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Imaging assessment of profound sensorineural deafness with inner ear anatomical abnormalities

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Abstract

Objective: : To explore the value of a combined computed tomography (CT) and magnetic resonance imaging (MRI) in evaluating profound sensorineural deafness patients before cochlear implant (CI) surgery.
Methods: A retrospective analysis of 1012 cases of profound sensorineural deafness that received CI was performed.
Results: A total of 96 cases were diagnosed with inner ear abnormalities including large vestibular aqueduct syndrome (LVAS, n = 61), Michel deformity (n = 3), cochlear incomplete partition I (n = 2), cochlear incomplete partition II (n = 6), cochlear hypoplasia with vestibular malformation (n = 3), cochlear ossification (n = 3), bilateral internal auditory canal obstruction (n = 5) and internal auditory canal stenosis (n = 2).
Conclusion: High resolution CT (HRCT) can display bony structures while MRI can image the membranous labyrinth in preoperative evaluation for cochlear implantation. The combination of these two modalities provides reliable anatomical information regarding the bony and membranous labyrinths, as well as the auditory nerve.
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Keywords: Cochlea; Hearing loss; Multimodal imaging

1. Introduction

Cochlear implant (CI) is the primary method to restore hearing in patients with severe sensorineural hearing loss. In China, increasing number of patients achieve satisfactory hearing restoration and speech and spoken language skills through CI surgery. Experience and studies show that strict and comprehensive candidate selection, improved surgical skills, effective rehabilitation training and post-implantation psychotherapy are important for the success of CI. Contraindications to cochlear implantation may include a defect of the

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auditory nerve, and deafness caused by a severe cochlear malformation, although some cases of inner ear anomalies can achieve satisfactory outcomes. To ensure the success of CI surgery, complete preoperative evaluation should include imaging studies for temporal bone anatomy and the auditory nerve pathway. High resolution computed tomography (HRCT) can clearly reveal the anatomy of the mastoid, outer ear, middle ear, inner ear, bony labyrinth, and internal auditory meatus. Moreover, magnetic resonance imaging (MRI) allows evaluation of the auditory nerve, brain and auditory center, in addition to detecting the bony labyrinth and its pathological changes. Comprehensive evaluation of imaging studies is of important significance in determining the suitable ear for CI, evaluating electrode placement, and predicting intraoperative and postoperative complications (Li et al., 2006). In this paper, we analyze pre-operative imaging before CI surgery from November in 2005 to April in 2014 in our hospital and discuss the value of combined computed tomography (CT) and MRI in evaluating profound sensorineural deafness patients before CI surgery.

2. Materials and methods

2.1. Clinic data

We included 1012 patients with profound sensorineural deafness who received CI at the 2nd XiangYa Hospital of Central South University between November 2005 and April 2014 (the research group). Inclusion criteria included auditory examination showing binaural profound sensorineural deafness (PTA >90 dB HL); age ≥12 months; no significant improvement in hearing and speech after hearing rehabilitation training for 3–6 months and meeting the conditions of hearing and speech rehabilitation training; parents and family members having a strong desire to improve patient's hearing and holding realistic expectations of CI. All the subjects and their family members agreed to partake in this research and signed the informed consent form.

2.2. Imaging examination method

All the children in the research and control group received HRCT scan and MRI examination. A 64-slice and dual-source layer 256 spiral CT scanner was used for CT scans. Patients took a supine position, with the chin tucked and the orbit line kept parallel with scan baseline. The entire structures of both middle and inner ears were included in the scan range. Volume data were collected to reconstruct cross-sectional, coronal and sagittal plane images and combined with volume rendering technology to show bony labyrinth. Pneumatization of mastoid, the size of sigmoid sinus and jugular fossa, cochlear niche, development of cochlea and internal auditory canal were examined separately. Meanwhile, the length and width of mastoid were measured. We measured the diameter of vestibular aqueduct at its external aperture and midpoint of a line connecting the posterior and anterior semicircular canals. The scan parameters were: 120 kV, 100 mA, beam collimation 0.75 mm, Pitch 1 and FOV 100 mm. We also reconstructed the ear with 0.1 mm reconstruction interval and 50 mm FOV overlapping amplification reconstruction.

A GE Twin speed 1.5T superconducting MRI scanner was used for MRI scan. Children who could not cooperate were given 0.5 mg chloral hydrate per kilogram body weight orally or per rectum for sedation. Head scan was performed conventionally. Inner ear and auditory nerve scans were performed twice using FIESTA sequence on standard axial views and the parameters were TR 12.25 ms, TE 59.0 ms, Flip angle 700, effective slice thickness 0.6 mm, matrix 230 × 512, vision 200 mm, that was used to observe the vestibular nerve, cochlear nerve and inner ear membranous labyrinth. To acquire auditory nerve images, MRP was performed perpendicular to the long axis of the internal auditory canal.

Referring to the classification criteria of inner ear malformations by Sennaroglu, diagnosis standards were established and inner ear malformations were divided into cochlear malformation, vestibular malformations, semicircular canal malformation, malformation of internal auditory canal, vestibular aqueduct malformations and cochlear aqueduct deformity. Among these malformations, cochlear malformation was divided into Michel deformity, cochlear aplasia, common cavity, cochlear hypoplasia, incomplete partition I and incomplete partition II, also known as Mondini dysplasia.

2.3. Imaging analysis of cochlear translocation malformation

2.3.1. Case groups

(1) Normal controls: temporal bone CT scan from 20 children (40 ears) with normal hearing; (2) Normal cochlear position group: axial temporal bone CT scans before CI surgery from 20 children (40 ears) with binaural profound sensorineural deafness, who matched the inclusion criteria; (3) Abnormal cochlear position group: axial temporal bone CT scans from three 1–3 years old children whose cochleae could not be successfully accessed from the normal position during the CI surgery.

2.3.2. Measuring method

Each case was measured as follows: (1) the angle between cochlear basal turn plane and head midsagittal plane (α) (Fig. 1A), (2) the angle between a line connecting the midpoint of the facial nerve vertical section and the upper edge of the round window niche and head midsagittal plane (β) (Fig. 1B), (3) in the round window plane, the vertical distance from the surface of facial nerve vertical section to the external canal wall (Fig. 1C).

In addition, we also evaluated cochlear ossification and fibrosis that could affect CI through radiography.

3. Results and analysis

3.1. Absence of inner ear abnormalities in majority of cases

HRCT and MRI results showed normal inner ear structures in 916 of the 1012 cases, with clear imaging of the cochlea,

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