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Otolaryngology -- Head and Neck Surgery 2011 144: 64
DOI: 10.1177/0194599810390884

The online version of this article can be found at:
http://oto.sagepub.com/content/144/1/64

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Differences in Cochlear Nerve Cross-Sectional Area between Normal Hearing and Postlingually Deafened Patients on MRI

Björn Herman, MD¹, and Simon Angeli, MD¹

Abstract

Objectives. To demonstrate that parasagittal constructive interference in steady state (CISS) magnetic resonance imaging (MRI) can be used to accurately measure cochlear nerve cross-sectional area and thereby evaluate for statistically significant differences in the cochlear nerve cross-sectional areas of postlingually deafened and normal-hearing adults.

Study Design. Cross-sectional study.

Setting. Tertiary care medical center.

Subjects and Methods. Parasagittal CISS MRIs of postlingually profoundly deafened cochlear implant candidates and normal-hearing patients at a tertiary care academic medical center between 2006 and 2009 were retrospectively identified. Two independent and blinded investigators measured the cochlear nerve height and width and calculated the cross-sectional area \( \pi (H/2)(W/2) \) at the fundus of the internal auditory canals. Measurements of both investigators were analyzed for reliability and agreement with an Altman plot, and deafened patient measurements were compared with results of the normal-hearing patients via Wilcoxon rank sum tests.

Results. The cochlear nerve cross-sectional area of postlingually deafened patients (mean ± SD = 0.61 ± 0.16 mm²) was less than normal-hearing patients (0.94 ± 0.28 mm²). The difference was statistically significant (\( P = .002 \)). There was good agreement between independent observer measurements.

Conclusion. Parasagittal CISS MRI can be used to measure the cochlear nerve with good interobserver agreement, and there is a significant difference between the cross-sectional area of postlingually deafened and normal-hearing adults. The cross-sectional area may correlate with residual spiral ganglion cells and provide a prognostic indicator for post–cochlear implant performance, which is the focus of our ongoing research.

Keywords
cochlear nerve, magnetic resonance imaging, cochlear implants, sensorineural hearing loss

Magnetic resonance imaging (MRI) has been shown to reliably measure the diameter of the cochlear nerve in normal-hearing ears.¹ MRI studies also have been used to evaluate the cochlear nerve of deaf patients. Glastonbury et al² reviewed T2-weighted fast-spin echo MRI of deaf patients and found that most had a deficient cochlear nerve. Morita et al³ studied the diameter of the cochlear nerve on MRI as a predictor of higher scores on the Infant-Toddler-Meaningful Auditory Integration Scale following cochlear implantation in prelingually deafened patients and found that sufficient outcome from cochlear implants could be determined only by whether the nerve was imaged on MRI. A study by Sildiroglu et al⁴ attempted to show a difference in cochlear nerve size between elderly patients with sensorineural hearing loss and young patients with normal hearing but found no statistically significant difference. Despite this study’s findings, it seems reasonable that the cochlear nerve cross-sectional area in postlingually deafened adults should be smaller than in normal-hearing controls on MRI, since autopsy studies by Nadol and Xu⁵ have shown that the maximum diameter of the cochlear nerves is smaller in deaf populations compared with normal-hearing controls. The purpose of this study is to demonstrate a difference using MRI between the cochlear nerve cross-sectional area in postlingually deafened and normal-hearing adults.

Methods

University of Miami Institutional Review Board approval was obtained. We performed a cross-sectional study of postlingually deafened adults identified through the University of Miami Department of Otolaryngology Cochlear Implant Database from 2006 to 2009 as well as normal-hearing controls.
patients identified by International Classification of Diseases (ICD-9) codes for vertigo and tinnitus during the same time period who had undergone MRIs of their internal auditory canals (IAC) at the University of Miami. All patients were older than 18 years. Normal-hearing patients were defined as having an audiogram with 6 frequency pure-tone average (PTA) at 250, 500, 1000, 2000, 4000, and 8000 Hz less than 25 dB and a word recognition score of 92% or greater. Each subject had to have a high-resolution 3-dimensional (3D) constructive interference in steady state (CISS) sequence MRI of the brain that could be used to measure both the right and left cochlear nerve at the fundus of the IAC. MRIs were performed on a Siemens Sonata scanner (Siemens AG, Munich, Germany) via an 8-channel head coil with a magnetic field strength of 1.5 T. Gradient echo T2 3D (CISS) sequences were obtained and reconstructed to create a parasagittal plane perpendicular to the IAC. Time of repetition was 8.58 milliseconds, time of echo was 4.28 milliseconds, and 2 averages were taken. Slice thickness was 0.7 mm, and 52 slices were obtained. Matrix size was 256 × 256 pixels and was reconstructed to 512 × 512 pixels. The field of view was 170 mm. Two independent and blinded investigators measured cochlear nerve anterior-posterior and superior-inferior diameter and calculated cross-sectional area \[\pi(H/2)(W/2)\] on each parasagittal CISS-MRI at the fundus of the IAC (Figure 1). Measurements were obtained on the Centricity Picture Archiving and Communication System (General Electric, Fairfield, Connecticut) with 0.1-mm electronic calipers. The measurements from both investigators were analyzed for reliability and agreement with an Altman plot. Both ears were measured for each patient, and then 1 random ear from each patient was used for analysis. A random number–generating computer program was used to determine which ear was used for each patient. Measurements of the postlingually deafened adults’ cochlear nerves were compared via Wilcoxon rank sum tests with results of the normal-hearing patient MRIs. Our data were imported into JMP version 8.0.1 software (SAS Institute Inc, Cary, North Carolina) for statistical analysis. Mean values and standard deviations were obtained. A \(P\) value of .05 or less was considered statistically significant.

**Results**

There were 19 postlingually deafened and seven normal-hearing adults included in the study. The mean age in the postlingually deafened group was 53 ± 18 years (range, 26-80 years), and the mean age in the normal-hearing group was 47 ± 9 years (range, 33-59 years). The 6 frequency PTAs for the deaf patients were all equal or greater than 100 dB, and the PTAs for the normal-hearing patients were all less than 25 dB. Eleven male and 8 female patients made up the postlingually deafened group, and 7 female patients made up the normal-hearing group. Anterior-posterior cochlear nerve diameter was 1.07 ± 0.17 mm in the normal-hearing group versus 0.85 ± 0.13 mm in the postlingually deafened group. The difference was statistically significant (\(P = .0009\)). The superior-inferior cochlear nerve diameter was 1.10 ± 0.17 mm in the normal-hearing group versus 0.90 ± 0.15 mm in the postlingually deafened group. The difference was statistically significant (\(P = .0054\)). The cochlear nerve cross-sectional area between deaf and normal-hearing patients. Our data for both deaf and normal-hearing subjects compare well with Nadol and Xu’s cadaver-derived measurements of cochlear nerve diameter.\(^5\) We found a vertical diameter of 1.10 mm and a horizontal diameter of 1.07 mm, and Nadol and Xu reported a maximum diameter of 1.04 mm in normal-hearing subjects. In deaf patients, we found a vertical diameter of 0.90 mm and a horizontal diameter of 0.85 mm, and Nadol and Xu found a maximum diameter of 0.81 mm. Our control group of normal-hearing patients was made up entirely of female patients, but Nadol and Xu found that there was no difference between male and female cochlear nerve diameters in their cadaver studies, so there is no reason to think that this coincidental cohort characteristic distorts our results.\(^7\)

Nadol and Xu also correlated their finding of a smaller cochlear nerve in deaf patients with fewer residual spiral ganglion cells.\(^3\) Since cochlear implants stimulate residual spiral

![Figure 1. (A) Parasagittal magnetic resonance image (MRI) of a deaf patient. (B) Parasagittal MRI of a normal-hearing patient.](image-url)
ganglion cells of the cochlear nerve, thus providing auditory cues to patients with profound sensorineural hearing impairment. More available spiral ganglion cells may mean a more successful cochlear implantation outcome. Even once patients have been identified as candidates for cochlear implantation, it is difficult to predict who will ultimately experience the best effects. Were more prognostic tools available, they could help surgeons determine who will be successful following implantation. Now that MRI has been shown to demonstrate differences in cochlear nerve cross-sectional area between deaf and normal-hearing patients, study of whether stratifying cochlear nerve cross-sectional area on MRI among cochlear implant candidates can help predict cochlear implant success is warranted.

**Author Contributions**

Björn Herman, study design, data collection, manuscript preparation; Simon Angeli, study design, data analysis, manuscript editing.

**Disclosures**

**Competing Interests:** Simon Angeli, MD, Medtronic, Osmopharm: recipient of research grant.

**Funding source:** None.

**References**