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Original Article

Evaluation of Internal Auditory Canal Structures in Tinnitus of Unknown Origin

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Objectives. The aim of the present study was to evaluate the internal auditory canal (IAC) and the nerves inside it to define possible structural differences in cases with subjective tinnitus of unknown origin.

Methods. Cases applying to the ear, nose and throat department with the complaint of tinnitus with unknown origin and having normal physical examination and test results were included in the study (n=78). Patients admitted to the radiology clinic for routine cranial magnetic resonance imaging (MRI) and whose MRI findings revealed no pathologies were enrolled as the control group (n=79). Data for the control group were obtained from the radiology department and informed consent was obtained from all the patients. Diameters of the IAC and the nerves inside it were measured through enhanced images obtained by routine temporal bone MRIs in all cases. Statistical evaluations were performed using Student *t*-test and statistical significance was defined as $P<0.05$.

Results. Measurements of IAC diameters revealed statistically significant differences between the controls and the tinnitus group ($P<0.05$). Regarding the diameters of the cochlear nerve, facial nerve, inferior vestibular nerve, superior vestibular nerve, and total vestibular nerve, no statistically significant difference was found between the controls and the tinnitus group.

Conclusion. Narrowed IAC has to be assessed as an etiological factor in cases with subjective tinnitus of unknown origin.

Keywords. *Tinnitus, Diameter of internal auditory canal, Cochlear nerve, Vestibular nerve, Facial nerve, Magnetic resonance imaging*

INTRODUCTION

Ringing or humming of one or both ears without any stimulus is called "tinnitus." Its prevalence is 7%–32% in the general population. Tinnitus may be classified as "pulsatile-non-pulsatile" or "objective-subjective." Subjective tinnitus is heard by the patient only, whereas objective tinnitus is the ringing or humming sound heard by both the examining physician and the patient. Objective tinnitus usually has a vascular origin (dural arterio-venous malformation, carotid-cavernous fistula, and arteriovenous malformation of the vascular structures of the neck). Subjective tinnitus is observed more frequently (internal auditory canal [IAC] pathology, presbycusis, acoustic trauma, Meniere's disease, otosclerosis, labyrinthitis, effusion, ossicle system deformities, cholesteatoma, tumors, external auditory canal pathology, metabolic, neurologic, and psychological causes) [1].

One of the most frequent causes of non-pulsatile tinnitus is cerebello-pontine junction neoplasms while the most frequent cause is acoustic neurinomas. Non-pulsatile tinnitus is nearly always subjective. The etiology of tinnitus has not been completely understood despite all the developments in the area of modern medicine. Since the etiological causes of subjective tinnitus are extremely variable, much more studies have to be performed to find actual causes and effective treatment methods [2].

Computerized tomography and magnetic resonance imaging (MRI) procedures recommended in evaluating the IAC help identifying pathologies inside the canal rather than the ones in

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the canal itself. Up to date, no study has been performed to assess the natural form of the structure of the canal and the contents of it [3]. The aim of the present study was to evaluate the internal acoustic canal and the nerves in it to determine possible structural differences in patients presenting to the outpatient clinic of the ear, nose, and throat (ENT) department with the complaint of subjective tinnitus with no known causes.

MATERIALS AND METHODS

Ethical approval was obtained from the Ethics Committee of Elazig Training and Research Hospital.

Study population

Seventy-eight cases selected with random sampling method with no gender or sociologic discrimination among patients presenting to the ENT clinic with tinnitus in both ears between February 2010 and July 2011 were included in the study. Otorhinolaryngological examinations and routine audiological, biochemical and imaging tests were normal in all of the cases.

The selection criteria were as follows: having tinnitus complaint for at least for six months, having a normal ENT examination, having no hearing to possibly cause tinnitus (hearing threshold lower than 30 dB in pure sound audiogram, having a normal high frequency audiometry), having no ENT pathology to possibly cause tinnitus (such as Meniere's disease, causes of objective tinnitus, and otosclerosis), and having no systemic disease or a known neuropsychiatric disease. All the cases included in the study were informed about their diseases and the tests to be performed.

Cases admitted to the radiology clinic for routine cranial MRI and having no pathology in their MRIs were included as the control group. Data for the control group were obtained from the radiology department, and informed consent was obtained from the patients. In the control group, all the selection criteria stated above, except having a tinnitus complaint, were applied.

Imaging

Perpendicular to IAC, oblique-sagittal and mediolateral tilted orientated planning images were obtained. Imaging was conducted using a MR device with a power of 1.5 Tesla (1.5T GE Signa HDxt scanner; General Electric Healthcare, Pittsburgh, PA, USA) and a brain coil (8-channel HD Brain Coil). MRI parameters were: the field of view was 220 mm; the slice thickness was 0.8 mm and three-dimensional FIESTA Hi-Res gradient echo. Matrix, number of excitations, repetition time, and echo time values were 512×512, 1, 4.809 ms, and 1.876 ms, respectively.

Evaluation of the images/image analysis

Selected standard images at the level of posterior and superior semi-circular canals confluens (V shape appearance) were used for image analysis. Obtained image was converted into a 512×512 raw gray level image by removing the Digital Imaging and Communications in Medicine (DICOM) header information. A sample of the image used in this study is shown in Fig. 1. The region of interest (ROI) in the images including the IAC was extracted by a radiologist manually. The extracted image is given in Fig. 2A. Since the ROI images had a low resolution (about 25×25 pixels), a resolution improvement was required for a suitable examination. In order to improve the image quality of an ROI image, a resizing procedure was implemented using an interpolation kernel, particularly a Lanczos-2 kernel [4]. The improved image of the ROI image in Fig. 2A is given in Fig. 2B. The gray level image was converted to a binary image to expose the object in the image by calculating a threshold using Otsu's method [5]. After the interactive selection of a particular object, the IAC was denoted by a radiologist, and the pixels of the object in the image were counted to calculate the area of the selected IAC. Thus, the size measurements of the IAC and nerves in the image were estimated using the number of the counted pixels and the voxel information retrieved from the DICOM information of the given MR image.

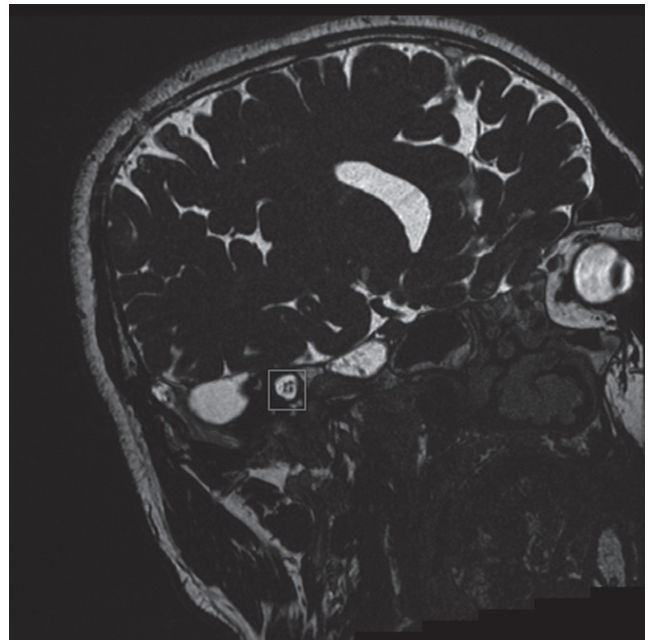

Fig. 1. A sample magnetic resonance image and selection region of interest including internal auditory canal and its content.

Statistics

IAC cross-sectional area (CSA), superior vestibular nerve (SVN) CSA, inferior vestibular nerve (IVN) CSA, cochlear nerve (CN) CSA, and facial nerve (FN) CSA data were expressed as mean±SD. Differences between data were studied using Student *t*-test and Mann-Whitney *U*-test. Level of statistical significance was taken as $P<0.05$. Data were analyzed using SPSS ver. 15.0 (SPSS

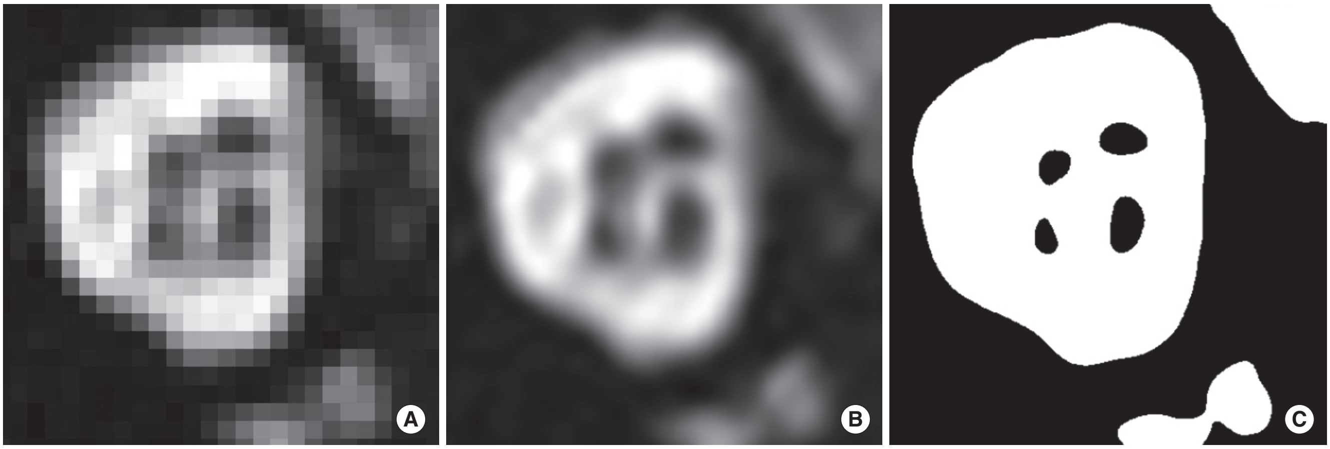

Fig. 2. Internal auditory canal at original (A), improved (B), and threshold (C) versions of selected region of interest in Fig. 1.

Table 1. Ages and the results obtained in the study group

Variable	Controls (n=158)	Tinnitus (n=156)	*P*-value
Age (yr)	46.31±14.86	49.78±14.20	0.724
Cross-sectional area (mm^2)			
Facial nerve	0.49±0.24	0.44±0.23	0.366
Superior vestibular nerve	0.55±0.24	0.54±0.13	0.120
Inferior vestibular nerve	0.32±0.24	0.31±0.13	0.119
Total vestibular nerve	0.87±0.37	0.85±0.26	0.140
Cochlear nerve	0.64±0.37	0.57±0.21	0.235
Internal auditory canal	25.04±6.75	21.61±5.67	0.007

Values are presented as mean±SD.

Inc., Chicago, IL, USA).

RESULTS

The mean age was 49.78 years (38 years in males and 40 years in females) in the tinnitus group and 46.31 years (36 years in males and 43 years in females) in the control group (Table 1). The ages of the tinnitus group ranged from 23 to 80 years.

There was no statistically significant difference between the tinnitus group and the control groups in terms of age ($P=0.724$) and gender ($P=0.908$). The IAC CSA measurements of the tinnitus group were statistically significantly lower than those of the control group ($P<0.007$). No statistically significant difference was found between the control group and the tinnitus group in terms of the FN CSA ($P=0.366$), the SVN CSA ($P=0.120$), IVN CSA ($P=0.119$), the total vestibular nerve CSA ($P=0.140$), and the CN CSA ($P=0.235$). All of these data are shown in Table 1.

DISCUSSION

Tinnitus, which has been a subject studied increasingly in recent years, is a symptom that might cause many problems in patients. Tinnitus may be classified as pulsatile-non-pulsatile or as objective-subjective. However, the exact etiological mechanism of tinnitus has not been completely understood yet [6]. Tinnitus can be associated with a number of conditions that may occur at any level of the auditory system. However, it is generally linked to lesions associated with the acoustic nerve and the inner ear, and it has been found that there is increased spontaneous activity in the nerve fibers in almost all of the lesions [7].

Tinnitus is a frequently encountered health problem observed especially in individuals over the age of 40. Its prevalence is higher in industrialized countries [8]. In the present study, the mean age of the patients with tinnitus was 49.78 years, as expected. Tinnitus has a roughly equal prevalence in men and women [7]. The male/female ratio was 0.95 in the present study. Many studies advocate that the probability of tinnitus is increased in patients having hearing loss [7]. This study excluded patients with hearing loss of more than 30 dB as such a loss could be a confounding factor in the etiological evaluation of the tinnitus.

MRI has recently been employed to visualize neuronal structures in the IAC and inner-ear morphology [9-16]. Improvements in MRI resolution have allowed identification of the cochlear, facial, and vestibular nerves and differentiation of them from other nerves within the IAC [17]. In the IAC, vestibulocochlear nerve splits into three parts (cochlear, superior vestibular, and inferior vestibular). These three vestibulocochlear nerve branches, along with the FN, have a characteristic appearance on the sagittal oblique steady-state free precession (SSFP) cross-sectional images (Fig. 2). Images in that plane are most frequently used for the detection of CN aplasia [18].

On any single axial SSFP image, only two of the four nerves within the IAC are typically visible. If one of the nerves is seen to enter the modiolus of the cochlea, then the two visible nerves are the cochlear and IVNs. If the central modiolus is not depicted on the image, the visible nerves are the facial and SVNs. At the lateral aspect of the IAC, the FN lies in the anterosuperior portion, the CN lies in the anteroinferior portion, the SVN lies in the posterosuperior portion, and the IVN lies in the posteroinferior portion. A filling defect within the IAC on SSFP images may signal a nerve abnormality in a branch of the facial or vestibulocochlear nerve [9,13,15,18].

To take full advantage of these imaging sequences, radiologists must be aware of the appearances of similar anatomic details of these nerves and the IAC on SSFP MR images [18]. Consistent with the literature, CN was larger than the branches of the vestibular nerve and had similar or larger size compared to the FN and no abnormality was detected in the IAC caliber of any cases. Through this detailed anatomical information and by applying the above mentioned MRI technique, it is possible to determine the IAC and its content such as vestibular or CN anomalies [9].

Clinical symptoms produced by cross-compression of the cranial nerves were first introduced by Dandy in 1934 [19]. In hemifacial spasm, trigeminal neuralgia and glossopharyngeal neuralgia caused by neurovascular decompression, one of the effective treatment options is microvascular decompression (MVD) [19]. The term cochleovestibular neurovascular compression was introduced after a couple of decades. Microvascular decompression in vertigo was first reported by Jannetta [20] in 1975. These developments encouraged CN MVD operation in tinnitus [21]. Decompression of the 8th nerve through MVD surgery has been reported to improve tinnitus complaints in patients having tinnitus [22].

Clinical symptoms of the acoustic neurinomas are related directly to the tumor dimensions. Tinnitus due to the pressure of the enlarging acoustic neurinomas in the IAC on the CN in the IAC has been reported [23]. Having a temporary improvement in patients with acoustic tumor, sudden hearing loss and tinnitus complaints after steroid treatment was interpreted as the outcome of decompression of the 8th nerve by steroid [24]. Cerebellopontine angle or internal acoustic canal lipomas cause many symptoms depending on the structures adjacent to them.

In a study of Korkut et al. [25], the symptoms were improved with dexamethazone administration in patients with tinnitus who were diagnosed with lipoma in the IAC. This improvement was suggested to be due to decreased pressure on the CN upon decompression [25].

Osteomas, as well as exostoses of the IAC, are rare, benign and usually slow-growing lesions. Reported aetiological factors contributing to the formation of these lesions include injury, inflammation, developmental disorders, and genetic defects. These may cause symptoms in the internal acoustic canal due to pressure [26]. In a study of Coakley et al. [27], internal acoustic canal osteoma was found in a 42 years old patient with normal hearing presenting with a long history of tinnitus. It was reported that the symptoms of tinnitus were abolished after retrosigmoid removal of osteoma [27].

In the present study, the diameters of the IAC in the patients group were found to be statistically significantly smaller when compared to those in the control group ($P<0.01$). It was thought that narrowed IAC caused a pressure on CN inside the canal and thus tinnitus.

Having original images with low resolution is the limitation of the present study. To what extend the images whose resolution were mathematically enhanced by computer reflected the reality is open to interpretation. However, the images of both the control and the tinnitus groups were treated similarly. Evaluations made by others may have the same standards if the viewer having the capacity of processing DICOM uses the same/similar resolution enhancing logarithms. Three-dimensional SSFP sequence applied by a computer program provides superior results in imaging the IAC and its contents. In the present study, there were significant differences observed in the IAC size in the MRI.

In conclusion, the width of the IAC should be evaluated to detect etiological causes and possible treatment strategies, especially in cases having subjective tinnitus with unknown origin.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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