



Original Article

A Comparison of Cochlear Nerve Size in Normal-Hearing Adults Using Magnetic Resonance Imaging

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OBJECTIVE: Cochlear implantation is a clinical and cost-effective treatment for severe hearing loss. Cochlear nerve size assessment by magnetic resonance imaging (MRI) has been investigated for use as a prognostic indicator following cochlear implantation. This study aimed to further that research by assessing nerve size in normal-hearing adults for symmetry.

MATERIALS and METHODS: Patients with tinnitus presenting to our center retrospectively had their nerve size assessed by MRI.

RESULTS: The study found no significant differences between right and left cochlear nerves in normal-hearing adults, supporting our hypothesis of symmetry in these individuals. This was a previously unproven and uninvestigated hypothesis.

CONCLUSION: Nerve size assessment should remain an active area of research in otological disease.

KEYWORDS: Cochlear implant, cochlear nerve, facial nerve, sensorineural hearing loss

INTRODUCTION

The prognostic relevance of cochlear nerve size on cochlear implantation is currently not well-established. Kutz et al. ^[1] found that cochlear nerve hypoplasia or aplasia predicted poor outcome following cochlear implantation in children. A recent study in adult patients demonstrated a positive correlation between cochlear nerve size on magnetic resonance imaging (MRI) and post-operative auditory performance, as well as negative correlation between both the duration and degree of hearing loss and the size of the cochlear nerve ^[2]. The authors hypothesized that measuring the size of the cochlear nerve before cochlear implantation may be helpful in preoperative counseling of the patients as well as in potentially determining the eligibility and timing for the operation ^[2].

Several other studies reported conflicting data between sensorineural hearing loss (SNHL) and cochlear nerve size. Russo et al. ^[3] found that the size of the cochlear nerve is mildly hypoplastic in children with SNHL as compared with normal-hearing children. Similarly, Herman et al. ^[4] demonstrated a significant difference in cochlear nerve cross-sectional area (CSA) between postlingually deaf and normal-hearing adults. However, Sildiroglu et al. ^[5] found no statistically significant difference in cochlear nerve size between sensorineural deaf adults and healthy controls.

The present study investigates the currently unproven hypotheses that there is no difference in cochlear nerve size between the two ears in normal-hearing adults. We also hypothesize there is a constant ratio between the sizes of the cochlear and facial nerves in healthy individuals.

MATERIALS and METHODS

All patients presenting with tinnitus to an Ear, Nose and Throat (ENT) outpatient clinic between January 2012 and August 2013 at our center were retrospectively assessed to select study subjects with normal hearing and no nerve pathology. Patient demographics, pure tone audiometry (PTA) averages at frequencies of 500 Hz, 1 kHz, 2 kHz, and 4 kHz, side of the tinnitus, and any predisposing factors for cochlear or facial nerve disorders were recorded. We made the assumption that if the PTA score was normal and the clinical assessment and MRI were normal too, then the cause of the tinnitus was not organic ear disease and would not affect cochlear nerve diameter.

Table 1. Exclusion criteria in a cohort of patients with normal hearing and unilateral tinnitus

Exclusion criterion	Number of patients
Abnormal hearing on PTA	48
Facial nerve palsy / previous inner ear surgery	2
Demyelinating disease	1
No MRI scan	2
PTA: pure tone audiometry	

Table 2. Cochlear and facial nerve size in normal-hearing adults with tinnitus

	Right cochlear nerve	Left cochlear nerve	p
Mean±SD, mm ²	1.16±0.34	1.16±0.30	0.827
Range, mm ²	0.75-2.30	0.71-1.90	
	Right facial nerve	Left facial nerve	p
Mean±SD, mm ²	0.84±0.23	0.86±0.25	0.723
Range, mm ²	0.58-1.68	0.51-1.62	
SD: standard deviation			

**Figure 1.** Parasagittal CISS MRI image through the internal auditory meatus. Example: measurement of the facial nerve (anterosuperior) diameter is demonstrated with the region of interest outlined. In this patient, the cross-sectional area of the facial nerve was 0.79 mm²

Exclusion criteria were abnormal hearing, described as average PTA scores equal to or greater than 30 at the four measured frequencies, history of facial nerve palsy, previous ear surgery, and demyelinating disease (Table 1).

Appropriate ethical approval was requested from and approved by the audit department of the appropriate hospital. Informed consent was not required, as no patient's identifiable information was collected.

Measurement of Nerve Sizes

The MRI scans were performed on 1.5-T or 3.0-T MRI systems using sensitivity-encoding head coils. T2-weighted constructive interference in steady state (CISS) axial sequence was used for nerve visualization.

All MRI scans were independently reviewed by two observers (CH and LZ), who were blinded to patients' information (including side of the sensorineural deafness) as well as each other's measurements. The in-

ternal auditory meatus (IAM) was identified on axial CISS sequence using the AGFA IMPAX Image Viewing Software. The multi-planar reformatting of the images allowed parasagittal images perpendicular to the nerve course to be viewed. The facial nerve was identified as the anterosuperior nerve in the IAM and the cochlear nerve as the antero-inferior nerve (Figure 1, 2). The CSA of each nerve was obtained using the polygon measurement tool. Measurements were made at the midpoint of the IAM where each nerve could be confidently assessed with surrounding cerebrospinal fluid (CSF) (Figure 1). The cochlear nerve/facial nerve ratio was determined by dividing the CSA of the cochlear nerve by the CSA of the ipsilateral facial nerve.

Statistical Analysis

Statistical analysis was performed using Microsoft Excel and Statistical Package for Social Sciences version 20 (IBM Corp.; Armonk, NY, USA) software. Shapiro-Wilk test was used to determine whether the data were normally distributed. Where data were normally distributed, paired samples t-tests were used to test for statistical significance. Where data were not normally distributed, Wilcoxon signed rank test was used to test for a statistically significant difference. $p < 0.05$ was considered statistically significant.

The interclass correlation coefficient (ICC) was used to assess the interobserver variability. A two-way model was used accounting for the random patient selection and the fixed effect from the pre-selected reviewers.

RESULTS

During the study period, 151 adult patients presenting with tinnitus had undergone MRI scans to rule out cerebellopontine angle lesions; 53 had some cause for exclusion (see Table 1). Results of 98 normal-hearing adults were analyzed further.

Of the 98 patients whose MRIs were reviewed for the study, scans of 37 (38%) patients were considered of adequate quality to visualize and measure the CSA of cochlear and facial nerves bilaterally. Inadequate scans were most likely due to movement artifact making the nerves inseparable on MRI. Seventy-eight (80%) of these scans were performed on a 1.5-T MRI scanner; of which 32 (41.0%) were adequate for interpretation. Twenty scans (20%) were performed on a 3.0-T scanner; of which five (25%) were adequate. Of the 37 patients included in the final stage of the study, 19 patients were male and the remaining 18 female (age, 18-81 years; mean, 52 years).

The ICC of nerve size measurements between the two observers (CH and LZ) was >0.85 in all measurement groups, indicating an almost perfect agreement. For the purpose of this study, measurements of the first observer are provided.

The mean size of the cochlear and facial nerves in normal-hearing adults with tinnitus is demonstrated in Table 2. There was no statistically significant difference between right and left ears of either the cochlear nerve or the facial nerve sizes, p -values 0.827 and 0.723, respectively (Table 2).

Cochlear/facial ratio (right) - Mean: 1.38 (SD: 0.20; range: 1.02-1.93)
Cochlear/facial ratio (left) - Mean: 1.38 (SD: 0.22; range: 1.05-1.91)
 $p=0.896$

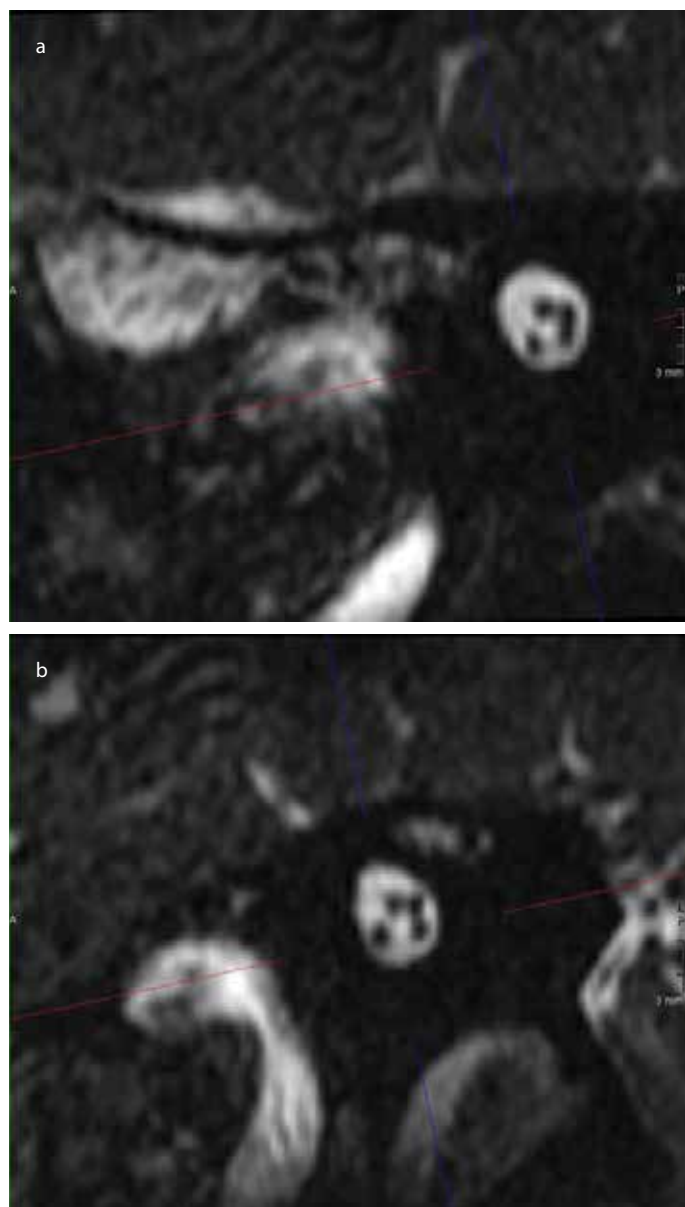


Figure 2. a, b. Example of parasagittal CISS MRI images of right IAM (a) and left IAM (b) in a patient with unilateral right-sided sensorineural deafness, present for more than 40 years. In healthy individuals, cochlear nerve (antero-inferior nerve in the IAM) is larger than the facial nerve (anterosuperior nerve) (b). However, in this patient, the right cochlear nerve (a) is smaller than the right facial nerve (a), and the facial/cochlear nerve ratio changes between the two images

There was no statistically significant difference in the sizes of the cochlear and facial nerves when results were analyzed separately for male and female. Similarly, no significant difference was found when comparing nerve sizes in tinnitus-affected ears versus normal ears. There was also no correlation found between nerve size and age (Appendix 1).

We also looked at whether the magnet size in the MRI had an effect on whether we measured a statistically significant difference in nerve size. Results of the cochlear and facial nerve sizes also did not depend on the magnet strength of the MRI scan, as there was no significant difference in the sizes of the nerves between the ears on either 3.0-T or 1.5-T MRI scans.

DISCUSSION

The current study demonstrates that sizes of the cochlear and facial nerves are symmetrical in normal-hearing adults. The CSA of the cochlear nerves (mean of both sides, 1.15 mm²) was larger than the CSA of the facial nerves (mean, 0.84 and 0.86 mm² in the right and left sides, respectively), a finding consistent with previous articles [6, 7]. In addition, there was very good inter-rater agreement between the measurements of the two observers, and the mean nerve sizes in this study were comparable to normal diameters published earlier by Nakamichi et al. [6] (mean CSA of the cochlear nerve, 1.07 mm²; mean CSA of the facial nerve, 0.83 mm²), indicative of good overall reproducibility of the results.

The nerve sizes were not affected by gender, strength of the MRI magnet, and presence or absence of tinnitus. Moreover, there was no significant correlation between the nerve size and patient's age, which is consistent with earlier studies in normal-hearing children and adults [6-8].

Previous research has demonstrated that hearing loss may cause anatomical and histological changes in the auditory pathway [9, 10]. For example, diameters of the cochlear and vestibular nerves were smaller in deaf people as compared to normal-hearing population in the human temporal bone study, and hearing loss was associated with reduction in cochlear nerve size and loss of spiral ganglion cells in mice models [9, 10]. Moreover, recent articles have shown that there is a significant reduction in CSA of the cochlear nerve in postlingually deafened compared to normal-hearing adults, as measured on parasagittal CISS MRI, as well as in children with SNHL compared to normal-hearing cohort [3, 4]. Clearly, all these results hinge on whether the nerves are symmetrical in "normal" ears, which we have now proven.

One of the limitations of our study was poor quality of the MRI images, requiring exclusion of >50% of study individuals. The main reasons the nerve sizes could not be measured adequately were movement artifact and nerve clustering in the internal auditory meatus or adherence to the walls of the IAMs, so the nerve could not be reliably separated from other structures with sufficient amount of surrounding CSF. It is interesting that the higher definition 3.0-T scanner yielded fewer usable scans (25%) than the 1.5-T scanners (41%), which may be due to small sample size of 3.0-T scans, but merits further investigation. Better application of the surface coils, improvement of the software, and patient information leaflets and reassurance at the time of the scan may be some of the factors to help improve scan adequacy in the future.

CONCLUSION

This study establishes that cochlear and facial nerve sizes are symmetrical in normal-hearing adults and are not affected by age or gender. The adequacy of the MRI imaging to allow nerve size measurement remains quite poor at the moment, but as quality of scans and the software used to interpret them improves so should our ability to assess nerve size. Nerve size assessment should remain an active area of research in otological disease.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of University Hospitals Birmingham (Approval Date: 14.10.2013/Approval No: CAD 05492-13).

Informed Consent: Informed consent was not received due to the retrospective nature of the study.

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Conflict of Interest: Chris Coulson is CEO of Endoscope-I a company which makes and sells endoscope adaptors for iphones.

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Appendix 1

MALES

		Mean	N	Std. Deviation	p
Males	Cochlear right	1.15	19	.32	0.308
	Cochlear left	1.22	19	.31	
Males	Facial right	.83	19	.20	0.093
	Facial left	.92	19	.30	

FEMALES

		Mean	N	Std. Deviation	p
Females	Cochlear right	1.17	18	.36	p=0.191
	Cochlear left	1.08	18	.27	
Females	Facial right	.85	18	.26	p=0.163
	Facial left	.79	18	.18	

Nerve size with age correlation: NO CORRELATION

FEMALES

Correlation of nerve size with age	p value of pearson x ² statistic
Right cochlear	0.379
Left cochlear	0.267
Right facial	0.256
Left facial	0.342
Right c/f ratio	0.679