Magnetic Resonance Cisternography Using the Fast Spin Echo Method for the Evaluation of Vestibular Schwannoma

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Abstract

Neuroimaging of vestibular schwannoma was performed with the fat-suppression spoiled gradient recalled acquisition in the steady state (SPGR) method and magnetic resonance (MR) cisternography, which is a fast spin echo method using a long echo train length, for the preoperative evaluation of the lateral extension of the tumor in the internal auditory canal, and the anatomical identification of the posterior semicircular canal and the nerves in the canal distal to the tumor. The SPGR method overestimated the lateral extension in eight cases, probably because of enhancement of the nerves adjacent to the tumor in the canal. The posterior semicircular canal could not be clearly identified, and the cranial nerves in the canal were shown only as a nerve bundle. In contrast, MR cisternography showed clear images of the lateral extension of the tumor and the facial and cochlear nerves adjacent to the tumor in the internal auditory canal. The anatomical location of the posterior semicircular canal was also clearly shown. These preoperative findings are very useful to plan the extent to which the internal auditory canal can be opened, and for intraoperative identification of the nerves in the canal. MR cisternography is less invasive since no contrast material or radiation is required, as with thin-slice high-resolution computed tomography (CT). MR cisternography should replace high-resolution CT for the preoperative neuroradiological evaluation of vestibular schwannoma.

Key words: internal auditory canal, magnetic resonance cisternography, spoiled gradient recalled acquisition in the steady state magnetic resonance imaging, vestibular schwannoma

Introduction

Vestibular schwannoma primarily originating in the cerebellopontine cistern usually involves the internal auditory canal, and most tumors occupy much of the internal auditory canal. Therefore, opening of the internal auditory canal for surgical removal of vestibular schwannoma is essential.

We have adopted the unilateral suboccipital transmeatal approach for surgical removal of vestibular schwannoma. One limiting factor for the preservation of hearing is the anatomical location of the posterior semicircular canal, which determines whether opening of the canal can be sufficiently achieved by this approach. During the dissection of the intracanalicular portion of the tumor, the facial and cochlear nerves must first be anatomically identified. Therefore, a method of preoperative neuroradiological imaging for identification of the anatomical location of the posterior semicircular canal, the lateral extent of the tumor in the canal, and the anatomical relationship between the tumor and the facial and cochlear nerves in the internal auditory canal would be extremely useful.

We describe our method of magnetic resonance (MR) cisternography using a long echo train length fast spin echo method for the preoperative evaluation of vestibular schwannoma and for the determination of the surgical strategy.

Clinical Materials and Methods

Preoperative neuroradiological imaging was performed in 10 patients with vestibular schwannoma who underwent surgery.

The findings of three-dimensional fat-suppression fast spoiled gradient recalled acquisition in the steady state (SPGR) MR imaging with gadolinium-diethylentriaminepenta-acetic acid (Gd-DTPA) administration, and MR cisternography using a long echo train length fast spin echo method were eval-
uated. All scans were performed with a GE Signa Advantage 1.5 tesla MR imaging unit (GE Medical Systems, Milwaukee, Wis., U.S.A.). The parameters of fast SPGR MR imaging were repetition time (TR)/echo time (TE) = 13.9/2.2 msec, and the thickness of slices was 1.0 mm with a slice gap of 0 mm. After precontrast imaging, Gd-DTPA (0.2 ml/kg) was injected, and postcontrast MR imaging was performed.

The parameters of MR cisternography with a fast spin echo method was TR/TE 2700/200 msec, axial imaging, echo train length 24, and field of view 19 × 19 cm. The matrix was 512 × 256, the slice thickness was 3.0 mm, the interslice gap was 0 mm, and the number of excitations (NEX) was 6 to 8. A fat suppression-pulse was used. The time required for a scan was 8 minutes and 40 seconds when NEX was 6. The images obtained on each side were magnified three times, and printed.5)

We previously reported the importance of the sigmoid-fundus line for the identification of the opening of the internal auditory canal by high-resolution computed tomography (CT).11) The length of the internal auditory canal was defined as the distance from the porus to the fundus. The porus was set on the line which connected the inner and outer petrous ridges. The length of the internal auditory canal was divided into three parts, medial, middle, and lateral, to assess the lateral extent of the tumor. Both MR imaging methods were used to evaluate identification of the posterior semicircular canal, visualization of the facial nerve distal to the lateral end of the tumor in the internal auditory canal, and the agreement between MR imaging and surgical findings of the lateral extent of the tumor in the internal auditory canal.

Results

MR cisternography clearly visualized the anatomical location of the posterior semicircular canal in all cases. MR cisternography clearly delineated the sigmoid-fundus line and the anatomical location of the posterior semicircular canal to this line was also identified more clearly than with high-resolution CT. SPGR MR imaging does not provide good bone images, so these data were not obtained by this method.

The surgical and SPGR MR imaging findings were identical in two out of 10 operated cases, but the SPGR MR findings overestimated the lateral extent of the tumor in eight cases. In contrast, MR cisternography findings were exactly the same as the surgical findings in all cases. SPGR MR imaging with Gd failed to clearly identify the intracanalicular facial and cochlear nerves in all cases, only showing a nerve bundle. In contrast, MR cisternography clearly showed the facial nerve in the distal part of the internal auditory canal, and the anatomical relationship between the intracanalicular portion of the tumor and the facial nerve in eight cases. These findings were confirmed during surgery. The intracanalicular facial nerve was not visualized in the other two cases, because the lateral extent of the tumor had reached the fundus of the internal auditory canal and completely occupied the canal.

Representative Cases

Case 1: A 55-year-old male presented with a right vestibular schwannoma. Three-dimensional fat-suppression fast SPGR MR imaging with Gd showed part of the tumor located in the internal auditory

Fig. 1 Case 1. Three-dimensional fat-suppression fast spoiled gradient recalled acquisition in the steady state magnetic resonance images showing a right vestibular schwannoma (upper), and part of the tumor in the internal auditory canal, and the nerves in the canal appearing as a "nerve bundle" (arrow) (lower). The posterior semicircular canal is not seen.
canal (Fig. 1 upper). However, the lateral extension of the tumor was unclear, and the affected nerve in the internal auditory canal could not be identified, only the nerve bundle (Fig. 1 lower). The posterior semicircular canal was not identified. MR cisternography clearly delineated the whole tumor and the intracanalicular portion of the tumor (Fig. 2 upper). The facial and cochlear nerves distal to the tumor in the internal auditory canal, and the lateral extent of the tumor were also clearly visualized. The posterior semicircular canal was clearly identified, and the sigmoid-fundus line was easily obtained (Fig. 2 middle). The normal cranial nerves, internal auditory canal, cochlear nerve, and labyrinth in the contralateral side are also shown (Fig. 2 lower) for comparison. Surgical findings obtained through a right suboccipital transmeatal approach were exactly the same as the results of preoperative MR cisternography, and the facial and cochlear nerves were preserved.

**Case 2:** A 27-year-old female presented with a huge left cerebellopontine tumor with peripheral enhancement (Fig. 3 upper). SPGR MR imaging with Gd showed part of the tumor in the internal auditory canal. However, the lateral extent of the tumor could not be clearly determined. MR cisternography showed a tumor with intratumoral hemorrhage, and clearly visualized the extension in the internal auditory canal of the tumor (Fig. 3 lower). The facial and cochlear nerves were identified at the distal part of the tumor in the canal. The posterior semicircular canal was also well delineated. The sigmoid-fundus line was identified showing that the internal auditory canal could be opened without any damage to the posterior semicircular canal. During surgery, the facial nerve was easily identified in the position corresponding to the MR cisternography results and the nerve was preserved, although no recovery of hearing acuity was obtained.

**Case 3:** A 45-year-old female presented with a left vestibular schwannoma with marked lateral extension on SPGR MR imaging with Gd (Fig. 4 upper). MR cisternography showed that the tumor com-

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**Fig. 2** Case 1. upper: Magnetic resonance (MR) cisternogram using a long echo train length fast spin echo method showing clear anatomical findings of the tumor, the internal auditory canal, and the intracanalicular portion of the tumor (single arrow). middle: Magnified view of the MR cisternogram showing the facial (double arrowheads) and cochlear (single arrowhead) nerves in the internal auditory canal, the posterior semicircular canal (double arrows), and the sigmoid-fundus line (continuous line), as well as the intracanalicular portion of the tumor (single arrow). lower: MR cisternogram of the contralateral side.
Fig. 3 Case 2. upper: Fast spoiled gradient recalled acquisition in the steady state magnetic resonance (MR) image with gadolinium showing a huge left vestibular schwannoma, but the extent of tumor extension into the internal auditory canal, and the anatomical relationship between the tumor and nerves in the internal auditory canal are not obvious. lower: MR cisternogram showing the precise anatomical location of the facial (single arrow) and cochlear (double arrows) nerves in the internal auditory canal, the sigmoid-fundus line (continuous line), and the posterior semicircular canal (arrowhead).

Fig. 4 Case 3. upper: Fast spoiled gradient recalled acquisition in the steady state magnetic resonance (MR) image with gadolinium showing a left vestibular schwannoma with marked lateral extension in the internal auditory canal. lower: MR cisternogram clearly showing that the tumor completely occupies the internal auditory canal and reaches the fundus (arrow), the sigmoid-fundus line (continuous line), and the posterior semicircular canal (arrowhead). The nerves in the canal are not visualized distal to the lateral extent of the tumor.

Discussion

Our present study of the neuroimaging of vestibular schwannoma using MR cisternography showed that MR cisternography could determine the lateral extent of the tumor in the internal auditory canal, completely occupied the internal auditory canal and that the lateral extension reached the fundus (Fig. 4 lower). However, MR cisternography did not show the nerves in the internal auditory canal. The sigmoid-fundus line was identified and the posterior semicircular canal was located on that line.

Our present study of the neuroimaging of vestibular schwannoma using MR cisternography showed that MR cisternography could determine the lateral extent of the tumor in the internal auditory canal, consistent with the operative findings, clearly delineate the posterior semicircular canal, and identify the anatomical relationship between the facial nerve and the tumor in the internal auditory canal, unless the tumor completely occupied the canal and reached the fundus.

The benefits of the fast spin echo method adopted in this study are that a heavily T₂-weighted image is available within a very short time by shortening the echo train length. The time saved by shortening of the echo train length can be used for summation, resolving the problem of the weak signal accompanying a decreased number of voxels. This achieves high spatial resolution, and fine anatomical imaging is available which cannot be obtained by a conventional spin echo method. Furthermore, no injection of contrast material is necessary.⁴,⁵

Preoperative neuroradiological imaging can pro-

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vide extremely useful information for planning of surgical treatment of vestibular schwannoma. The facial nerve is exceptionally difficult to identify in the intracranial portion of a case of large vestibular schwannoma. Identification of the opening of the internal auditory canal and the facial nerve at the distal part of the lateral extent of the intracranial portion of the tumor are necessary to preserve the facial nerve. If the anatomical location of the intracranial portion of the tumor can be preoperatively determined by neuroradiological imaging, it can be easily identified in surgery and safely followed to the porus and cisternal portion with dissection of the tumor from the nerve. SPGR MR imaging with Gd only visualized a nerve bundle in the canal, and the facial nerve could not be clearly discriminated, nor was the precise anatomical relationship between the tumor and the facial nerve determined.

Removal of the intracranial portion of the tumor with preservation of the cochlear nerve requires identification of the intracranial facial and cochlear nerves. Preoperative neuroradiological imaging can be used to determine the extent to which the internal auditory canal should be reduced and whether this can be achieved without damage to the posterior semicircular canal. The anatomical location of the posterior semicircular canal is the limiting factor which determines whether the canal can be safely opened. We previously reported the importance of the sigmoid-fundus line using high-resolution CT to evaluate the anatomical location of the labyrinth. Although this method delineates the labyrinth, scanning with very thin slices (1.5 mm) is necessary, which is associated with a significant amount of radiation exposure compared to routine CT. Preoperative MR cisternography can provide this information more accurately than high-resolution CT, and no radiation exposure is required.

Inflamed neural structures are enhanced by Gd-DTPA. Bell's palsy and other inflammatory conditions induce enhancement of the facial nerve. Moreover, even the normal nerve shows variable enhancement on T1-weighted MR imaging. Enhanced neural structures in the internal auditory canal may be due to nerve edema, increased vascularity, or alteration of vascular permeability, all of which may occur adjacent to tumors. Such manifestations could explain the overestimation of the lateral extension of the vestibular schwannoma in the internal auditory canal in our present study. Details of the posterior semicircular canal could not be obtained by SPGR MR imaging.

SPGR MR imaging with Gd is necessary as a routine neuroradiological evaluation to identify the presence of vestibular schwannoma. However, preoperative MR cisternography is extremely valuable for the surgical management of vestibular schwannoma. High-resolution CT should be replaced by MR cisternography for preoperative neuroradiological evaluation of this tumor.

References

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Owing to remarkable advancement in the field of MRI in recent years, it has become possible not only to identify a mass but also to recognize the border between the mass and surrounding tissue as clearly elucidated in this paper. Recently, 3 Tesla MRI has been introduced into clinical practice and therefore it is expected that structures on the micron scale can be identified in the near future.

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1: This is a good technique for visualization of the cranial nerves.

This sequence will routinely allow visualization of individual nerves within the IAC. The T2 weighting allows better visualization of cochlea, vestibule, and semicircular canals. Fat suppression is also important in allowing the high signal of the optic capsule structures to be distinguished from fat within the petrous bone. This is an excellent sequence to be used in addition to the post-contrast T1-weighted or fast spin sequences.

2: Can it replace thin-section CT?

Although this sequence can identify the borders of the IAC, it cannot accurately assess air-cells within the bone. Both air and bone will have the same signal intensity, thus air-cells within the posterior wall of the IAC will not be seen with this technique.

3: Cystic components

Another potential problem is cystic components of a vestibular schwannoma which on a T2-weighted sequence may be difficult to distinguish from adjacent CSF within the C-P angle or within the IAC.

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Nishizawa et al. evaluated MR cisternography by a fast spin echo method using a long echo train length for visualization of the anatomical structures in the CP angle, internal auditory canal and temporal bone of the patients with vestibular schwannoma. They beautifully demonstrated the nerve bundles in the internal auditory canal between the schwannoma and fundus and fine structures in the temporal bone such as the semicircular canals or cochlea. The CISS (constructive interference in the steady state) technique or a fast spin echo method using a peripheral pulse gating (Mamata et al.1) are also recommended to visualize the intracisternal fine structures, and the authors of this article should compare their technique with CISS or Mamata’s methods. In general, the term “MR cisternography” is inappropriate, because these techniques are useful to visualize not only the intracisternal structures but also other structures outside of the cisterns.

Reference


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