Evaluating current and experimental post-labyrinthine concussion tinnitus management treatments

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1. Introduction

Labyrinthine concussions (Langguth, 2015) involve damage to the structures of the inner ear due to head trauma, potentially resulting in sensorineural hearing loss and accompanying vestibular symptoms. It is assumed that labyrinthine concussions are the results of an acceleration-deceleration movement of the membranous labyrinth against the bony labyrinth within the inner ear, causing hemorrhaging sites and microcirculation disturbances within the cochlea (Langguth, 2015). The rupturing of vessels is in turn assumed to destroy the sensory epithelium in the membranous labyrinth (Langguth, 2015).

The membranous labyrinth (Holstein, 2012), located loosely in the bony labyrinth surrounded by the perilymph, is an intercommunicating system of sacs and canals lined with sensory epithelium and auditory hair cells. These cells convert mechanical stimuli into electrical stimuli by the bending of apical surfaces (stereocilia). Following the vibration of the basilar membrane in the cochlea, the hair cells embedded within the sensory epithelium of the organ of Corti are activated, causing the stereocilia located on the surface of the hair cells to bend in response to the movement of fluid inside the cochlea. The bending of stereocilia results in the opening and closing of ion channels on hair cell surfaces, altering the electrical potential across the hair cell membrane, thus generating electrical signals. Finally, the release of a neurotransmitter from the hair cell's synapses up the spiral ganglion neurons occurs following the change in electrical potential. The action potentials are then carried via the auditory nerve fibers to the brainstem and relayed to various auditory processing centers in the brain, where they are interpreted as sound.

Tinnitus (Langguth et al., 2013), an auditory phantom sensation (ringing in ears) experienced when no external sound is present, is a common consequence of labyrinthine concussions. Whilst the exact cause of tinnitus remains variable and unclear, it is thought to be the result of abnormal auditory input, as a result of cochlear and plastic damage (Langguth, 2015) (potentially anatomically altering the connectivity of the Central Nervous System) incurred upon injury. These alterations (Saunders, 2007) may in turn result in a changed balance between the excitatory and inhibitory brain processes, potentially resulting in increased neural activity between the brain stem and cortex, producing the characteristic sounds associated with tinnitus.

2. Current Treatments

Whilst it is estimated that 5-15% (Management, 2021) of the general population is affected by tinnitus, with 1-3% experiencing a decreased quality of life as a result, limited effective treatment options are available. Due to the physiological nature of tinnitus, its treatment requires a comprehensive and multi-faceted approach and generally only aims to reduce the severity of symptoms (Management, 2021) as opposed to treating the cause.

2.1.Mechanism-driven tinnitus drug development

Currently, no specific medications are universally available and have been proven to effectively relieve tinnitus following a labyrinthine concussion (*TINNITUS RESEARCH*, 2021). Medications may however be used to treat underlying conditions, of which tinnitus is a symptom, but so far have not proven to be an effective treatment option. A multitude of compounds are currently under investigation including KCNQ potassium channel openers (aim to reduce hyperexcitability in the auditory brainstem), Group II mGlur (reduce hyperexcitability in the inferior colliculus), NMDAR channel antagonists (reduce excitotoxicity in the cochlea following noise exposure) and T-type calcium channel blockers (reduce inflammation following noise exposure, limiting subsequent tinnitus) (*TINNITUS RESEARCH*, 2021).

2.2.Cognitive behavioral therapy

Cognitive behavioral therapy (Cognitibe Behavioral Therapy for Tinnitus , s.d.) is a form of counseling designed to reduce the awareness of tinnitus by addressing and managing its mental and emotional effects. Discussion-based techniques are utilized in cognitive behavioral therapy to increase awareness regarding thought patterns and emotions surrounding the condition, aiming to replace negative thought patterns with positive ones, thus aiming to reduce the consequences tinnitus may have on other aspects of life (Cognitibe Behavioral Therapy for Tinnitus , s.d.) (Tinnitus , s.d.). Whilst proven to be effective, this form of therapy does not address the underlying pathophysiological mechanisms of tinnitus (Tinnitus , s.d.).

2.3.White noise

White noise (signals containing equal intensity across all frequencies in the audible spectrum) machines and treatments may be used to effectively reduce the severity of tinnitus symptoms. When played at low to moderate volumes, white noise may effectively mask the perceived tinnitus sounds, providing temporary relief (Tinnitus , s.d.) (Auckland, 2022). When continued over extended periods of time, white noise treatments, by means of the principles of neural plasticity, aim to alter the brain’s perception of tinnitus signals (Auckland, 2022). The brain’s ability to reorganize and adapt, by forming new neural connections, may thus help to reset abnormal neural activity associated with tinnitus by providing a consistent auditory stimulus which may help normalize neural firing patterns over time (Tinnitus , s.d.) (Auckland, 2022).

2.4.Repetitive Transcranial Magnetic Stimulation (rTMS)

As tinnitus is believed to be the result of hyperactivity in the brain's neural cortex, it is hypothesized that strong electromagnetic stimulation, which is known to reduce neural activity, may serve as a promising treatment to reduce the perception and severity of tinnitus (Association, s.d.). rTMS involves the delivery of electro-magnetic pulses, by means of a powerful, non-invasive coil placed adjacent to the patient's head, into the underlying cortical tissue. Furthermore, this treatment may help to promote corrective plasticity in the brain, thus further reducing the effects of tinnitus (Association, s.d.). Initial clinical research data has yielded mixed results, however, suggesting that further optimization protocols (stimulation frequency and intensity, coil placement etc.) are required in order to validate the safety and efficacy of rTMS (Association, s.d.).

2.5. Deep brain stimulation (DBS)

Deep brain stimulation is currently used to treat a variety of neurological disorders and chronic conditions, including Parkinson's disease, suggesting promise for tinnitus treatments (Association, s.d.). Deep Brain stimulation is classified as an invasive procedure as it involves the surgical implantation of electrodes into the brain (Healthline, 2023). These electrodes deliver pulses to target regions in the brain (generally the inferior colliculus when treating tinnitus), aiming to modulate abnormal neural activity and hyperexcitability responsible for tinnitus (Smit et al., 2015). Whilst the exact mechanisms by which deep brain stimulation diminishes the symptoms of tinnitus is not fully understood, it is believed to alter neural activity patterns (hyperexcitability) in the auditory pathway and promote neuroplasticity, normalizing auditory processing (Smit et al., 2015).

3. Conclusion

In conclusion, current treatments for post-labyrinthine concussion tinnitus primarily address symptom management, with varying degrees of success. Restorative plasticity-based approaches including DBS and rTMS offer exciting possibilities, but further research is needed to fully understand their mechanisms and optimize their effectiveness. The management of post-concussion tinnitus remains a complex and evolving field, requiring interdisciplinary collaboration and ongoing research to improve the quality of life for affected individuals.

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