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The application of direct current electrical stimulation of the ear and cervical spine kinesitherapy in tinnitus treatment

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ABSTRACT

Objective: The aim of the study was to evaluate the effectiveness of electrical stimulations of the hearing organ in tinnitus treatment adapting the frequency of stimulation according to tinnitus frequency, to assess the influence of cervical spine kinesitherapy on tinnitus, as well as to evaluate hearing after electrical stimulations alone and together with cervical spine kinesitherapy.

Methods: The study comprised 80 tinnitus, sensorineural hearing loss patients (119 tinnitus ears) divided into two groups. In group I (n – 58 tinnitus ears) electrical stimulation of the hearing organ was performed, in group II (n – 61 tinnitus ears) electrical stimulation together with cervical spine kinesitherapy. Hydrotransmissive, selective electrical stimulations were conducted using direct, rectangular current. The passive electrode was placed on the forehead, the active – a silver probe – was immersed in the external ear canal in 0.9% saline solution. The treatment involved fifteen applications of electrical stimulations (each lasted for 4 min) administered three or four times a week (whole treatment lasted approximately 30 days). The evaluation of the results considered a case history (change from permanent to temporary tinnitus), questionnaires (the increase/decrease of the total points) and the audiometric evaluation of hearing level.

Results: Before the treatment, group I comprised 51 ears (87.93%) with permanent, and 7 ears (12.07%) with temporary tinnitus; group II – 55 ears (90.17%) with permanent and 6 ears (9.83%) with temporary tinnitus. After the treatment, in both groups the number of ears with permanent tinnitus decreased considerably obtaining the pauses or disappearing of tinnitus. Directly after the treatment, group I comprised 25 ears (43.11%) with permanent, and 10 ears (17.24%) with temporary tinnitus, in 23 ears (39.65%) tinnitus disappeared; group II – 33 ears (54.1%) with permanent and 11 ears (18.03%) with temporary tinnitus, in 17 ears (27.87%) tinnitus disappeared.

Regarding questionnaires, improvement was observed in group I – in 43.11% of ears, in group II – 32.8%. In both groups audiometric improvement of hearing was recognized.

Conclusions: (1) Electrical stimulation of the hearing organ, with the application of current frequencies according to tinnitus frequencies (selective electrical stimulation), was an efficient method in severe tinnitus treatment. (2) Cervical spine kinesitherapy in the treatment of tinnitus, using electrical stimulation, did not have any supporting influence.

1. Introduction

Subjective tinnitus (a phantom perception of sound without any corresponding noise in the surroundings) is a result of a pathological activity in the nervous system, without any mechanical activity in the cochlea [1]. Despite intense, advanced research conducted all over the world, the factor directly responsible for such perception is still not clear. About 10–20% of the adult population suffers from tinnitus and it probably occurs with the same frequency among children [2]. Since its etiology is unclear, there still is no satisfactory method of treatment. However, numerous hypotheses on the etiology of tinnitus may suggest that there is no single mechanism of its onset. In many cases cochlea is an ignition site of tinnitus. That is why, in patients with cochlear lesion (tinnitus accompanied by sensorineural hearing loss) electrical stimulation (e.s.) can be applied as a treatment.

According to Latkowski, electrical stimulation increases transmission of neurotransmitters in the synapses, as well as it controls their secretion to the synaptic area [3]. Watanabe and Okawara state that e.s. improves the blood flow in the inner ear and

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synchronizes spontaneous impulses in the auditory nerve fibers [4], however, Portman et al. state, that it modifies the electrical potentials of the hearing organ [5]. Electrical stimulation gives satisfactory effects in pain, inflammation or nervous system disorders' treatment (improving the blood flow and trophism of tissues) [6]. However, with reference to the hearing organ, it is used in few clinical centers in the world. It was primarily used in the cochlear implantation in The House Ear Institute. In our department in the 1980s, an invasive – transtympanal – manner of stimulation was used (the stimulation of the promontory or the round window) at first, but nowadays only a non-invasive hydrotransmissive technique is in use [7,8]. Hydrotransmissive procedure was used by Szymiec et al., Konopka et al. and Morawiec-Bajda et al. Szymiec et al. using stimulation (50–1600 Hz) via electrode dipped in saline solution in the external auditory meatus, with the other placed on the ipsilateral mastoid, reported improvement in 48% of cases [9], which was comparable to Morawiec-Bajda's results – 46.6% [10]. Kuk et al. attempted to reduce tinnitus, stimulating with a ball-electrode placed at the tympanic membrane. The authors, using different parameters of current (square, sine, triangular current, within a range of frequencies 62–8000 Hz) adapted individually according to patients response to stimulation, obtained improvement in tinnitus in 50% of the cases [11]. Kozlowski et al. using similar method of e.s. adapted parameters individually (frequencies within 16–8000 Hz), reported improvement in tinnitus in 44% of patients [12].

On the other hand, tinnitus and hearing loss may be also the consequence of cervical spondylosis, as a result of increased activation of the sympathetic system. According to the neurovascular theory, the close anatomical neighbourhood of cervical spine and vertebral arteries' perivascular sympathetic fibers plexus, may result in some clinical symptoms e.g. vertigo, tinnitus [13]. The correlation between the abnormal cervical spine image and clinical audio-vestibular symptoms was highlighted in some research [14–16]. Strek et al., in group of 120 tinnitus patients, examined the condition of cervical spine and vertebro–basilar arterial system (Doppler ultrasonography). The authors found radiological abnormalities of cervical spine in 83% of cases, as well as revealed pathological blood flow in the vertebro–basilar arterial system in 45% of them. The authors stated to have excluded other otolaryngological or neurological causes of tinnitus [15]. Olszewski and Zalewski investigated the correlation between cervical spondylosis and the condition of hearing and balance system. It was showed, that abnormal results of hearing (hearing loss and tinnitus) or balance testing, were predominant in group of patients with pathological cervical spine X-ray (osteophytes and discopathy diagnosed) [16].

The aim of the study was to evaluate the effectiveness of electrical stimulations of the hearing organ in tinnitus treatment adapting the frequency of stimulation according to tinnitus frequency, to assess the influence of cervical spine kinesitherapy on tinnitus, as well as to evaluate hearing after electrical stimulations alone and together with cervical spine kinesitherapy.

Materials and methods: the study comprised 80 patients suffering from tinnitus and sensorineural hearing loss (n – 119 tinnitus ears) divided into two groups. The patients from group I (n – 58 tinnitus ears – 40 tinnitus patients, 17 females and 23 males), aged 21–74 years (average 56.4 ± 11.71), were treated with electrical stimulation of the hearing organ, whereas those from group II (n – 61 tinnitus ears, 40 tinnitus patients, 21 females and 19 males), aged 23–65 years (average 50.7 ± 12.6), treated with the electrical stimulation together with cervical spine kinesitherapy. The allocation to the groups was done according to the order of admission to our department. The group I was created by first forty patients admitted to our department to diagnose and treat tinnitus. However, group II was created by the following forty patients.

Before the beginning of the therapy, we performed the ENT examination, hearing tests (pure tone audiometry, speech audiometry, impedance audiometry, auditory brainstem responses, otoacoustic emissions) and radiological diagnostics (head and cervical spine computer tomography/nuclear magnetic resonance). Tinnitus accompanied by sensorineural hearing loss and cervical spine degenerative changes (abnormal cervical spine image) were an including criterion. On the basis of radiological diagnostics, 1 – discopathy (degenerative process limited to intervertebral spaces), 2 – cervical spondylosis (degeneration affecting intervertebral discs and vertebral bodies), 3 – spondyloarthrosis (when intervertebral joints were affected) was recognized. Pathology in the external and/or the middle ear was an excluding criterion. Patients who reported tinnitus in the head, not in ears, or their tinnitus lasted less than 1 year (to reduce a chance of spontaneous remission), were also disqualified from the research. The patients completed questionnaires (designed by the authors on the basis of the Tinnitus Handicap Inventory) involving 20 questions concerning tinnitus. Possible answers were: 'yes' obtaining 2 points, 'sometimes' – 1 point, 'no' – 0 points. The maximum score was 40, which meant that tinnitus is an enormous problem. On the other hand, receiving 0 points meant that tinnitus is not a disturbing ailment.

Electrical stimulation was conducted using a custom made apparatus supplied with 4 batteries of 1.5 V. The passive electrode was placed on the forehead after skin abrasion with a suitable sterile abrasive electrode paste and clean gauze. The active, silver probe – was immersed in the external ear canal filled with 0.9% saline solution, avoiding contact with the skin of the canal. Such placement of the two electrodes was in order to obtain the transmission of the current throughout the hypothetical plane (longitudinal axis) of cochlea. Direct rectangular, positive polarization current was applied via the active electrode. The frequency of the current was the frequency of the rectangular impulse. The duration of the rectangular pulse (the period) depended on the frequency. For 250 Hz, one period lasted 4 ms (2 ms pulse and 2 ms pause). The voltage was constant and equals 3 V. The intensity ranged from 0.15 mA to 1.15 mA and was applied according to patient's sensation. The stimulation was started using the maximal intensity of current 1.15 mA, if it was well tolerated, stimulation was continued. However, if the patient reported to feel the pain or other unpleasant sensation, the intensity of the current was decreased to the moment when this feeling stopped. The frequency of the current ranged from 250 Hz to 8000 Hz and was adjusted according to the tinnitus frequency, so that the frequency of the current and the tinnitus frequency were similar ($\pm$1000 Hz) – selective electrical stimulation. Single electrical stimulation lasted 4 min. The treatment involved fifteen applications of electrical stimulations administered three or four times a week (whole treatment lasted approximately 30 days).

In group II, the patients were additionally subjected to the cervical spine kinesitherapy. They did exercises twice a day throughout the whole analyzed period. Before the treatment, a physiotherapist demonstrated a set of 12 exercises of the cervical spine (stabilizing and improving the motility) to all group II patients. First they exercised under the physiotherapist's supervision, and then individually. Evaluation of tinnitus and hearing (in pure tone audiometry) was conducted before, directly after, 30 and 90 days after 15 applications of e.s. in groups I and II. Subjective assessment of the results considered a case history and a questionnaire. Change from permanent tinnitus (when patient reported to hear it every day, all the day) to temporary tinnitus (when appeared temporarily or the patient reported to have some periods without tinnitus) was considered an improvement.