Despite wide acceptance of Pantopaque cisternography/canalography as the definitive study for diagnosis or exclusion of acoustic neuromas, the examination frequently yields false-positive or equivocal results when no tumor is seen in the cistern or porus acusticus [4-6]. Fisch

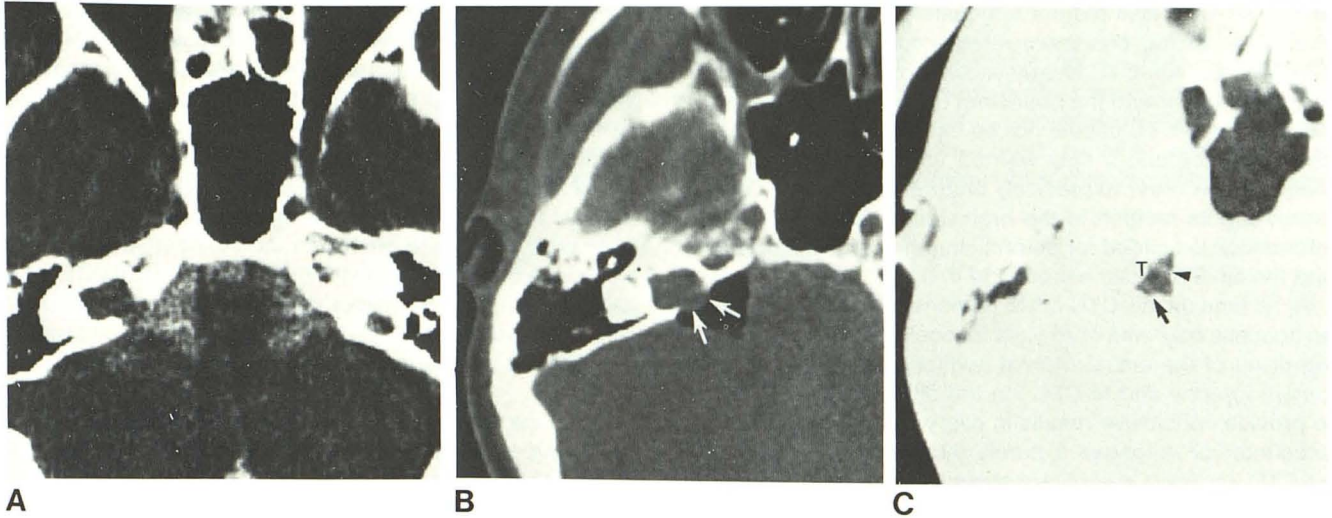
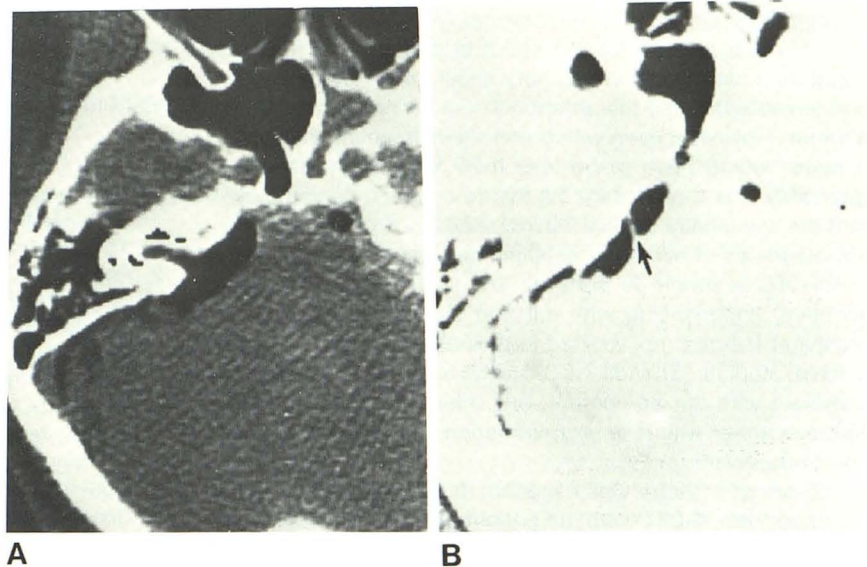


Fig. 5.—Acoustic neuroma at porus acusticus. **A**, Metrizamide cisternogram. Enlargement of internal auditory canal; contrast-opacified cerebellopontine angle cistern with clear density difference between cistern and canal. Tumor not clearly outlined. **B**, Air cisternogram. Nonfilling of internal auditory canal. Tumor outline just protrudes into air-filled cerebellopontine angle cistern (arrows). **C**, Same cut as **B** with (window width, 800 H; level, - 700 H). Tumor (T) at porus acusticus bulges into cerebellopontine cistern with VII nerve (arrowhead) and VIII nerve (arrow) split and separated from each other.

Fig. 6.—Additional cranial nerves. **A**, Air CT cisternogram. Air fills internal auditory canal and cerebellopontine cistern. **B**, Window variation, same cut as **A**. Single linear density (arrow) in air-filled cerebellonpontine cistern courses from brainstem to medial aspect of petrous bone. Density direction is away from porus acusticus and toward petrous tip, probably representing VI nerve.



et al. [6] analyzed 153 consecutive meato-cisternograms performed with Durolopaque, a material quite similar to Pantopaque. They observed that concave nonfilling of the porus acusticus was always associated with a tumor; however, 31 examinations with varying degrees of nonfilling of the canal itself yielded only five tumors at surgical exploration. In addition, this group reported a 28% technical failure rate when contrast material either did not fill the cistern or when only a few drops entered the canal.

A relatively narrow canal and arachnoid redundancy have been reported to be associated with inconclusive Pantopaque studies and the former seems to have caused Pantopaque failure in one of our cases. Although clinically considered a tumor suspect, both air-CTC and metrizamide CTC were normal in this patient even though only the air

study demonstrably filled the canal. A low volume Pantopaque posterior fossa cisternogram failed to fill the acoustic canal on two separate occasions in this patient. Follow-up audiograms failed to document any progressive hearing loss and this patient is consistent with a Pantopaque cisternogram "procedure failure" as described by Fisch et al. [6]. Thus in our limited series, air-CTC must be considered diagnostically superior in excluding an acoustic neuroma because no procedure failure occurred. While a very narrow canal or arachnoid webs could conceivably lead to nondiagnostic studies, such failures should occur far less frequently with air than with the more viscous Pantopaque.

In our four surgically-proven positive cases, two had Pantopaque cisternograms. In one case the actual cisternal size of the lesions was not appreciated on the Pantopaque

study. Air-CTC also did not adequately cap the tumor and evaluation of the brainstem attachment was difficult (fig. 4B). Metrizamide-CTC clearly showed contrast medium between the tumor and the brainstem (fig. 4A). Thus, while we believe the M-CTC should not be used for the diagnosis of acoustic neuroma, it may well be useful once a tumor is diagnosed in order to precisely characterize the size of the lesion and its relation to the brainstem when such precise information is needed for determining the surgical approach and the air-CTC does not provide it.

At no time did air-CTC fail to demonstrate the presence of an acoustic neuroma or to yield inconclusive results regarding filling of the entire internal auditory canal. Pantopaque cisternography and M-CTC, on the other hand, both failed to provide conclusive results in every case. We have yet to encounter or diagnose a purely intracanalicular tumor by air-CTC, for such lesions are somewhat unusual making up only 1.5% of the series described by Fisch et al. [6]. Until a few intracanalicular lesions are studied by air-CTC some reservation as to its sensitivity may be warranted.

CT numbers within the air-filled internal auditory canal were found to be 200–300 H higher than in the air-filled cistern, reflecting the presence of the neurovascular bundle averaged with the air. The neurovascular bundle and dura occupy 75% or more of the average (7 mm) canal leaving only 1¼ mm or less for the air. It is conceivable that air might fill a canal harboring a very small tumor and it is also conceivable that the low attenuation of air might hide such a tumor. However, even with 5 mm slices it seems that such a tumor would have to be less than 1.5 mm in diameter (probably less than 1 mm) for this to occur. It seems clear that the availability of very narrow slices (1.5 mm) will make the diagnosis of even tiny acoustic neuromas feasible.

Air-CTC is simple to perform. Our patient series is consecutive, commencing with our first study. There were no technical failures, no aborted examinations, and no inconclusive studies. The air-CTC study takes about 1 hr to complete with our equipment, but should be much shorter with a scanner with less reconstruction time and a localization scanogram.

The spinal catheter was essential to our study so that we could perform M-CTC with the patient prone followed by air-CTC and Pantopaque cisternography without subjecting patients to more than one lumbar puncture. However, an ordinary narrow-gauge spinal needle is all that is needed for air-CTC alone.

Sequential 5 mm slices were obtained 2–3 mm apart resulting in a similar overlap. This is necessary to ensure that at least one slice is totally within the canal unaffected by the partial volume effect of adjacent bone. Usually at least two slices achieve this condition with the overlap used. Where slices narrower than 5 mm are available, overlapping may be reduced.

Since our protocol evaluated three different contrast media, relating an adverse reaction to one particular contrast agent cannot be scientifically accomplished; however, some assessment may be in order. It is assumed that any immediate adverse reaction is related to the introduction of air; reactions delayed 3–6 hr were considered secondary to metrizamide or to the spinal tap itself.

All 17 patients experienced an immediate localized headache, most often retroorbital or postauricular. This was the only adverse effect noted with air introduction. In 12 patients this headache cleared by the time they left the x-ray department, usually 1 hr after the introduction of air. One patient had a headache for 8 hr after the procedure; another for 72 hr. Nine patients had delayed headache, and three patients had nausea and/or vomiting. These delayed reactions presumably are related to the metrizamide. The morbidity with the small amount of air used for air-CTC is quite low and significantly milder than with conventional pneumoencephalography [13]. It is our preliminary impression that air-CTC resulted in a lower morbidity than metrizamide CTC.

Thus, we believe that a sequence of radiologic studies consisting of polytomography, enhanced CT, and air-CTC is logical and diagnostically precise for detecting or excluding a small acoustic neuroma. Air-CTC is a simple technique to master, has a high degree of patient tolerance with short morbidity, and offers a significant cost saving in the radiologic workup. While our preliminary results are encouraging, complete acceptance of air-CTC as the definitive diagnostic study for small acoustic neuromas must await additional reports, particularly with exclusively intracanalicular tumors.

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Addendum

After submission of this manuscript, we became aware of prior work by O. Sortland that was presented at the Scandinavian Radiologic Society, Copenhagen, Denmark, September 1978. Sortland described use of air with CT for the diagnosis of cerebellopontine angle lesions (*Neuroradiology* **1979**;18:19-22).