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Anatomy of the Facial and Vestibulocochlear Nerves in the Internal Auditory Canal

David Rubinstein, Elliot J. Sandberg, and Ana G. Cajade-Law

PURPOSE: To define the anatomy of the facial and vestibulocochlear nerves in the internal auditory canal on parasagittal CT scans of cadaveric specimens and to compare this anatomy with findings on in vivo T2-weighted two-dimensional fast spin-echo and three-dimensional turbo spin-echo MR images. **METHODS:** Thirty-eight formalin-fixed cadaveric temporal bones were examined with 1-mm-thick contiguous parasagittal CT sections to determine the anatomy of the nerves in the internal auditory canal. Ten specimens underwent limited dissection. Fourteen canals in 12 patients were examined with T2-weighted two-dimensional fast spin-echo oblique parasagittal MR imaging and 12 canals in 8 patients were examined with T2-weighted three-dimensional turbo spin-echo MR imaging. The anatomy depicted on MR images was compared with the cadaveric anatomy. **RESULTS:** On cadaveric specimens, the facial nerve coursed superior and anterior to the vestibulocochlear nerve as a tubular structure throughout the length of the canal. The vestibulocochlear nerve entered the canal as a tubular structure but became crescent shaped in cross section in the middle portion of the canal and separated into individual nerves only in the most lateral portion of the canal. The anatomy of the nerves differed among the specimens. Similar anatomy was demonstrated by MR imaging. **CONCLUSION:** The ability to define the nerves in the internal auditory canal in the parasagittal plane may provide greater sensitivity and specificity in identifying abnormalities of this anatomic structure.

Index terms: Nerves, anatomy; Nerves, cranial; Temporal bone, anatomy

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Recent improvements in magnetic resonance (MR) imaging have made it possible to define the cranial nerves in the internal auditory canal. Imaging of this structure is usually performed in axial or coronal planes, but imaging in a parasagittal plane should delineate the relationship of the nerves better, because the nerves run mainly medially to laterally within the canal. The purpose of this study was to define the intracanalicular anatomy of the facial and vestibulocochlear nerves in the parasagittal plane.

We used computed tomography (CT) of cadaveric specimens to depict this anatomy and compared it with findings on in vivo T2-weighted two-dimensional fast spin-echo and three-dimensional turbo spin-echo MR images.

Materials and Methods

Thirty-eight formalin-fixed cadaveric temporal bones were examined on a CT scanner to determine the anatomy of the nerves in the internal auditory canal. One-millimeter-thick contiguous parasagittal scans were obtained at 120 kV and 200 mAs. The images were reconstructed with a 9.6-cm field of view and a bone reconstruction algorithm. Ten of the specimens then underwent limited dissection. That dissection consisted of drilling away the temporal bone superior to the internal auditory canal so that the facial and vestibulocochlear nerves could be viewed from above. The 10 specimens were then rescanned to determine if the relationship of the nerves had been disrupted by the drilling. The nerves were then inspected in situ and with manipulation of the facial nerve to gain greater exposure of the vestibulocochlear nerve.

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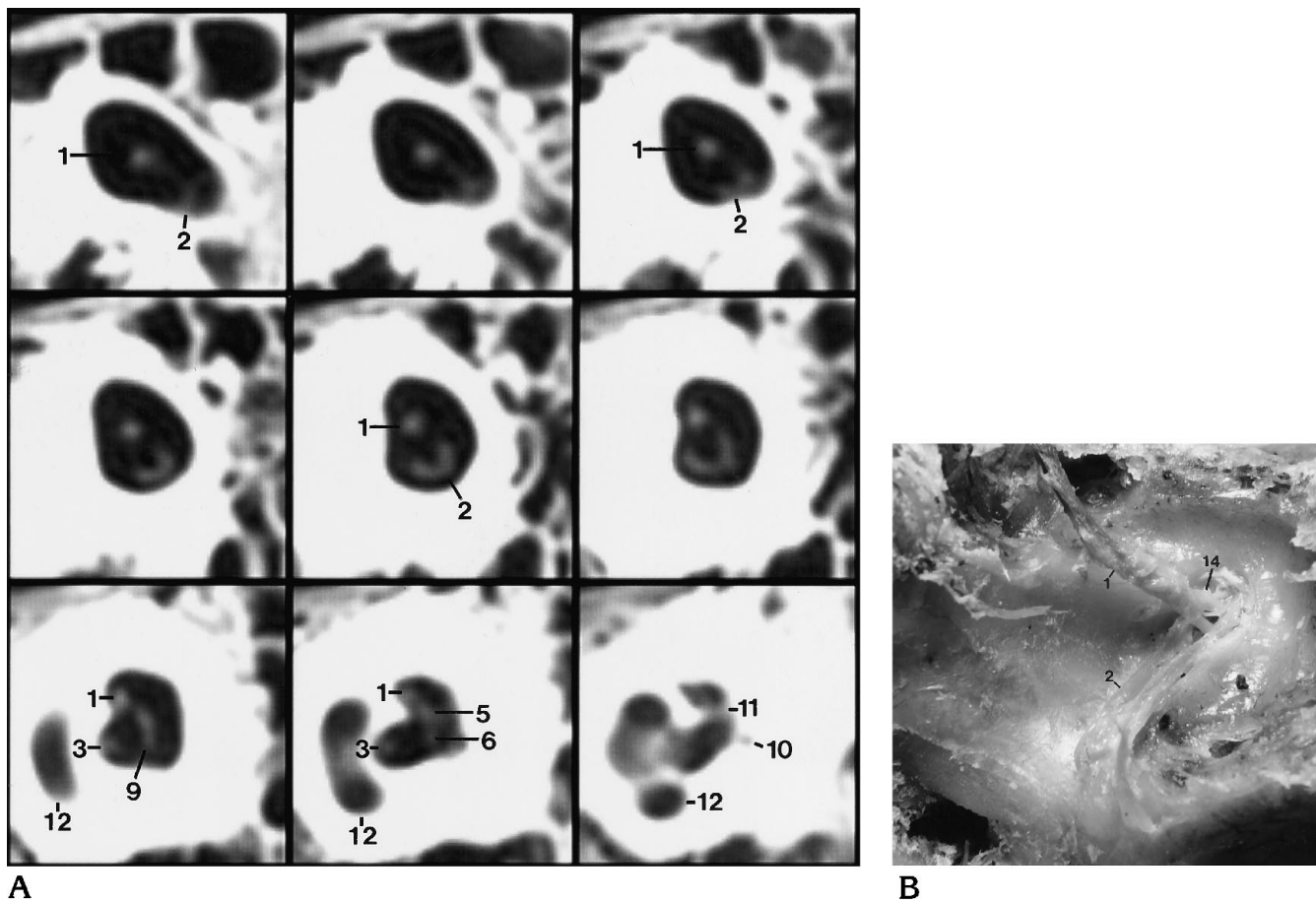


Fig 1. A, One-millimeter-thick contiguous parasagittal CT sections of this cadaveric specimen are displayed medially to laterally. Anterior is on the left of the images and posterior is on the right. In the specimen, the facial and vestibulocochlear nerves enter the internal auditory canal as two well-separated structures. The vestibulocochlear nerve assumes its crescent shape more medially than usual, but separation of the cochlear and vestibular nerves does not occur until the lateral aspect of the canal has been reached. The vestibular nerve has an hourglass configuration, possibly representing the vestibular ganglion, just medial to its separation into the superior and inferior vestibular nerves. The foramen singulare is clearly shown.

B, The same specimen was photographed from above after the superior portion of the temporal bone had been drilled away to expose the internal auditory canal. The entrance to the canal is on the left and the fundus is on the right. The facial nerve has been reflected superiorly to expose the vestibulocochlear nerve. The vestibulocochlear nerve is gutter shaped in the internal auditory canal but has no separation into individual nerves until the apex. Some fibrous tissue can be identified adherent to the lateral aspect of the nerves.

Key for Figures

- 1 Facial nerve
- 2 Vestibulocochlear nerve
- 3 Cochlear nerve
- 4 Vestibular nerve
- 5 Superior vestibular nerve
- 6 Inferior vestibular nerve
- 7 Posterior ampullary nerve
- 8 Saccular nerve
- 9 Vestibular ganglion
- 10 Foramen singulare
- 11 Falciform crest
- 12 Cochlea
- 13 Vestibule
- 14 Fibrous tissue

The cadaveric anatomy was compared with the anatomy depicted on MR images in 20 patients. Fourteen canals in 12 patients were examined on a 1.5-T system with T2-weighted 2-D fast spin-echo oblique parasagittal sequences. Three-millimeter-thick contiguous sections were obtained in these patients perpendicular to the long axis of the internal auditory canal. The imaging parameters were as follows: 3000–3500/92/4 (repetition time/echo time/excitations), echo train of 16, 16-cm field of view, and 256 × 256 matrix.

Twelve canals in 8 patients were examined on a different 1.5-T unit with T2-weighted 3-D turbo spin-echo sequences. These 1.5-mm contiguous parasagittal images were obtained with parameters of 3000/150 effective/1, turbo factor of 16, 14.4 × 18-cm field of view, and 192 × 256 matrix.

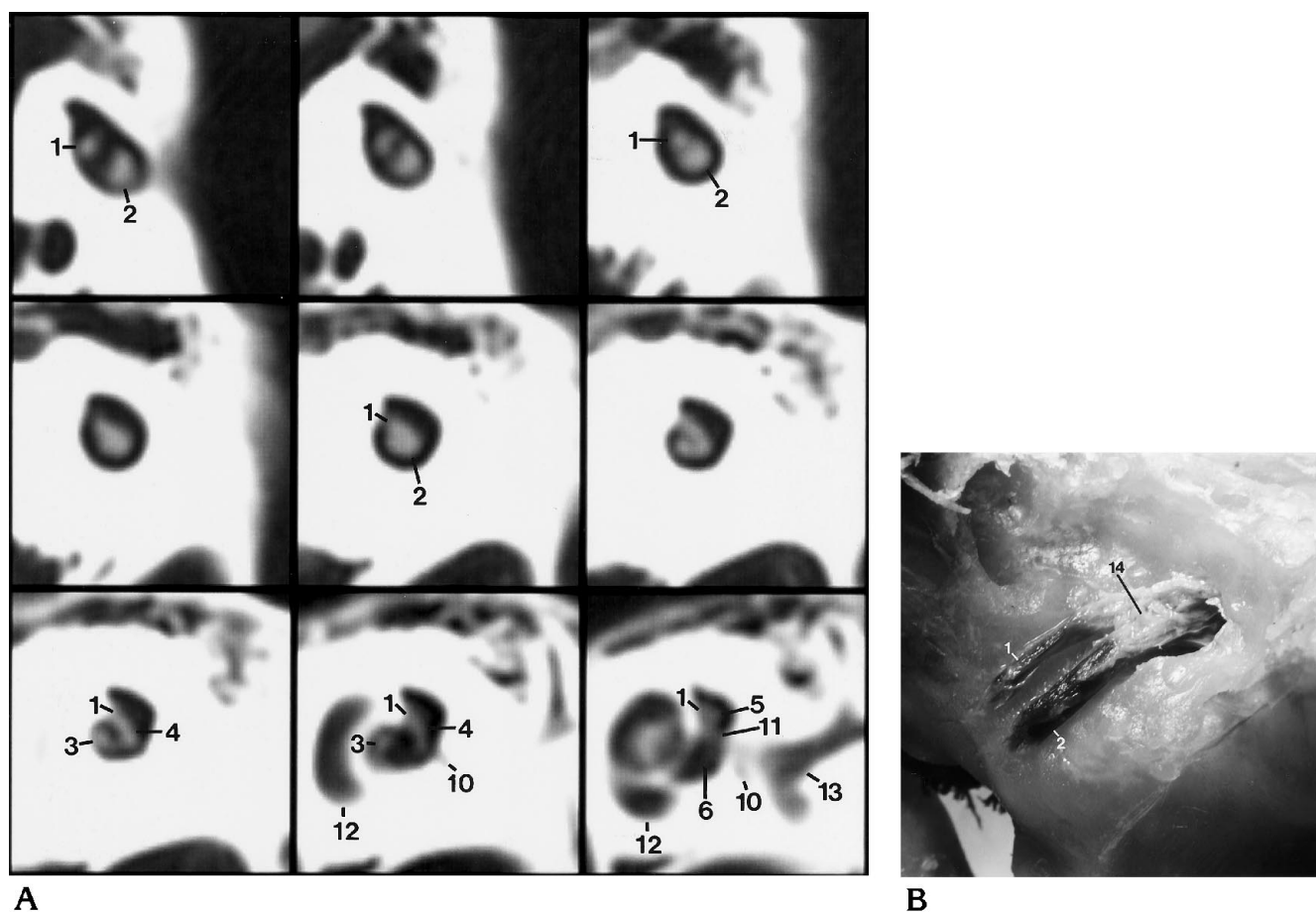


Fig 2. A, One-millimeter-thick contiguous parasagittal CT sections of this cadaveric specimen are displayed medially to laterally. Anterior is on the left of the images and posterior is on the right. In relation to the specimen in Figure 1, the facial and vestibulocochlear nerves are not as well separated and the vestibulocochlear nerve becomes crescent shaped more laterally in the canal. In this specimen, the superior and inferior vestibular nerves are not separated until they reach the falciform crest. The superior vestibular nerve cannot be separated from the facial nerve in the fundus of the canal.

B, The same specimen was photographed from above after the temporal bone had been drilled away to expose the internal auditory canal. The entrance to the canal is on the left of the photograph and the fundus is on the right. Compared with the specimen in Figure 1, the vestibulocochlear nerve is a more tubular structure throughout its course and a greater amount of fibrous tissue is present in the lateral portion of the canal.

These MR sequences were done to determine whether posterior fossa lesions were present. None of the patients had abnormalities demonstrated with any pulse sequence.

Results

The anatomy of the facial and vestibulocochlear nerves differed from specimen to specimen as well as medially to laterally within the internal auditory canal (Figs 1 and 2). In general, the facial nerve remained superior and anterior to the vestibulocochlear nerve or its branches and maintained its tubular shape throughout its course in the canal. The vestibulocochlear nerve occupied the posterior inferior portion of the canal. The shape of this nerve

changed along its medial to lateral course. The nerve was usually tubular as it entered the canal and then became crescent shaped in cross section before dividing into individual nerves. The cochlear and vestibular nerves usually separated about 3 to 4 mm from the lateral end of the internal auditory canal. The vestibular nerve divided into the inferior and superior vestibular nerves a millimeter or two from the falciform crest at the lateral end of the canal.

To describe the variations in anatomy identified in the specimens, the canal was divided into three sections: the medial internal auditory canal, including the entrance; the middle internal auditory canal; and the lateral internal auditory canal, including the fundus. While the difference

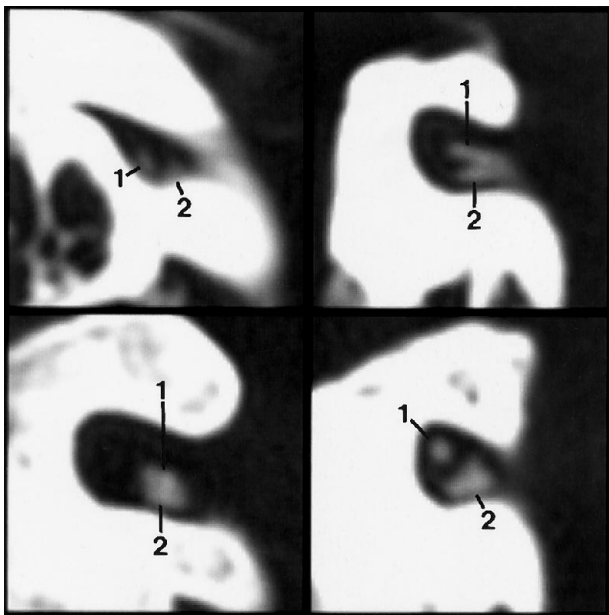


Fig 3. Parasagittal CT sections of the entrance to, or of the medial portion of, the internal auditory canal in four different specimens show the facial and vestibulocochlear nerves. Anterior is on the left of the images and posterior is on the right. The configuration of the nerves is dependent on the angle of the nerves relative to the imaging plane. In the specimen on the lower right, the vestibulocochlear nerve is assuming a crescent shape more medially than usual.

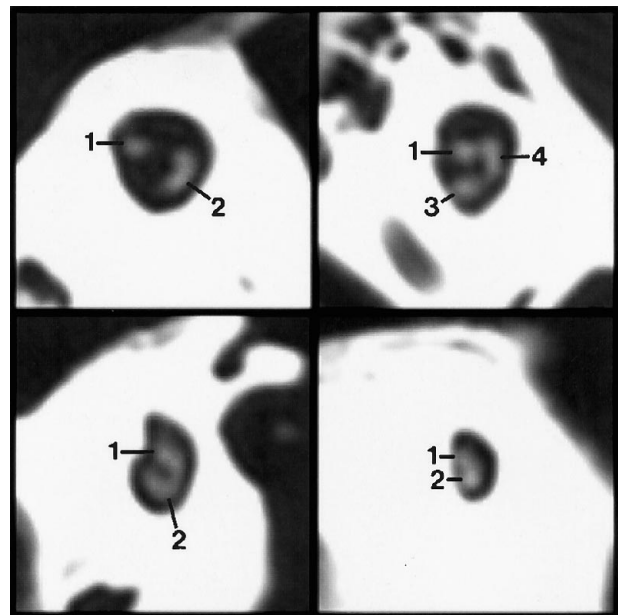


Fig 4. Parasagittal CT sections from the middle of the internal auditory canal of four specimens show various configurations of the vestibulocochlear nerve in this region. Anterior is on the left of the images and posterior is on the right. In the upper right specimen, the cochlear nerve separates from the vestibular nerve more medially than usual; in the lower right specimen, the vestibulocochlear nerve is more tubular than usual.

in anatomy between the two most different specimens was great, the differences identified in all of the specimens formed a spectrum of small variations that defied quantification. Consequently, the variations are described only qualitatively.

The anatomy was most consistent in the most medial portion of the internal auditory canal. In this region, separate facial and vestibulocochlear nerves could be identified with the facial nerve lying superior, or superior and anterior, or anterior to the vestibulocochlear nerve. The nerves were usually tubular structures in this portion of the canal and appeared round if cut in cross section or elongated if the section obtained was not perpendicular to the nerve (Fig 3). On occasion, the vestibulocochlear nerve obtained its crescent shape in the medial portion of the canal (Figs 1 and 3).

In the middle section of the internal auditory canal, the vestibulocochlear nerve began to change its shape. As the nerve coursed medially to laterally, it usually acquired a crescent shape (Fig 4). The vestibulocochlear nerve showed great variation of morphology in this section. Occasionally, the nerve remained

round (Figs 2 and 4) and sometimes the cochlear nerve separated from the vestibular nerve more medially than usual (Fig 4). The facial nerve remained superior and anterior to the vestibulocochlear nerve or its branches.

In the lateral internal auditory canal, the vestibulocochlear nerve first divided into the cochlear and vestibular nerves. Then the vestibular nerve divided into inferior and superior vestibular nerves. The separation of the superior and inferior vestibular nerves was usually seen only at the fundus of the canal (Fig 5), and, in several specimens, the superior and inferior vestibular nerves were seen as separate only when divided by the falciform crest (Figs 2 and 5). In approximately one third of the specimens, the superior vestibular nerve attained a position where it could not be separated from the facial nerve (Figs 2 and 5). The vestibular ganglion located just medial to the division of the superior and inferior vestibular nerves was not identified as an enlargement in the vestibular nerve but was suggested by an hourglass configuration of the vestibular nerve in approximately half the specimens (Fig 1). All of the specimens demonstrated the foramen singulare, the canal

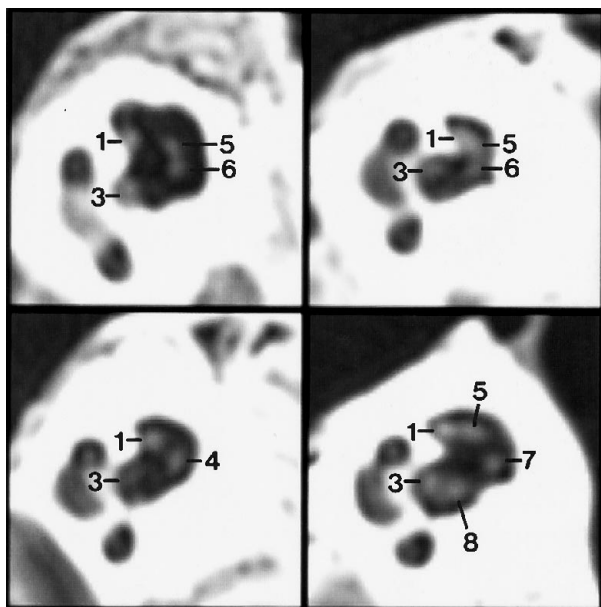


Fig 5. Parasagittal CT scans in the lateral portion of the internal auditory canal in four specimens show individual nerves. Anterior is on the left of the images and posterior is on the right. Four separate nerves are seen in the specimen on the upper left. In the specimen on the upper right, the facial and superior vestibular nerves cannot be separated. In the specimen on the lower left, the vestibular nerve has not yet separated, while in the specimen on the lower right, the inferior vestibular nerve has separated into the saccular and posterior ampullary nerves.

for the posterior ampullary nerve (Figs 1 and 2). However, in only two specimens, the inferior vestibular nerve divided into a posterior ampullary nerve and a saccular nerve that could both be seen (Fig 5).

The intermediate nerve was not identified in any portion of the canal in any specimen.

The dissections of the specimens revealed facial and vestibulocochlear nerves of different sizes and configurations corresponding to the variations seen on the CT scans (Figs 1 and 2). The configurations of the nerves as determined by CT did not change after the nerves were exposed. A varying amount of fibrous tissue was identified between the individual nerves in the middle and lateral sections of the internal auditory canal.

The MR studies exhibited a variation of anatomy that was similar to the specimens, but with less spatial resolution (Figs 6 and 7). The nerves, which had relatively low signal on both the 2-D fast spin-echo and 3-D turbo spin-echo imaging techniques, were difficult to see when adjacent to bone. Vascular structures could be seen in or near the entrance to the internal auditory canal on one third of the MR scans. Only

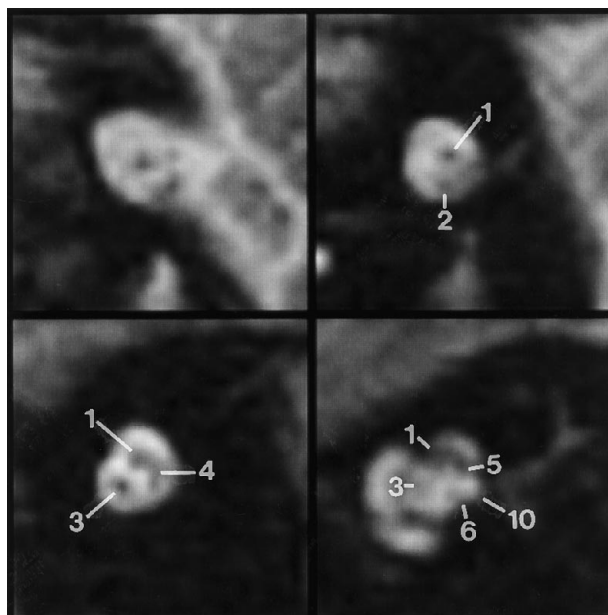


Fig 6. Contiguous 3-mm-thick parasagittal oblique T2-weighted 2-D fast spin-echo MR images of the internal auditory canal displayed medially to laterally. Anterior is on the left of the images and posterior is on the right.

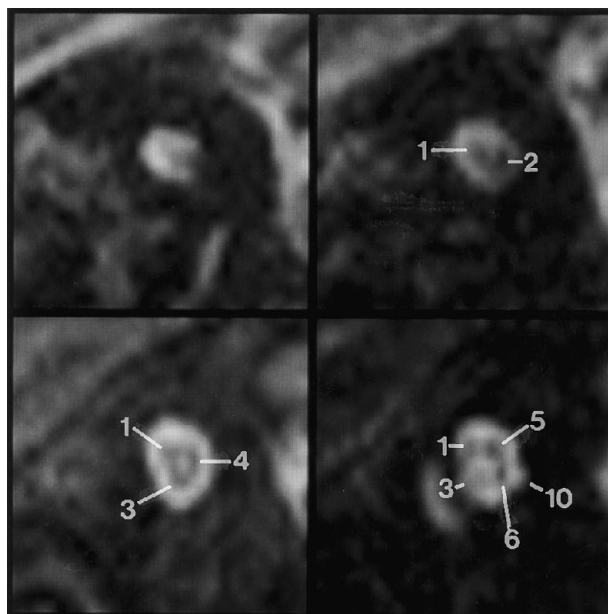


Fig 7. Contiguous 1.5-mm-thick parasagittal T2-weighted 3-D turbo spin-echo MR images of the internal auditory canal displayed medially to laterally. Anterior is on the left of the images and posterior is on the right.

two MR studies, obtained with each technique, failed to show an outpouching of the internal auditory canal as the entrance to the foramen singulare. The ability to differentiate nerves within the canal was similar for the two techniques, but the nerves appeared slightly sharper

on images obtained with the 3-D turbo spin-echo technique. All four patients in whom both internal auditory canals were examined with the 3-D turbo spin-echo technique had nearly identical anatomy on each side. The two patients in whom both internal auditory canals were examined with the 2-D fast spin-echo technique had slight differences in appearance of the two sides.

Discussion

Previous MR imaging studies of the internal auditory canal have concentrated on axial and coronal sequences and have led to the supposition that the facial, cochlear, superior vestibular, and inferior vestibular nerves are separate structures throughout the length of the canal (1-3). One study, which used T1-weighted imaging oriented perpendicular to the internal auditory canal, described the crescent shape of the vestibulocochlear nerve but identified that shape of the nerve in the cerebellopontine angle and entrance to the canal and suggested that there were four individual nerves throughout most of the length of the internal auditory canal (4). In contrast, both our cadaveric CT study and in vivo MR studies revealed that the facial and vestibulocochlear nerves enter the internal auditory canal as tubular structures. The vestibulocochlear nerve becomes crescent shaped in the middle portion of the canal and four individual nerves exist only in the most lateral portion of the canal. The division of the inferior vestibular nerve into the saccular and posterior ampullary could be discerned in only two specimens, although the foramen singulare was observed consistently. Our findings agree with the most detailed anatomic (5-8) and surgical (9) studies of the vestibulocochlear nerve. These studies demonstrated that the vestibulocochlear nerve divides into individual nerves only in the most lateral aspect of the internal auditory canal. Additionally, the cadaveric and MR studies showed that the anatomy of the vestibulocochlear nerve differs among individuals, which has also been described previously (15).

Our inability to separate the facial nerve from the superior vestibular nerve on some specimens may have been due to the various amounts of fibrous tissue along the nerves within the canal (5) or to the presence of nerve fibers that may have been connecting the two nerves (6).

We may not have identified the vestibular ganglion for certain, but we did identify the vestibular nerve with a cross-sectional appearance of an hourglass, similar to previous descriptions of the ganglion (8).

Because the temporal bones were not harvested in pairs, a comparison of sides was not possible in the cadaveric study. In four patients, a comparison of sides on 3-D turbo spin-echo images suggested symmetric anatomy within an individual. This is consistent with the previous description of similar-size vestibulocochlear nerves within an individual (5). Less symmetry was seen in the two patients in whom both internal auditory canals were imaged with the 2-D fast spin-echo technique. The use of 3-mm-thick sections with this technique may have resulted in different section positions within the canals, causing poorer correlation from side to side.

While the findings of our cadaveric study correlate well with previous findings, we noted two potential causes of artifacts. First, the vestibulocochlear and facial nerves were severed from the brain stem before the temporal bones were harvested. This manipulation may have altered the position of the cranial nerves at the entrance to the internal auditory canal. The nerves, however, are well anchored at the fundus of the canal and we believe this manipulation could have altered the position of the nerves only at the entrance to the canal. Second, formalin fixation most likely resulted in a small amount of shrinkage in the nerves. This may have allowed us to see separation of individual nerves that may not be apparent when they are full size. Despite this potential artifact, we found less separation of the nerves in the cadaveric study than suggested by previous MR studies (1-4).

In summary, the facial nerve remains tubular as it courses superior and anterior to the vestibulocochlear nerve in the internal auditory canal. The vestibulocochlear nerve enters the canal as a tubular structure, and then in the middle portion of the canal usually becomes crescent shaped in cross section of the canal before separating into individual cochlear, superior vestibular, and inferior vestibular nerves in the most lateral portion of the canal. The anatomy within the internal auditory canal differs from individual to individual, but limited data suggest symmetry of the anatomy of the canals within individuals. The anatomy of the nerves within the internal auditory canal can be demonstrated

with thin-section T2-weighted 2-D fast spin-echo and 3-D turbo spin-echo MR imaging. The ability to define the nerves in the internal auditory canal may provide greater sensitivity and specificity in detecting abnormalities of this anatomic structure.

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