

Tinnitus Research – Tinnitus and “Hidden Hearing Loss”

In most cases, tinnitus is associated with hearing loss, but around 10% of tinnitus patients do have a normal audiogram. In our latest study, we have provided physiological evidence that these patients might have “hidden hearing loss”, i.e. cochlear damage that is not detected by hearing threshold measurements. Using a computer model of tinnitus, we could further demonstrate that one common mechanism can explain the development of tinnitus after “normal” and “hidden” hearing loss. We believe that this is a significant step towards understanding tinnitus.

Many studies on tinnitus in humans and animals suggest a relation between tinnitus and hearing loss. Consequently, many research groups have focussed on understanding the relation between these two phenomena, i.e. how damage to the structures of the inner ear could trigger the development of tinnitus. We have developed a computer model that explains the development of tinnitus after hearing loss, where the main assumption was that the brain tries to stabilize the activity of nerve cells after hearing loss. The process of activity stabilization then leads to increased gain of neuronal circuits in the auditory system, and the tinnitus is generated as a side-effect through an amplification of neuronal noise. This simple model can account for a great variety of findings from studies on tinnitus in humans and animals.

However, around 10% of tinnitus patients do have a normal audiogram, i.e. their hearing thresholds are in the normal range and they are thus not considered to have cochlear damage. Does this mean that their tinnitus is generated by a different mechanism, or could it be that audiology actually failed to detect more subtle damage to structures of the inner ear? We decided to investigate the latter scenario and recruited a study group of 15 women (average age 35 years) with tinnitus and normal hearing thresholds, and an age-matched control group of 18 women without tinnitus, also with normal hearing. Apart from classical hearing tests and tinnitus characterization, we subjected them to auditory brainstem response (ABR) measurements. The ABR is electrical activity generated by the first processing stages of the auditory system, and it can be measured by placing electrodes behind the ears and on the forehead. In the human ABR, five waves can be distinguished, each corresponding to responses of a different structure of the auditory system. In our analysis, we concentrated on wave I, which is generated by the auditory nerve, and wave V which arises at the level of the midbrain. We found that at high sound intensities, our tinnitus group showed a significant reduction of the amplitude of wave I, whereas the amplitude of wave V was normal.

A recently published study on mice (Kujawa and Liberman, 2009) helped us deduce which kind of damage to the cochlea could reduce the amplitude of wave I while not affecting the hearing thresholds: After noise exposure at night club sound levels (2 hours at 100 dB SPL), the mice showed a temporary shift of the hearing thresholds that recovered to normal levels within days, but there was a permanent reduction of the amplitude of wave I, similar to our tinnitus group. A closer inspection of the inner ears of the mice showed that a large fraction of their auditory nerve fibres had lost the contact to the hair cells in the cochlea, which is a bit like unplugging half the cables between an array of microphones and the sound recorder. The mice had retained just enough auditory nerve fibres to still be able to hear soft sounds, but the loss of contact between many auditory nerve fibres and the hair cells meant that for

loud sounds, much fewer fibres were responding, thus reducing the total output of the auditory nerve.

How such “hidden hearing loss” can lead to tinnitus can be directly understood with the help of our computer model. As a large fraction of the auditory nerve fibres no longer respond to sound, the overall signal from the auditory nerve is decreased, and therefore the nerve cells in the auditory brain receive less input and become less active overall. When these nerve cells then try to get their mean activity back up to the healthy target level, they increase their response gain and respond more vigorously to incoming signals. This increased gain could also be seen in our human ABR data, as the amplitude of wave V was normal in the tinnitus group even though wave I (the input signal) was smaller than normal. However, a side-effect of the gain increase is an amplification of neuronal noise, which gives rise to increased spontaneous activity of the nerve cells – the model develops tinnitus.

Our results have helped me to understand my own tinnitus, which was caused by exposure to loud music in 1997. Two weeks after the festival, my hearing was tested, and my hearing thresholds were fine. In fact, they still are in the normal range today, 14 years later. However, just like the noise-exposed mice, I might have acquired “hidden hearing loss” despite normal hearing thresholds, which could give rise to my tinnitus.

References

- Kujawa SG, Liberman MC (2009) Adding insult to injury: cochlear nerve degeneration after “temporary” noise-induced hearing loss. *J Neurosci* 29:14077-14085.
Schaette R, McAlpine D (2011) Tinnitus with a Normal Audiogram: Physiological Evidence for Hidden Hearing Loss and Computational Model. *J Neurosci* 31:13452-13457.

Edited from an article that first appeared in Quiet, the journal of the British Tinnitus Association.