Biomedical Signal Processing and Control 9 (2014) 14–18

Contents lists available at ScienceDirect

Biomedical Signal Processing and Control

journal homepage: www.elsevier.com/locate/bspc

An investigation on magnetic imaging findings of the inner ear: A relationship between the internal auditory canal, its nerves and benign paroxysmal positional vertigo

Burhan Ergen [a,*], Murat Baykara [b], Cahit Polat [c]

[a] Department of Computer Engineering, Faculty of Engineering, Firat University, Elazig, Turkey
[b] Department of Radiology, Elazig Training and Research Hospital, Elazig, Turkey
[c] Department of Otolaryngology, Elazig Training and Research Hospital, Elazig, Turkey

ARTICLE INFO

Article history:
Received 26 March 2013
Received in revised form 3 September 2013
Accepted 6 September 2013
Available online 22 October 2013

Keywords:
Magnetic resonance imaging
Inner ear
Internal auditory canal
Benign paroxysmal positional vertigo

ABSTRACT

Visualization of the inner ear has been performed using magnetic resonance imaging (MRI) to investigate benign paroxysmal positional vertigo (BPPV). In the patients with BPPV, our recent findings indicate the thickness of some internal auditory canal (IAC) nerves narrower than the thickness of healthy subjects. The thickness of the IAC and its nerves are measured using brain MRI images. The cross sectional area (CSA) of a nerve is assumed as its thickness. Some statistical measurement and a statistical classification are performed on the CSA data to investigate any relation between IAC, the nerves and BPPV.

1. Introduction

Visualization of the inner ear has been performed using magnetic resonance imaging (MRI) to evaluate the changes of the inner ear components in benign paroxysmal positional vertigo (BPPV) cases. BPPV which can be described as disruption of vertical orientation or an illusion of movement is one of the most common entities in a neurotology clinic [1–3]. The BPPV characterized by repeated episodes of vertigo is frequently encountered in the adult population. BPPV can be easily diagnosed by careful attention to the history of vertigo associated with head position change [4]. The inner ear including the semicircular canals and the hearing nerves is a part of the auditory system. It is now known that BPPV is directly related to the disorders of the inner ear [5,6].

The auditory system consists of the outer ear, middle ear and inner ear, the auditory pathways and the auditory cortex. The hearing process in the auditory system can be explained briefly as follows; the sounds are captured by the outer ear and guided by the external auditory canal toward to the eardrum [7]. The incoming sound waves vibrate the membrane and the attached chain of auditory ossicles and are transmitted to the cochlea [8]. In the cochlea, the vibration is converted into nerve impulses in order to be delivered to the brain via the hearing nerve interpreting the impulses as sound. The anatomy of the human ear is illustrated in Fig. 1.

Although the hearing process is unaffected by BPPV, it is well known that the disorders of the inner ear consisting of hearing nerves can cause BPPV [5,6]. However, although most BPPV cases are idiopathic origin based [9], some proportion of BPPV is related to earlier dental treatment [10], ear surgery [6] and traumatic event including head trauma [11–13]. Viral vestibular neuritis, suppurative otitis media, Meniere disease, and migraine can also cause BPPV [3]. The otoconia movement from the ulricle into semi circular canals can raise symptoms of this inner ear disease. Otoconia determines an endolymphatic fluid movement leading to a stimulation of ampullar receptors [13]. The dizziness or vertigo also can cause a psychiatric disturbance which can be easily determined [14,15].

That the BPPV is associated with some diseases make it necessary to know how the hearing nerves change in BPPV cases, or if the changes of the nerves because of the disease may cause BPPV. The findings about the hearing nerves in BPVV cases help us to understand whether there is a nerve problem or not. If a relationship between the internal auditory canal, its nerves and BPPV can be determined clearly, it may be possible to find a means of prevention or a faster and easier treatment methodology for BPPV. However there are some studies related to cochlear nerve size in hearing loss cases [16–19], but none of these studies are interested in BPPV cases with detailed analysis.

* Corresponding author. Tel.: +90 424 2370000.
E-mail addresses: ergen@firat.edu.tr (B. Ergen), muratbaykara@hotmail.com (M. Baykara), drcahitpolat@yahoo.com (C. Polat).

1746-8094/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.bspc.2013.09.007

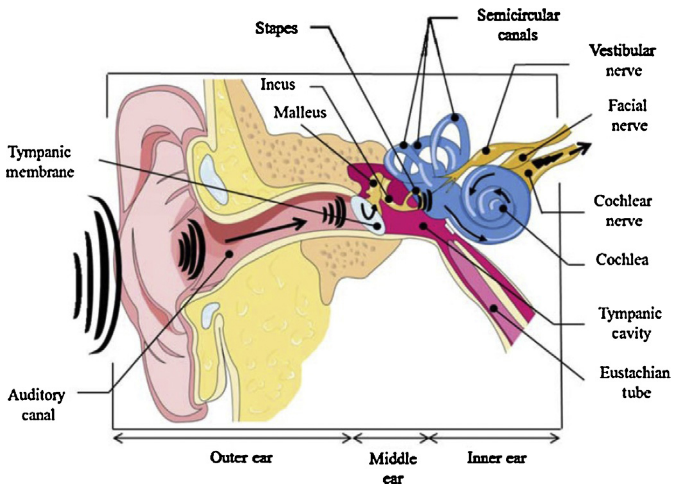

Fig. 1. Illustration of the anatomical structures of the auditory system. The outer ear includes the external auditory canal. The middle ear includes the membrane and three tiny bones. The inner ear contains the semicircular canals and the hearing nerves.

Therefore, we have particularly paid attention to the internal auditory canal (IAC) which consists of the hearing nerves. To demonstrate the conditions of the IAC canal and its verves, the thickness of the nerves in BPPV cases can be compared to the thickness of those of healthy subjects. If the measurement of the nerve thickness is possible, the conditions of the nerves can be known. In this study, the cross sectional area (CSA) of a nerve referring the thickness is assumed as a parameter determining the condition of the nerve under investigation.

Indeed, the IAC contains mainly two kinds of nerves; the facial nerve and the vestibulocochlear nerve (VCN). VCN has three divisions; the superior vestibular nerve (SVN), inferior vestibular nerve (IVN), and cochlear nerve (CN). Since the IAC canal is a very small canal, the visualization of this canal and its nerves requires use of high resolution imaging techniques [8,20]. Today, advances in magnetic resonance imaging (MRI) using techniques which include axial and oblique sagittal views have enabled detailed imaging of the nerves within the IAC [21]. So, it is now possible to determine the condition of the IAC and the nerves in BPPV cases by means of advanced MRI technology. Fig. 1 shows the anatomy of the IAC. In individuals with normal anatomy, two nerve bundles the facial and the CVNs are identified in the cerebellopontine angle (CPA) [22,23] (Fig. 2).

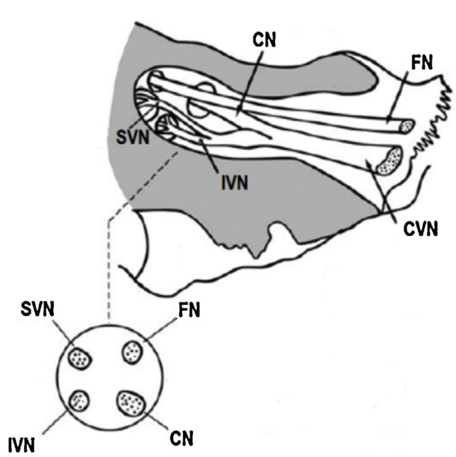

Fig. 2. Anatomy of the IAC and its nerves. Distally four bundles are present in the IAC: CN, SVN, IVN and FN. Cross section displays the position of the nerve bundles at the CPA and distally within the IAC.

In this study, the brain MRI images were analyzed to determine the thickness of the IAC nerves. After selecting and enhancing the region of interest (ROI) including the inner ear region, the thickness of the inner ear components is found out by measuring the CSAs. Here, the inner ear components are determined as the internal auditory canal (IAC) and its nerves described in the next section. Some statistical measurements and a classification were performed to investigate a relation between the thickness of the nerves and BPPV.

The rest of this paper is organized as follows. In Section 2, we provide the material and methods used in this study. Section 3 shows the experimental results. Lastly, some conclusions are given in Section 4.

2. Materials and methods

This study includes 29 patients with diagnosis of BPPV admitted to an Ear, Nose and Throat (ENT), Clinic (Otolaryngology) and 29 healthy subjects. Their mean age is 62 years; 18 are females, and 11 are males. The patients belong to the age range between 19 and 78 years with a mean of 40.55 years. The patients were clinically diagnosed with BPPV with normal results during routine audiological, biochemical, imaging tests, and Dix–Hallpike tests.

Particularly, the Dix–Hallpike [24,25] test is used to determine the affected side in patients with BPPV. The Dix–Hallpike is performed while the patient is in as seated position on a flat examination table. The patient's head is turned 45° to one side, then the patient is rapidly laid into a supine position with the head hanging about 20° over the end of the table and the patient's eyes are observed for approximately 30 s. The maneuver is repeated with the head turned to the opposite side. Nystagmus is a result of vestibular debris in the ear that is facing down, closest to the examination table. There is usually latent period of a few seconds before the patient develops nystagmus, and a sensation of vertigo for up to one minute. It is considered positive for BPPV if the rotational nystagmus occurs.

The control group consists of 29 subjects from cases referred to the radiology department to obtain brain MR imaging for various reasons. Twenty (68%) of the healthy subjects are females, where as the remaining part are males. The persons of the control group belong to the age range between 13 and 75 years with a mean of 36.31 years. The necessary permission was obtained from the patients and the control group. The study was also performed in accordance with the Helsinki Declaration and approved by the local ethics committee. The patients have no clinical signs and symptoms related to ear diseases. And, no significant abnormality is determined from the brain MR images of all BPPV patients. Both of the groups have similar demographic characteristic, such as a history of arterial hypertension, diabetes, high cholesterol, smoking, and previous stroke.

The measurements were performed on the images obtained using an MR device with the power of 1.5 Tesla (1.5 TGE Signa HD xt scanner, General Electric Healthcare, USA) and brain coil (8-channel HD Brain Coil). The parameters of the MRI scanning were field of view 220 mm; slice thickness 0.8 mm and 3D FIESTA Hi-Res gradient echo. Matrix, NEX, repetition time (TR) and echo time (TE) values were 512×512, 1, 4.809 ms and 1.876 ms, respectively.

Standard images of each ear, showing the level of posterior and superior semicircular canals, are used to determine the thickness. In this step, facial nerve (FN), vestibular superior nerve (VSN), vestibular inferior nerve (VIN), cochlear nerve (CN) and IAC particularly marked on MRI images showing the level of posterior and superior semicircular canals confluence ("V" shape appearance on images). Cross sectional area (CSA) of each nerve is measured as the thickness of the nerve under investigation.