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Topographical Relationship of the Facial and Vestibulocochlear Nerves in the Subarachnoid Space and Internal Auditory Canal

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PURPOSE: **Our purpose was to investigate the topographical relationship of the facial and vestibulocochlear nerves from the brain stem through the internal auditory canal.**

METHODS: **We dissected 15 formalin-fixed cadaveric heads and performed MR examinations in 35 healthy subjects in order to examine the topographical relationship of the facial and vestibulocochlear nerves. The cadaveric dissections and the in vivo MR imaging findings were compared indirectly.**

RESULTS: **The relationship between the facial and vestibulocochlear nerves showed some variation among individuals and according to the location of the nerves within the cisterns or canal. Near the brain stem, 53% of the vestibulocochlear nerves were partially segmented on MR images. The vestibulocochlear nerve was completely divided into separate nerves only in the most lateral portion of the canal, except in three cadaveric dissections, in which separation of the superior vestibular nerve was seen near the brain stem. The facial and cochlear nerves were of similar size on 36% of the MR images. The superior vestibular nerve was larger than the inferior vestibular nerve on 81% of the MR images.**

CONCLUSION: **The appearance of the facial and vestibulocochlear nerves was variable but followed certain consistent patterns.**

The facial and vestibulocochlear nerves run together from the brain stem to the internal auditory canal (IAC). The facial nerve can be displaced in various directions by an acoustic schwannoma, which arises from the superior or inferior vestibular nerve. Understanding of the topographical relationship of these nerves is important in the diagnosis and surgical planning of acoustic schwannomas.

Definition of the CSF-tumor/nerve interface is crucial for the detection of small masses or inflammatory thickening of the nerves. Oblique parasagittal fast spin-echo (FSE) T2-weighted MR imaging has been suggested as optimal for evaluation of the IAC and its contained structures (1).

The purpose of this study was to examine the topographical relationship between the facial nerve and each part of the vestibulocochlear nerve in the subarachnoid space and IAC by comparing, although indirectly, cadaveric dissections and in vivo MR imaging studies in the hope that this may prove helpful in the diagnosis and treatment of pathologic conditions.

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Methods

Fifteen formalin-fixed adult cadaveric heads were used to investigate the anatomic relationship of the facial and vestibulocochlear nerves. Red neoprene latex was injected through the internal carotid artery and vertebral artery for identification of vessels. More than 2 weeks later, the cranium and dura were removed. After resection of the brain in the midbrain level, the roof of the IAC was opened with a drill. The relationship and course of the facial and vestibulocochlear nerves were investigated at four levels in anatomic position after resection of the brain stem: near the brain stem, at the mid portion between the brain stem and the porus acusticus, at the porus acusticus, and at the mid portion of the IAC (Fig 1).

MR imaging was performed with a superconducting unit operating at 1.5 T in 58 facial and vestibulocochlear nerves of 35 subjects (20 males and 15 females; mean age, 43 years; range, 14 to 69 years). No subject had symptoms or signs relating to these nerves.

After obtaining proper consent, axial and coronal spin-echo T1-weighted images and high-resolution FSE T2-weighted images were obtained parallel to the IAC. For better evaluation of the facial and vestibulocochlear nerves, oblique parasagittal high-resolution FSE T2-weighted images were obtained perpendicular to the long axis of the canal. The anthropologic

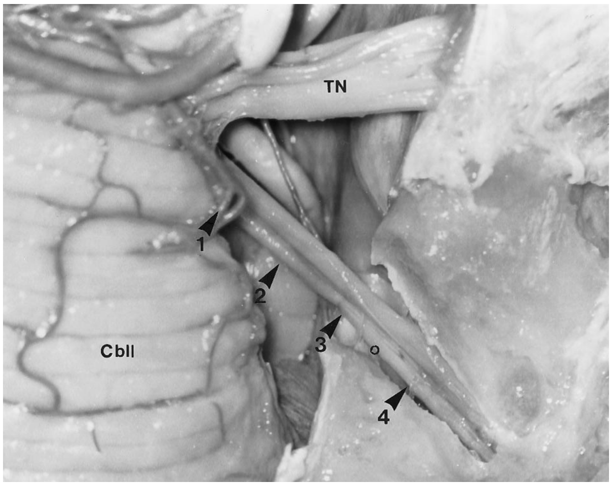

FIG 1. Topographical relationship of the facial and vestibulocochlear nerves was investigated at four levels: *1*, near the brain stem; *2*, at the midportion between the brain stem and porus acusticus; *3*, at the porus acusticus; and *4*, at the midportion of the IAC. *TN*, trigeminal nerve; *Cbll*, cerebellum.

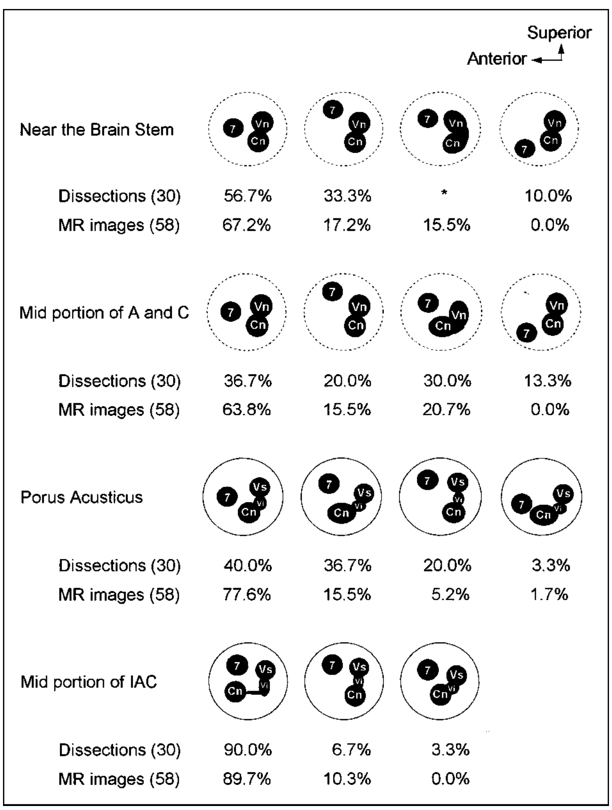

FIG 2. Topographical relationship of the facial and vestibulocochlear nerves in the subarachnoid space and IAC. On 5% of the MR images, the vestibulocochlear nerve, which was ovoid or rectangular when leaving the brain stem, changed to a curved shape in the midportion between the brain stem and porus acusticus. At the porus acusticus, most of the vestibulocochlear nerves were curved and the cochlear nerve was heading for the anteroinferior portion of the canal. In the midportion of the IAC, the facial nerve occupied the anterosuperior portion of the canal. Most of the inferior vestibular nerves were small and round to ovoid in the portion inferior to the superior vestibular nerve, with some fibers connected to the cochlear nerve. *Asterisk* indicates that, near the brain stem, the shape (rectangular or curved) of the vestibulocochlear nerve was not evaluated in the cadaveric dissections.

basal line (the line that joins the infraorbital point to the superior border of the external auditory meatus) was used to establish the axial plane relative to a sagittal scout view. All subjects also had spin-echo T1-weighted MR imaging after intravenous administration of 0.1 mmol/kg of gadopentetate dimeglumine. Imaging parameters for spin-echo T1-weighted sequences were 400/11/2 (TR/TE/excitations), 256 × 192 matrix, 16 × 16-cm field of view, 3-mm-thick continuous sections, 16 kHz bandwidth, and 5 minute 20 second acquisition time. Imaging parameters for high-resolution FSE T2-weighted sequences were 4000/100/4, echo train of 20, 512 × 256 matrix, 16 × 16-cm field of view, 3-mm-thick continuous sections, 15.6 kHz bandwidth, and 7 minute 44 second acquisition time. To increase the signal-to-noise ratio, dual surface temporomandibular joint coils were used. All images were reviewed by two experienced radiologists.

The relationship and course of the facial and vestibulocochlear nerves were investigated at four locations, as in the cadaveric dissections, and the results of dissection and MR imaging were compared at each location. The cross-sectional shape and the number of trunks of the vestibulocochlear nerve were investigated near the brain stem with MR imaging. The relative size of the facial, cochlear, and superior and inferior vestibular nerves was also investigated in the region in which the nerves were clearly separable (usually, in the lateral portion of the IAC) on MR images.

Results

The relationship between the facial and vestibulocochlear nerves showed some variation among individuals and according to location (Fig 2). Near the brain stem, the facial nerve was anterior to the midportion of the vestibulocochlear nerve complex in 57% of dissections and on 67% of MR images. In the remaining cases, the facial nerve was anterosuperior or anteroinferior to the vestibulocochlear nerve (Fig 2A). The cross-sectional shape of the vestibulocochlear nerve at this location was approximately rectangular (Fig 3A) in 83%, crescentic (Fig 4A) in 16%, and round (Fig 5A) in 2% of in vivo MR images. On MR images, 47% of the vestibulocochlear nerves were seen as a single, solid trunk and 53% had at least partial segmentation. The cochlear nerve represented the most inferior part of the vestibulocochlear nerve near the brain stem (Figs 3–6). In three cadaveric dissections, the superior vestibular nerve was completely separated from the remaining portion of the vestibulocochlear nerve (Fig 7).

In the midportion between the brain stem and porus acusticus, the facial nerve was located anterior to a shallow groove of the vestibulocochlear nerve in 37% of dissections and on 64% of MR images. The shape and relationship of the facial and vestibulocochlear nerves in this portion were similar to the results obtained near the brain stem in 77% of dissections and on 91% of MR images (Figs 3–5). On 5% of MR images, the vestibulocochlear nerve, which was rectangular near the stem, changed to a curved shape, but this change did not relate to earlier or later division of the vestibulocochlear nerve (Figs 2B, 6).

At the porus acusticus, the vestibulocochlear nerve occupied the posterior portion of the canal, and the parts of the vestibulocochlear nerve were not yet separated (Figs 2C, 3, 4, 6, and 8). Instead, the cochlear and superior vestibular nerves were identified

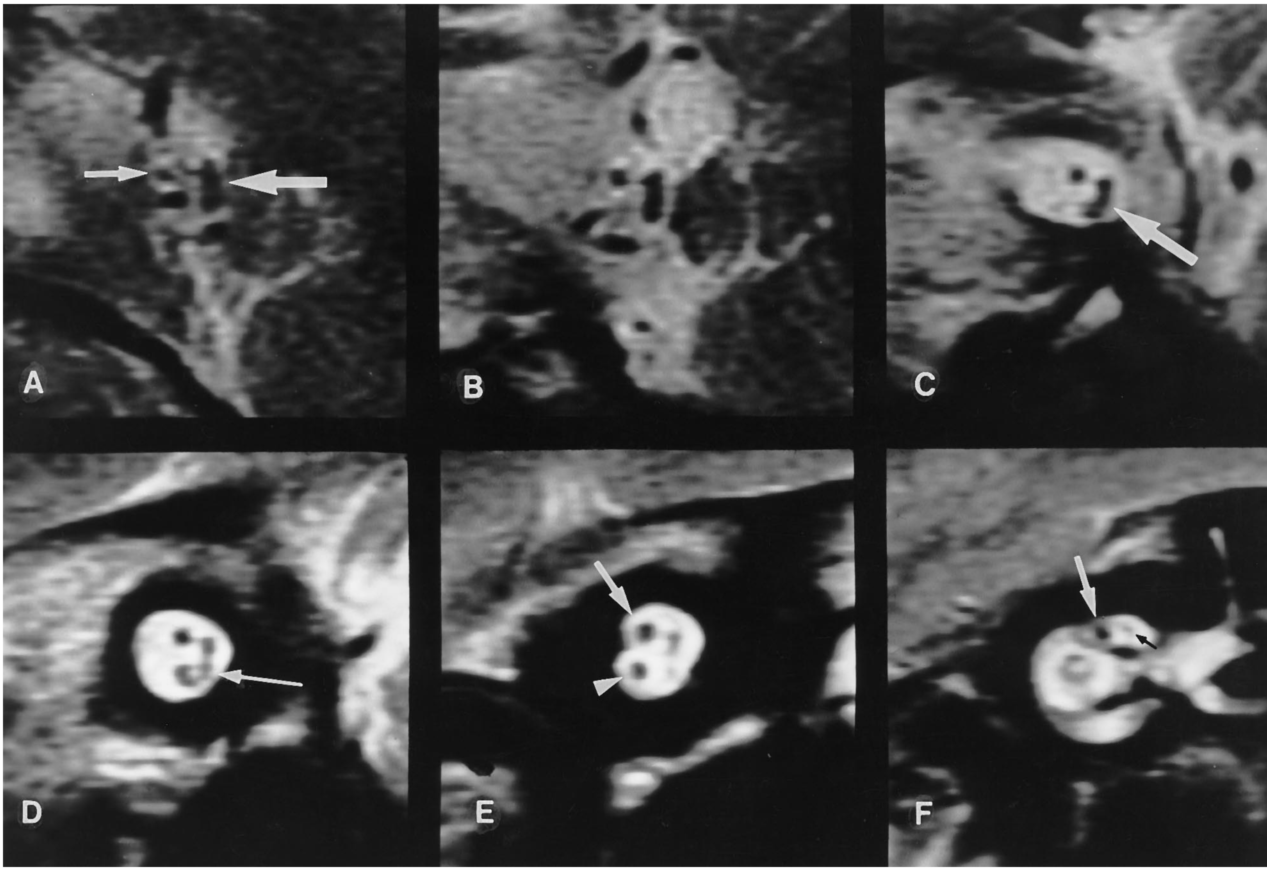

FIG 3. 3-mm-thick oblique parasagittal FSE T2-weighted images show topographical relationship of the facial and vestibulocochlear nerves.

A, Near the brain stem, the cross section of the vestibulocochlear nerve (*large arrow*) is rectangular in cross section without a definite groove. The facial nerve (*small arrow*) is located anterior to the superior portion of the vestibulocochlear nerve.

B, Near the brain stem and in the midportion between the brain stem and porus acusticus, the facial and vestibulocochlear nerves have a similar shape and relationship.

C, At the porus acusticus, the vestibulocochlear nerve (*arrow*) has changed to a curved shape.

D, In the midportion of the IAC, the vestibulocochlear nerve divides into the superior vestibular, inferior vestibular, and cochlear nerves. The inferior vestibular nerve (*arrow*) is oval, with a connecting portion between the superior vestibular and cochlear nerves.

E, In the lateral portion of the canal, the facial (*arrow*) and cochlear (*arrowhead*) nerves are similar in size. The inferior vestibular nerve is the smallest one.

F, The facial (*white arrow*) and superior vestibular (*black arrow*) nerves above the transverse crest are seen in the most lateral portion of the canal.

as rounded enlargements of the nerve complex. The inferior vestibular nerve was observed as a shallow region or a small, round structure between the cochlear and superior vestibular nerves. Ninety-five percent of the vestibulocochlear nerves had a curved, crescentic shape and 5% appeared relatively rectangular on MR images. The facial nerve was located anterior to the shallow groove of the vestibulocochlear nerve in 40% of dissections and on 78% of MR images.

In the midportion of the IAC, the facial nerve occupied the anterosuperior portion of the canal. Where the vestibulocochlear nerve curved at the porus acusticus, the cochlear and vestibular portions of the vestibulocochlear nerve occupied anteroinferior and posterosuperior portions of the canal, respectively. The inferior vestibular nerve was identified as a small, round, or oval structure inferior to the superior vestibular nerve with some fibers connecting to the cochlear nerve. Ninety percent of dissections and of MR images showed this pattern (Figs 2D, 6, and 9).

In the lateral portion of the IAC, the cross sections of the facial, cochlear, and superior vestibular nerves were round, and small fibers connected the superior and inferior vestibular nerves as well as the cochlear and inferior vestibular nerves on MR images. Most of the inferior vestibular nerves were irregularly shaped, with connecting fibers to the cochlear and superior vestibular nerves. Near the transverse crest, the superior and inferior vestibulocochlear nerves were completely separated on MR images, and the facial and cochlear nerves moved farther anterosuperiorly and anteroinferiorly, respectively (Figs 3–6).

In the lateral portion of the IAC, the facial and cochlear nerves were similar in size in 36% of the cases (Figs 3, 5, and 6). The cochlear nerve was the largest segment of the vestibulocochlear nerve in 88%

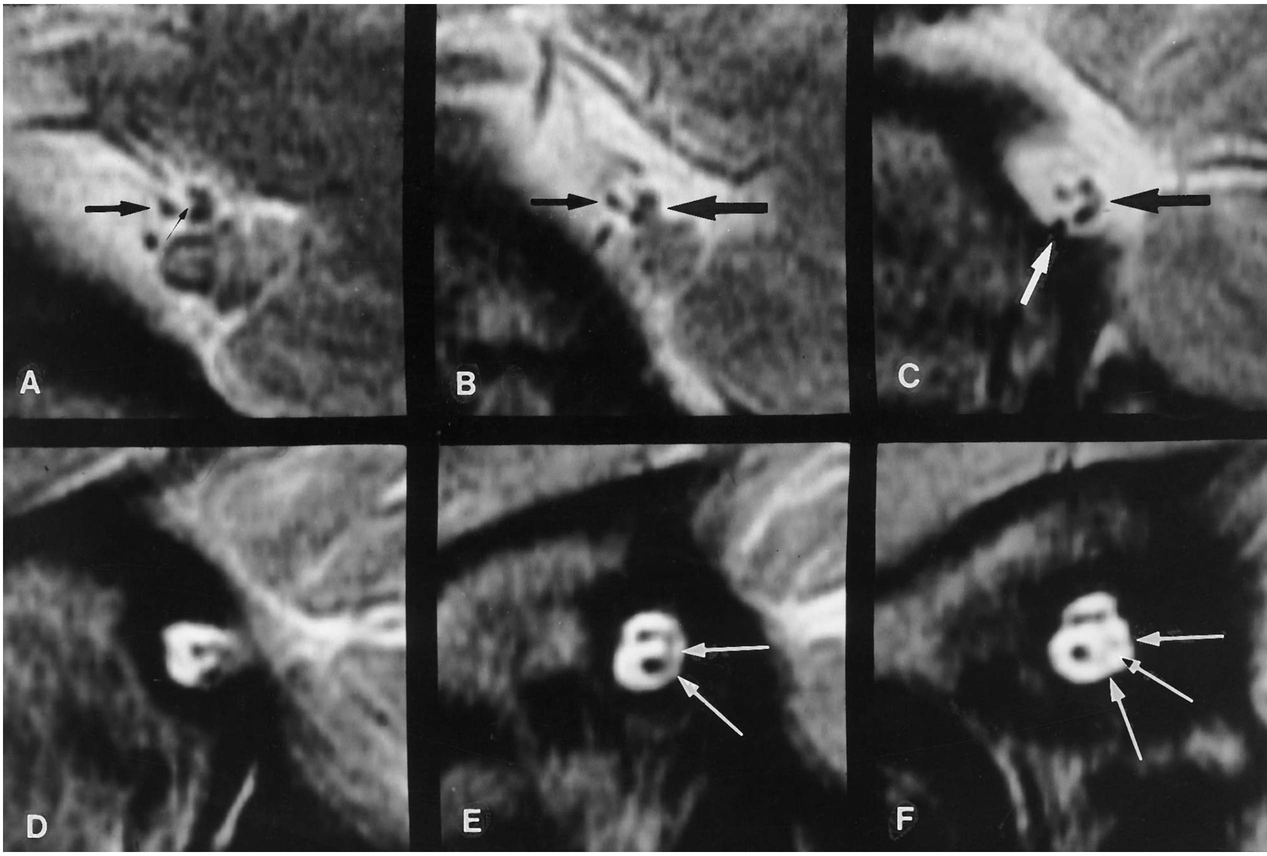

FIG 4. 3-mm-thick oblique parasagittal FSE T2-weighted images show topographical relationship of the facial and vestibulocochlear nerves.

A, Near the brain stem, the vestibulocochlear nerve has a shallow groove (*thin arrow*). The facial nerve (*thick arrow*) is located anterior to the groove of the vestibulocochlear nerve.

B, In the midportion between the brain stem and porus acusticus, the vestibulocochlear nerve (*large arrow*) has slightly rotated to a position inferior to the facial nerve (*small arrow*).

C, A vessel (*white arrow*) enters into the porus acusticus anteroinferior to the crescentic, vestibulocochlear nerve (*black arrow*).

D, the vestibulocochlear nerve curves anteroinferiorly. A vessel seen in *A–C* is not well seen at a position 3 mm lateral to *C.*

E, In the midportion of the canal, the inferior vestibular nerve (*arrows*) is oval, with a connecting portion to the superior vestibular nerve.

F, In the lateral portion of the canal, the cochlear nerve is the largest among four nerves and located in the anteroinferior portion of the canal. The inferior vestibular nerve (*arrows*) is faintly seen as having a branching appearance in the posteroinferior portion of the canal.

of the cases (Table and Figs 3, 4, and 6). The superior vestibular nerve was larger than the inferior vestibular nerve in 81% of the cases. When right and left sides were compared, the relative sizes of the four nerves were symmetrical in 16 (70%) of the 23 subjects.

Discussion

The facial nerve is a round structure located anterior to the vestibulocochlear nerve. Moving laterally in the IAC, it courses anterosuperior to the vestibulocochlear nerve until it leaves the canal. The cross section of the vestibulocochlear nerve as it leaves the brain stem is most frequently rectangular or crescentic. It divides completely into the superior, inferior, and vestibular nerves and the cochlear nerve only in the most lateral portion of the IAC. The topographical relationship of the facial and vestibulocochlear nerves has been documented in some reports of cadaveric, surgical, or MR studies (1–6). The results of the present study are similar to those described previously (1, 5, 6).

As it leaves the brain stem, the vestibulocochlear nerve assumes different configurations in different people; for example, a single trunk, of which little more than half is found (on microscopic examination) to be vestibular and the rest cochlear; two distinct trunks, of which one seems to be purely vestibular while the other is mostly cochlear; partially fused cochlear and vestibular nerves through most of their course in the IAC, the cerebellopontine angle, and the subarachnoid space; and a single cochlear vestibular trunk with incomplete glial septa, roughly indicating a division between the cochlear and vestibular fibers (5). Silverstein (6) described a complete separation of the cochlear and vestibular nerves in 34% of surgical cases, a complete septum separating these

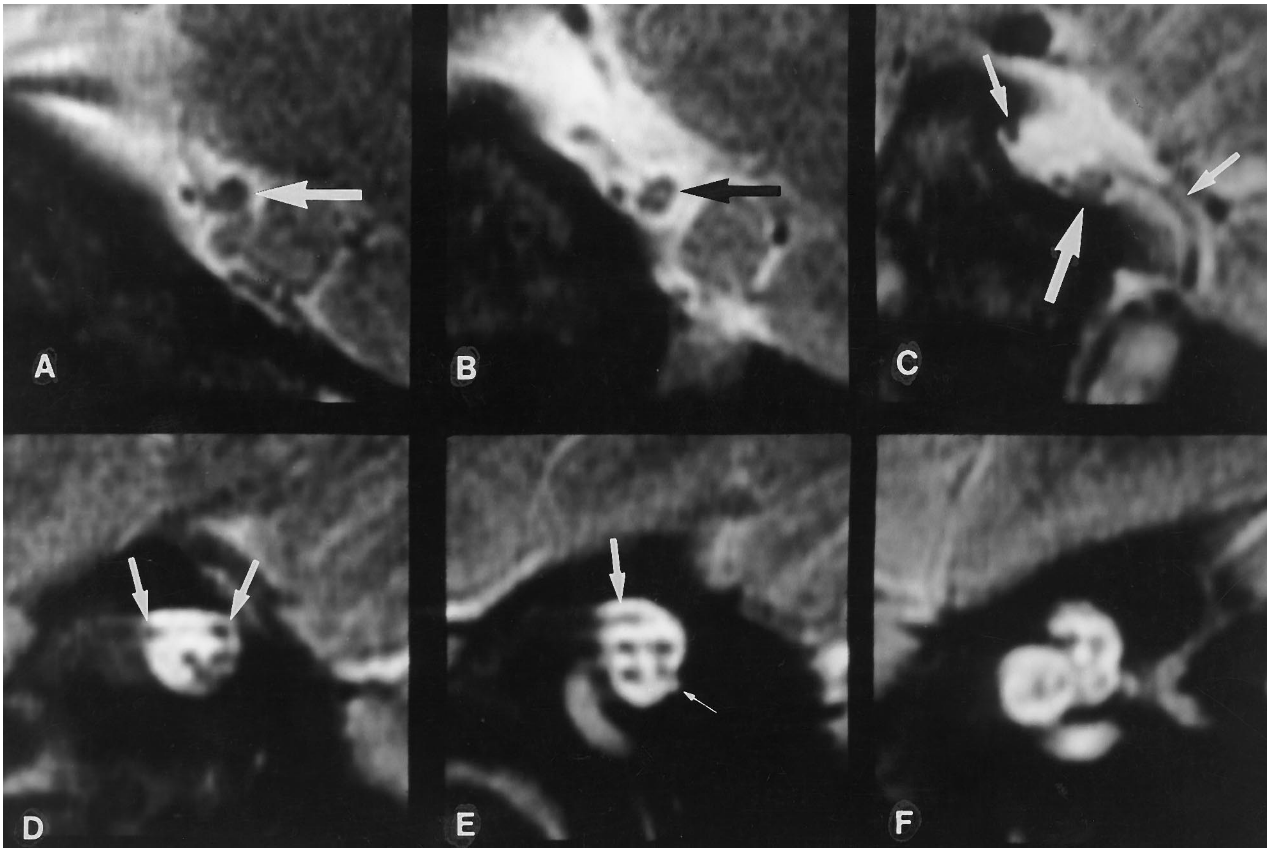

Fig 5. 3-mm-thick oblique parasagittal FSE T2-weighted images show topographical relationship of the facial and vestibulocochlear nerves.

A–F, The vestibulocochlear nerve (*large arrows*) has a round to oval shape from the part near the brain stem (*A*) to the porus acusticus (*C*). A vascular loop (*small arrows*) enters into the IAC. In the midportion (*D*) of the canal, the facial and vestibulocochlear nerves are displaced posteroinferiorly because of the vascular loop. In the lateral portion (*E*) of the canal, the facial, cochlear, and superior vestibular nerves are similar in size. The foramen singulare has a beaked appearance (*thin arrow*).

nerves in 31%, an incomplete septum in 15%, and no cleavage plane in 20%. In the present study, 53% of the vestibulocochlear nerves had two or three trunks that were at least partially separated on MR images.

In the midportion of the IAC, the inferior vestibular nerve was identified as a small, round to oval segment inferior to the superior vestibular nerve with some fibers connected to the cochlear nerve. Observations at cadaveric dissection correlated well with in vivo MR imaging findings.

In the lateral portion of the IAC, the facial, cochlear, and superior vestibular nerves were smooth and round except for very small fibers/bands of low signal intensity between the superior and inferior vestibular nerves and between the cochlear and inferior vestibular nerves. Near the transverse crest, components of the vestibulocochlear nerve were completely separated. Our findings agree with those of most anatomic (5, 7–9) and surgical (6) studies, in which the vestibulocochlear nerve was reported to divide into individual nerves only in the most lateral aspect of the IAC. Even in cases in which the vestibulocochlear nerve changed to a crescentic, cross-sectional shape in the midportion between the brain stem and the porus acusticus, it did not divide into separate parts earlier or later than it did in other cases. No previous reports and none of the present in vivo MR images displayed the completely separated superior vestibular nerves seen on cadaveric dissections near the brain stem (Fig 7). In most cases, the inferior vestibular nerve had an irregular shape with connecting fibers to the cochlear and superior vestibular nerves. Some fibers of the inferior vestibular nerve heading for the inferior or posteroinferior aspect of

TABLE: Relative size of the facial (F), cochlear (C), and superior (Vs) and inferior (Vi) vestibular nerves in the lateral portion of the internal auditory canal (n = 58)

Pattern	No. of Cases (%)
F = C ≥ Vs ≥ Vi*	22 (38)
F > C > Vs ≥ Vi*	15 (26)
C > F > Vs > Vi	12 (21)
Vs > F > C > Vi	5 (9)
C > Vs > F > Vi	3 (5)
F > Vs C > Vi	1 (2)

* In 19% of the cases, the superior and inferior vestibular nerves were similar in size.

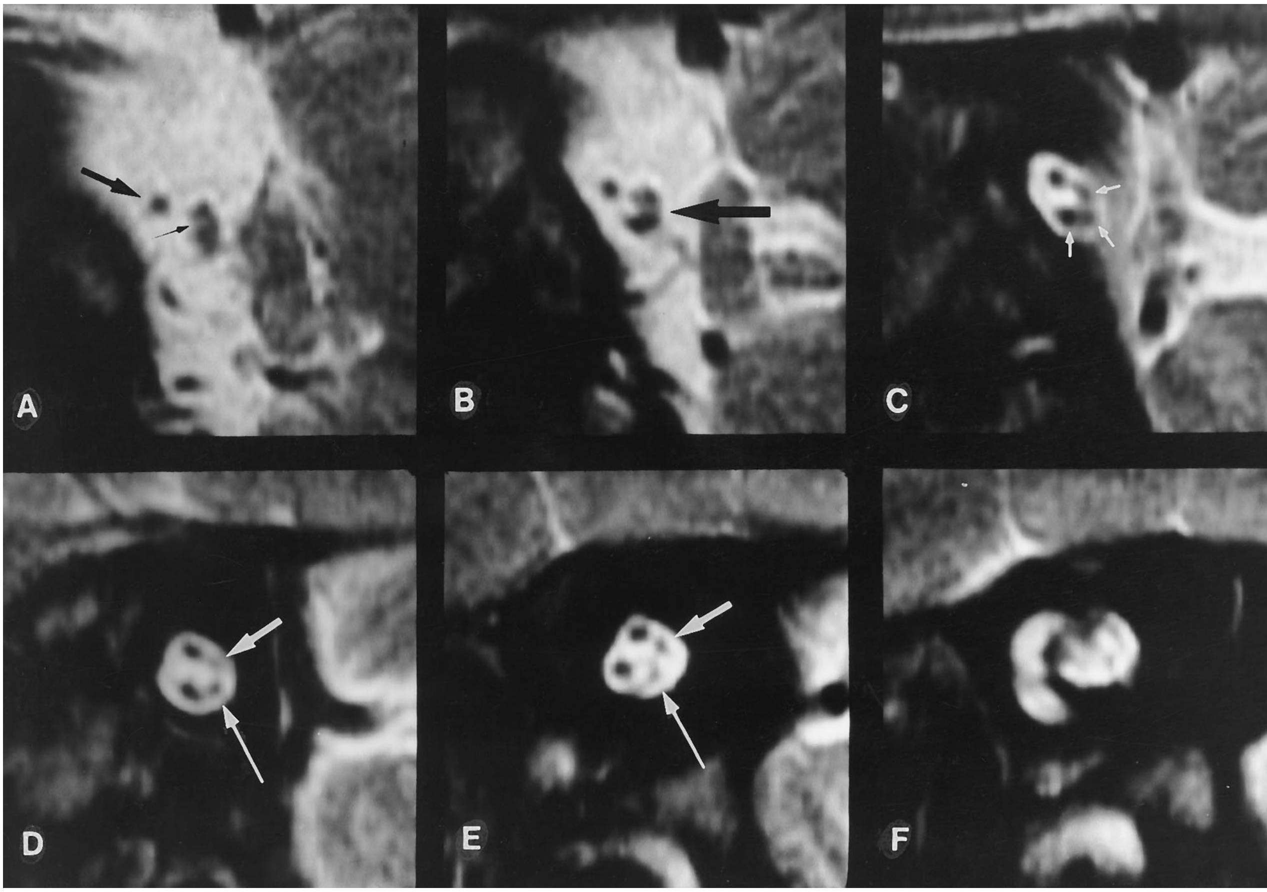

FIG 6. 3-mm-thick oblique parasagittal FSE T2-weighted images show topographical relationship of the facial and vestibulocochlear nerves.

A, Near the brain stem, the straight vestibulocochlear nerve is identified as two trunks by a thin septum or groove (*small arrow*). The facial nerve (*large arrow*) is located anterosuperior to the vestibulocochlear nerve.

B, In the midportion between the brain stem and porus acusticus, the vestibulocochlear nerve (*arrow*) has changed to a curved (crescentic) shape earlier than in the other cases.

C, At the porus acusticus, three portions of the vestibulocochlear nerve (*arrows*) are relatively well identified but not yet separated.

D–F, The facial and cochlear nerves are similar in size in the mid (*D*) and lateral (*E*) portions of the IAC. The superior vestibular nerve (*short arrow*) is approximately the same size as the inferior vestibular nerve (*long arrow*).

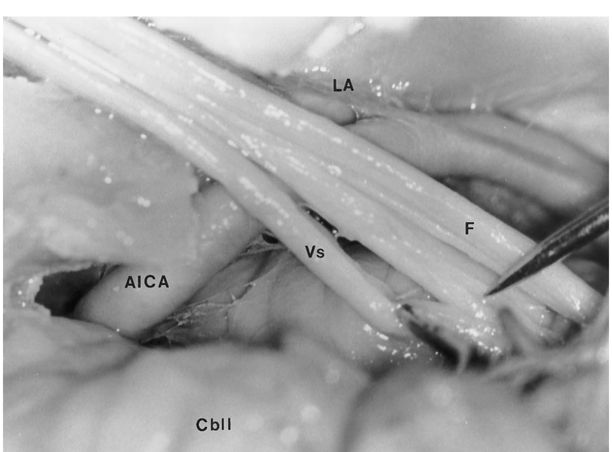

FIG 7. The roof of the IAC was opened and viewed from above. Near the brain stem, the superior vestibular nerve (*Vs*) was completely separated from the remaining portion of the vestibulocochlear nerve. The facial nerve (*F*) was anterosuperior to the vestibulocochlear nerve. *AICA*, anterior inferior cerebellar artery; *LA*, labyrinthine artery; *Cbll*, cerebellum.

the canal were questionable in some of the MR cases; these could have represented the posterior ampullar and saccular nerves.

Although the superior vestibular nerve was larger than the inferior vestibular nerve in most cases, the superior and inferior vestibular nerves were of similar size in 19% of the cases. The relative sizes of the facial, cochlear, and superior and inferior vestibular nerves on MR images were symmetrical in 70% of the subjects. Previous articles have described similarly sized vestibulocochlear nerves within an individual (1, 5), but no data were available about the relative size, symmetry, or shape of the four nerves in the lateral portion of the IAC.

Conclusion

The appearance of the facial and vestibulocochlear nerves is variable but follows certain consistent patterns.

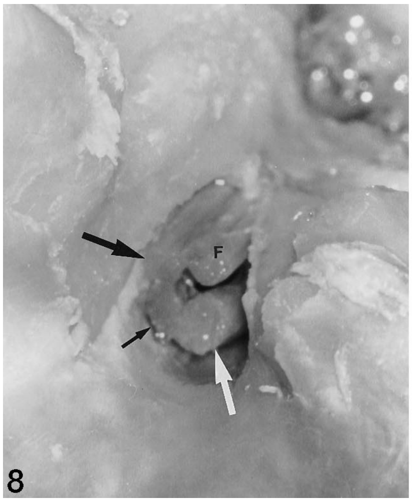

FIG 8. At the porus acusticus, the vestibulocochlear nerve was curved and occupied the posterior portion of the canal. The parts of the vestibulocochlear nerve were not separated yet; instead, the cochlear (*white arrow*) and superior (*large black arrow*) and inferior (*small black arrow*) vestibular nerves were identified as rounded enlargements. *F*, facial nerve.

FIG 9. Where the cochlear nerve divided from the vestibulocochlear nerve in the midportion of the canal, the inferior vestibular nerve (*small black arrow*) was identified as a small, oval portion inferior to the superior vestibular nerve (*large black arrow*), with some fibers (*arrowhead*) connected to the cochlear nerve (*white arrow*). *F*, facial nerve.

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