Virtual Endoscopy of the Labyrinth Using a 3D-FastASE Sequence

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Introduction
Virtual endoscopy (VE) using helical CT data is now widely performed. Virtual bronchoscopy and colonoscopy are the most frequently employed clinical applications. Recently, VE using MRI data has been employed for the examination of the colon, arteries, the pancreatic duct, the eisterns, the bladder, and so on (1). Although VE of the labyrinth using CT data has been attempted, bone algorithm CT cannot visualize the soft tissue masses in the labyrinth. Consequently, the clinical significance of VE for the labyrinth using CT data has been limited. To our knowledge, VE of the labyrinth using MR data has not been attempted. The purpose of the present study was to evaluate the spatial resolution requirements for the generation of VE images of the labyrinth, the usefulness of zero-fill interpolation in VE, and the application of VE of the labyrinth in the clinical setting.

Materials and Methods
All scans were performed on a 1.5-T MR unit (VISARTIEX, Toshiba, Tokyo, Japan) using a QD surface phased-array coil. VE images were generated from the acquired data using a 3D workstation (Alatoview, Toshiba, Tokyo, Japan).

a) Volunteer study
Spatial resolution
Initially, heavily T2-weighted 3D fast asymmetric spin echo (3D-FastASE) images (2) were acquired in a healthy volunteer using the following parameters: TR 5000/TE 250, echo train length 116, and 512 x 384 x 80 matrix axial slab.
Three kinds of isotropic voxel size data were obtained as follows: (0.4 mm)³, (0.5 mm)³, and (0.6 mm)³. The scan time for acquiring each data set was 14 minutes. The upper and lower thresholds were determined on the original heavily T2-weighted images at the level of the cochlear modiolus, and then 3D data for VE was segmented using the region-growing method. The segmented volume was 1.3 cm³ for each data set.

Zero-fill interpolation (ZIP)
ZIP was applied in three axes for the three data sets with different spatial resolutions. Consequently, six data sets were generated.

VE image evaluation
The VE images from the six data sets were evaluated with regard to the following points:
1) Ability to fly through the entire length of the three semicircular canals
2) Continuity of the nerves in the internal auditory canal
3) Visualization of Reissner's membrane
4) Visualization of the osseous spiral lamina

b) Patient study
Case of right intravestibular schwannoma
An 18-year-old man presented with a chief complaint of vertigo and sensorineural hearing loss. High-resolution MRI was performed with a voxel size of (0.6 mm)³ in 3 minutes. ZIP was applied in three axes.

Results
a) Volunteer study
VE image evaluation, Effects of spatial resolution and ZIP
1) Ability to fly through the entire length of the three semicircular canals
The (0.6 mm)³ data without ZIP did not allow us to do so (Fig. 1).
Fig. 1 shows a view from inside the common crus of the semicircular canals. This is (0.6 mm)³ data with ZIP.
2) Continuity of the nerves in the internal auditory canal
The nerves were visualized with the best continuity on images generated from (0.4 mm)³ data. The effect of ZIP was not apparent on (0.4 mm)³ data.
3) Visualization of Reissner's membrane
Reissner's membrane was not visualized even in the original source images generated from (0.4 mm)³ data with ZIP.
4) Visualization of the osseous spiral lamina
The osseous spiral lamina was visualized even on the original source images generated from (0.6 mm)³ data without ZIP. However, on VE images, none of the data sets allowed the visualization of the osseous spiral lamina, which disappeared during procession.

b) Patient study
Case of right intravestibular schwannoma
On the original T2-weighted images, a low-signal mass measuring 3 mm in diameter was visualized in the right vestibule (Fig. 2A, arrow).

VE images permit visualization of the relationships between the mass (Fig. 2B, arrow) and the entrance of the cochlea. Note the widely patent vestibule on the normal side (Fig. 2C, Arrow indicates the entrance of the cochlea).

Discussion and Conclusion
In this study, internal structures such as Reissner's membrane and the osseous spiral lamina were not visualized even on (0.4 mm)³ data with ZIP. The present method allows us to fly through the labyrinth without a border between the scala vestibuli and scala tympani or between the endolymph and perilymph.
Thus, based on the findings of the present study, we conclude that the minimum spatial resolution requirement for VE of the labyrinth is met by (0.6 mm)³ data with ZIP.
VE of the labyrinth with MR is now possible, allowing us to understand the complex 3D anatomy of the labyrinth. Currently, direct surgical intervention in the labyrinth is, for the most part, limited to cochlear implantation. Thus, VE of the labyrinth may currently be of limited clinical significance. However, in the future, with the development of new surgical procedures, the clinical significance of VE of the labyrinth is expected to increase greatly.

References