Research Article

An Investigation of Internal Auditory Canal and its Content Diameters in Patients With Benign Paroxysmal Positional Vertigo

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Summary

Objective: This study's aim is to research the caliber of the Internal Auditory Canal (IAC) and its content sizes whether it is related with Benign Paroxysmal Positional Vertigo (BPPV) or not.

Method: Cases that were evaluated at Ear, Nose and Throat (ENT) clinics with vertigo complaints and were clinically diagnosed as BPPV with normal results during routine tests were studied. Control group data was obtained from cases referred to the radiology department in order to perform brain magnetic resonance imaging (MRI). The study group consisted of left ears of right-handed 49 control clients (30 females) and left ears of right-handed 132 BPPV patients (88 females). Images of ears at the posterior level and superior semicircular canal (SSC) confluence in IAC were used for image analysis. Internal Auditory Canal and its content nerve diameters were analyzed by computer. A statistical assessment was performed on noted high significance levels.

Result: No statistically significant difference was detected between nerve diameters of the control and BPPV groups except the superior vestibular nerve (SVN). In the BPPV group, cross sectional areas (CSA) of SVNs were found to be lower in statistical significance (p<0.001) than control group.

Conclusion: This trial suggests that vestibular nerve changes are observed more in BPPV cases and should be assessed as a factor in BPPV etiology or as a result of the disease.

Key words: Benign paroxysmal positional vertigo, magnetic resonance imaging, vestibular nerve, petrous bone

An Intervention of Internal Auditory Canal and Its Content Diameters in Patients With Benign Paroxysmal Positional Vertigo

Benign Paroksismal Pozisyonel Vertigolu Hastalarda Internal Akustik Kanal ve İçeriğinin Çaplarının Araştırılması

Özet

Amaç: Bu çalışmanın amacı internal akustik kanal (İAK) çapi ve içeriğinin boyutları ile benign pozisyonel paroksismal vertigo (BPPV) arasında ilişki olup olmadığını araştırmaktır.

Method: Kulak, Burun ve Boğaz (KBB) kliniğinde vertigo şikayeti ile değerlendirilen, rutin test sonuçları normal çıkan, klinik olarak BPPV tanısı alan olgular değerlendirildi, 49 kontrol (30 kadın) sol kulağı ve 132 BPPV hastasının (88 kadın) sol kulağından oluşuyordu. Internal akustik
INTRODUCTION

Vertigo is a disruption of vertical orientation or the illusion of movement. Benign paroxysmal positional vertigo (BPPV) is a common entity and is a component of peripheral vestibular disorders. These are especially prevalent with older patients\(^5\). Because the underlying pathophysiological mechanisms of vertigo cannot be explained precisely, the intended success of patient treatment is not always achieved\(^2\).

As radiologic imaging technology improves and more intricate details of the anatomy can be observed and evaluated, images will provide more precise diagnostic information and allow a more precise localization of abnormalities.

We think that some change may be observed at the caliber of the internal auditory canal (IAC) or contented nerves in BPPV, as a neural loss may develop over a long time. That difference may be observed by MRIs and the dimensional evaluation of the IAC and its content. Comparing these findings with the control subjects might be guide for diagnose of BPPV. In our recent study, we presented the preliminary results of correlation between the thickness of IAC nerves and BPPV in a smaller patient group\(^6\).

MATERIAL AND METHODS

Ethical approval was obtained from the Ethics Committee of our institution and patient's consents were obtained.

Study population

Patients referred to Ear, Nose and Throat (ENT) clinics with vertigo complaint were compiled during three years. Patients that were clinically diagnosed with BPPV with normal results during routine audiological, biochemical, imagining tests and Dix-Hallpike tests positive, were taken to the study. Otological asymptomatic control group data was obtained with permission from cases who referred to the radiology department for non-audiological reasons to perform brain MRI. None of these patients had any past medical history, clinical signs or symptoms related to ear diseases. No patient had any significant abnormities as determined from the brain MRIs. The study group consisted of left ears of right-handed 49 control clients (30 females) and left ears of right-handed 132 BPPV patients (88 females).

Imaging

Perpendicular to IAC, oblique-sagittal and mediolateral tilted orientated planning images were obtained. Imaging was conducted with a MR device with 1.5 Tesla power (1.5T GE Signa HDxt scanner, General Electric Healthcare, USA) and a brain coil (8-channel HD Brain Coil). The parameters of the MRI scanning were: 200 mm field of view, 0.8 mm slice thickness and a 3D FIESTA Hi-Res gradient echo. Matrix, NEX, Repetition Time (TR) and Echo Time (TE) values were 512x512, 1, 4.809 ms, 1.876 ms respectively.
**Image Evaluation and Analysis**

As reported in our previous preliminary study, selected standard images of each ear showing posterior and superior semicircular canals confluence levels (a “Y” shape appearance on images) were used for image analysis\(^3\). The acquired images were converted into 512x512 raw gray level images by removing the DICOM (standard for Digital Imaging and Communications in Medicine) header information. A sample of the typical image used in this study is shown in Figure 1a. The region of interest (ROI) in the images including the IAC was manually extracted by a proficient radiologist. The extracted image is shown in Figure 1b. Since ROI images have low resolution (about 25x25 pixels), they require a resolution improvement for a suitable examination. In order to improve the image quality of the ROI image, a resizing procedure using an interpolation kernel, particularly a Lanczos-2 kernel as described was implemented\(^14\). The improved image of the ROI image shown in Figure 1c. The gray level image was converted to a binary image to highlight any objects in the image by calculating a threshold using Otsu's method\(^15\). The pixels of the object in the image were counted to calculate the area of the selected IAC. 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 specific MRI.

**Statistics**

Data IAC CSA, Superior Vestibular Nerve (SVN) CSA, Inferior Vestibular nerve (IVN) CSA, Cochlear Nerve (CN) CSA, Facial Nerve (FN) CSA and ratio of these nerves CSA to IAC CSA, CN CSA and FN CSA are expressed as the mean±SD. The differences between the data were studied using the Student t test. The level of statistical significance was taken as p<0.05. Data was analyzed using Statistical Package for the Social Sciences (SPSS) for Windows v.15.0 (SPSS Inc., Michigan, IL, USA).

*Figure a-d:* Oblique-sagittal (a) 3D FIESTA Hi-Res gradient echo MR image and original (b) improved (c) and thresholded (d) versions of selected image show a sample MR image and a selection ROI including the internal auditory canal and its content.
RESULTS

There was no significant statistical difference between the demographic characteristics of cases in both groups such as age (p=0.237), gender (p=0.497), a history of arterial hypertension, diabetes, high cholesterol, smoking, previous stroke, etc.

In the BPPV group, SVN CSA (p<0.001), VN total CSA (p<0.001), FN CSA (p<0.01) and CN CSA (p<0.05) were found to be low in statistical significance. There was no significant statistical differences in observed IAC CSA (p=0.127) and IVN CSA (p=0.307) between the control and BPPV groups. The ratio of SVN CSA to IAC CSA (p<0.001), VN CSA to IAC CSA (p<0.001), CN CSA to IAC CSA (p<0.01), FN CSA to IAC CSA (p<0.001), SVN CSA to FN CSA (p<0.001), IVN CSA to CN CSA (p<0.01) and SVN CSA to CN CSA (p<0.001) were found to be low in statistical significance in the BPPV group in contrast to IVN CSA to FN CSA (p<0.05) as high. Also, IVN CSA to IAC CSA (p=0.405), CN CSA to FN CSA (p=0.803) and VN CSA to CN CSA (p=0.158) showed no differences. All of this data is shown in Table 1 and statistically significant findings are summarized in Graph 1.

<table>
<thead>
<tr>
<th></th>
<th>Controls (49)</th>
<th>BPPV (132)</th>
<th>p value</th>
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</thead>
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<tr>
<td>Age (years)</td>
<td>Mean 35.49</td>
<td>Mean 37.96</td>
<td>0.237</td>
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<td></td>
<td>Std. Dev. 14.61</td>
<td>Std. Dev. 13.62</td>
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<td>Internal Auditory Canal (IAC) CSA</td>
<td>25.0886</td>
<td>27.1443</td>
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<td>0.3047</td>
<td>0.2777</td>
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<tr>
<td>Superior Vestibular Nerve (SVN) CSA</td>
<td>0.5372</td>
<td>0.3477</td>
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<tr>
<td>Vestibular Nerve (VN) (SVN + IVN) CSA</td>
<td>0.8419</td>
<td>0.6254</td>
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<td>Cochlear Nerve (CN) CSA</td>
<td>0.6259</td>
<td>0.5279</td>
<td>&lt;0.05</td>
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<tr>
<td>Facial Nerve (FN) CSA</td>
<td>0.4981</td>
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<td>IVN CSA / IAC CSA</td>
<td>0.0116</td>
<td>0.0108</td>
<td>0.405</td>
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<tr>
<td>SVN CSA / IAC CSA</td>
<td>0.0151</td>
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<td>&lt;0.001</td>
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<tr>
<td>VN CSA / IAC CSA</td>
<td>0.0338</td>
<td>0.0245</td>
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<tr>
<td>VN CSA / CN CSA</td>
<td>0.7982</td>
<td>0.8912</td>
<td>0.158</td>
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CSA, Cross-sectional area (mm²); VN, Vestibular Nerve; SVN, Superior vestibular nerve; IVN, Inferior vestibular nerve; CN, Cochlear nerve; FN, Facial nerve; IAC, Internal auditory canal
DISCUSSION

Cases with vertigo complaint (the illusion of motion) should be considered with medical, neurological, and otological reasons. It is especially important to distinguish the peripheral (otologic) and central (neurologic) reasons for vertigo. BPPV, Meniere's disease, and vestibular neuritis are considered among the otologic reasons. BPPV is the most common vestibular disorder. Epidemiological studies show that the average age of the onset of vertigo is 54. However, vertigo may occur in some people between the ages of 11 to 84. In this study the vertigo cases all had similar ages (13-75 years). Current literature shows no differences between control groups in regards to other demographic factors.

MRIs have recently been employed to visualize neuronal structures in IAC and inner-ear morphology. Improvements in MRI resolution have allowed the identification of the cochlear, facial, and vestibular nerves and distinguish them from other nerves within the IAC. Standard T2-weighted magnetic resonance imaging (MRI) sequences reveal only the larger cranial nerves. Current steady-state free precession (SSFP) sequences are capable of depicting the segments of all cranial nerves. SSFP sequences provide submillimetric spatial resolution and high contrast resolution between cerebrospinal fluid and solid structures. This allows the reconstruction of elegant multiplanar images that highlight the course of each nerve. These sequences have become a mainstay in the evaluation of the cerebellopontine angles and inner ear. These are usually referred to by their trade names or acronyms: Constructive Interference Steady State (CISS), and Fast Imaging Employing Steady-State Acquisition (FIESTA). SSFP sequences allow precise differentiation between branches of the facial and vestibulocochlear nerves, accurate
detection of small masses in the cerebellopontine angles and internal auditory canals, and the detailed evaluation of endolymph and perilymph within the inner ear. To take full advantage of these imaging sequences, radiologists must be aware of the appearances of similar anatomic details of these nerves and IAC on SSFP MR images\(^\text{17}\).

The Cochlear Nerve is larger than the branches of the Vestibular Nerve and is similar or larger compared with the Facial Nerve (this is consistent with recent studies). No abnormality was detected in the IAC caliber of any cases\(^\text{18,13}\). With this information on the detailed anatomy and by applying the mentioned MRI technique, it is possible to determine IAC and its contents such as Vestibular Nerve Anomalies\(^\text{18}\).

Age-related hearing loss has also been reported to cause neuronal loss, which could cause a reduction in the CN CSA. These studies compared the CN diameter with the diameter of the opposite CN or other nerves in IAC, and the nerve diameter was found to be decreased in sensorineural hearing loss\(^\text{18,4,22,2,11,7,19}\).

Recently, size of auditory canal and its content were reported in our preliminary study to be related to BPPV in a smaller group\(^\text{6}\). SVN CSAs had been found lower in BPPV group than control group similar to the current study.

SVN innerves utricle, superior and lateral SSC; IVN innerves saccüle and posterior SSC\(^\text{23}\). There are some anastomosis between these nerves\(^\text{24}\). The incidence of BPPV of the horizontal and superior SSCs is much less than that of BPPV due to affection of the posterior SSC\(^\text{25}\). In current study in the BPPV group, CSA of SVN were found to be lower in statistical significance (p<0.001) than control group. We speculated that anastomosis between SVN and IVN may contribute to our results. But for clear explanation of these results further anatomical and physiological studies are needed. In this study, no statistically differences were found between BPPV and control groups in regards to IAC and its contents except SVN and total VN CSAs. We believe that losses of the myelin or fibers, as neural loss develops over a long time, no differences in caliber may be observed by MRI in BPPV. A loss in neural mass in small-diameter VN may cause sufficient differences to be reflected in these study results. All these factors may explain why significant SVN deficiencies in BPPV were detected.

In this study there have been several limitations such as lower resolution of the original images and the small number of cases especially in the control group. Because of the low-resolution originals, images required increased resolution enhanced with the help of a computer. The real dimensions of the structures is doubtful as to how much can be calculated accurately. The same procedures can be applied to the control group and the BPPV group. The DICOM Viewer is capable of processing all the similar or same resolution algorithms to increase the usage by others to achieve the same set of standards. Thereafter studies may reveal any changes of VN/SVN CSAs whether the duration of the disease.

In conclusion, the 3D SSFP sequence that was applied by computer aids provided superior results in IAC and its imaging. In BPPV we observe significant changes in VN sizes in MRI images. Postmortem studies can contribute to support our findings with macroscopic measurements and microscopic details.

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REFERENCES


