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TINNITUS: THE PHANTOM SOUND (PART II)

AUDITORY EVOKED POTENTIALS OF SHORT LATENCY

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Tinnitus: The phantom sound (part II). Auditory evoked potentials of short latency

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In our February newsletter we began to look at tinnitus, and called it the phantom sound (part I). If you haven't done so, we recommend you read the previous newsletter for a fuller picture.

In terms of how we evaluate patients with the tinnitus audiologically, it is true that there has been an improvement in the quality of the available procedures.

Nevertheless, the starting point must always be the anamnesis, and here it should include:

- Previous and current health conditions;
- Previous and current medications, including ototoxic or tinnitus-specific medications;
- Presence of symptoms of depression and/or anxiety;
- Difficulty in concentrating or alterations in attention;
- Existence of any type of traumatic brain injury;
- Check for neurovestibular symptoms;
- Previous family history of hearing and/or tinnitus disorders;
- Previous or current history of exposure to noise;

• Previous or current history of hearing loss;

• Difficulty understanding speech in noise;

• The type of tinnitus (waterfall, bee buzzing, pressure cooker, whistling, etc.);

• Tinnitus characteristics such as time, duration, frequency, laterality;

• When the tinnitus started;
• Changes in the type or intensity of the tinnitus over time;

• Triggering or exacerbating factors;

• Impact of tinnitus on the patient's daily life, such as changes in sleep, well-being, work performance, interpersonal relationships, etc.

The use of a questionnaire is very useful, as it can help an evaluator as well as the patient track how the tinnitus has evolved or regressed.

A professional should look at available questionnaires in their native language, and choose one which is based on scientific evidence, has been validated, and has good clinical applicability.

DETAILED ASSESSMENT OF THE PERIPHERAL AND CENTRAL AUDITORY NERVOUS SYSTEM IS PARAMOUNT.

Tinnitus is frequently a symptom of some dysfunction within the auditory system, often with a degree of hearing loss. Nevertheless, not all patients with tinnitus have hearing loss, suggesting it is possible that tinnitus can arise without auditory system damage.

Besides the anamnesis and questionnaire, the assessment should include:

- **PREVIOUS OTOLOGIC EVALUATIONS;**
- **OTOSCOPY AND/OR MEATOSCOPY;**
- **BASIC AUDIOLOGICAL EVALUATION: TONAL AND SPEECH AUDIOMETRY,**
- **TYMPANOMETRY INCLUDING TESTING OF IPSILATERAL AND CONTRALATERAL ACOUSTIC REFLEXES;**
- **ACUFENOMETRY;**
- **AUDITORY DISCOMFORT LEVEL ANALYSIS;**
- **HIGH-FREQUENCY AUDIOMETRY;**
- **PSYCHOACOUSTICAL TINNITUS EVALUATION;**
- **ELECTROPHYSIOLOGICAL EVALUATION (WHICH WILL BE DESCRIBED IN MORE DETAIL BELOW).**

The combination of hearing evaluation methods can help in pinpointing the origin or mechanisms that cause the tinnitus. However, it is important to keep in mind that the pathophysiology of tinnitus, even after decades of study, is not yet understood or defined.

CORRELATIONS BETWEEN TINNITUS AND ELECTROPHYSIOLOGY

ELECTROCHLEOGRAPHY (ECOCHG)

Electrocochleography is the electrophysiological evaluation of the earliest auditory evoked potential, and its responses are related to how the hair cells and the auditory nerve function (see chart 1).

COMPONENT	GENERATING SOURCE
Cochlear microphonic	Large numbers of hair cells along the basilar membrane
SP (Summating potential)	Inner and outer hair cells Major contribution from inner hair cells at low and moderate intensity
AP (Action potential)	Spiral ganglion neurons that give rise to a physiological response in the auditory nerve

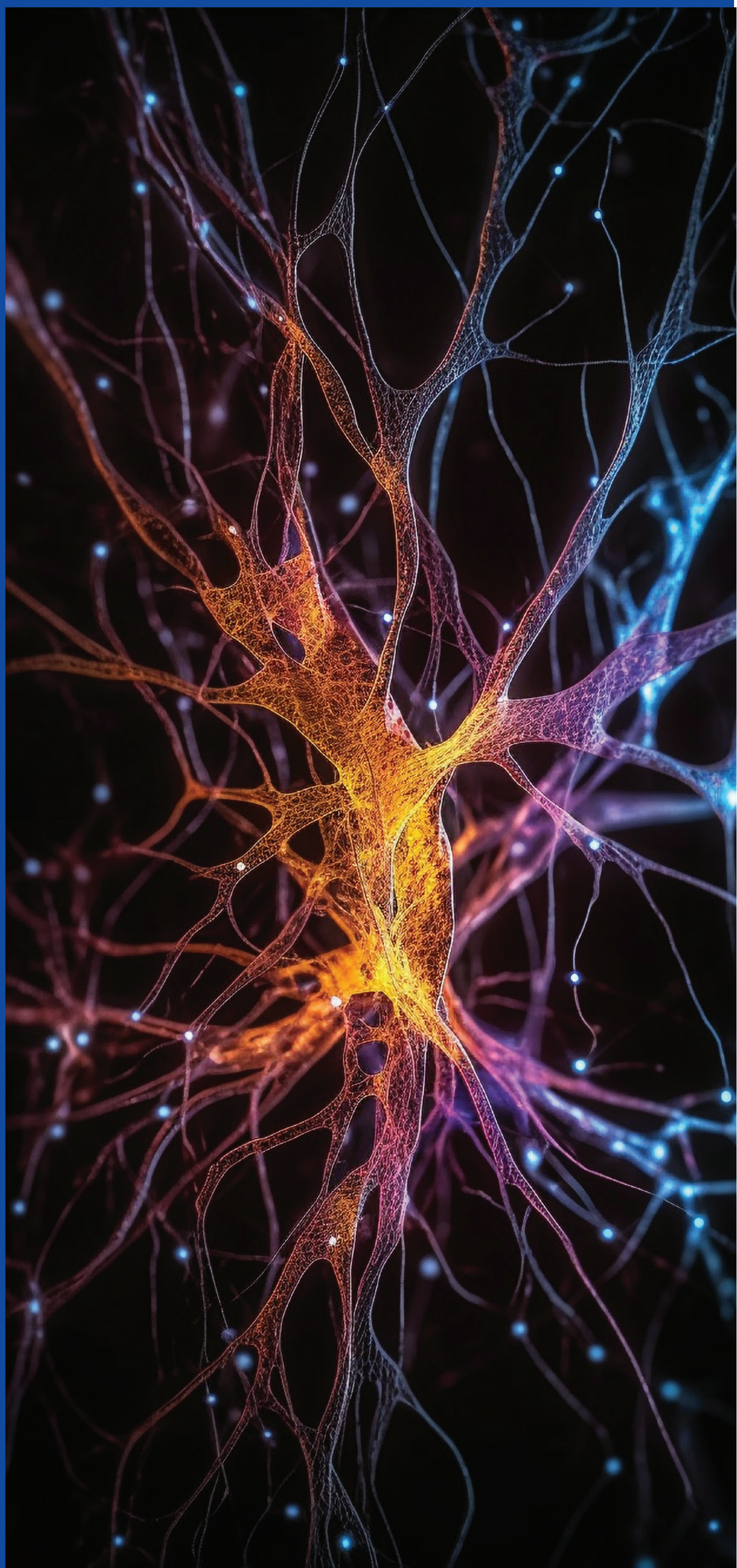
Chart 1: The sources which contribute to electrocochleography

Since electrophysiological assessments rely directly on neuronal activity – that is, firing of neuronal synapses – electrophysiological procedures can in some degree serve as a marker of tinnitus. In addition, these techniques can be used to monitor the evolution of tinnitus.

Studies show that damage to the inner hair cells is frequently observed in patients who complain of tinnitus, regardless of whether they have a hearing loss.

In addition, there are some reports that after an intervention program for tinnitus, there has been a reduction in the latency and amplitude of action potentials. Whether or not this is generally true, one should be aware that excessive exposure to high levels of noise often leads to hyperactivity in the auditory system, and this is a likely substrate for tinnitus.

HAVE YOU HEARD OF COCHLEAR SYNAPTOPATHY?



Cochlear synaptopathy refers to changes in **the synapses of hair cells at the same time as auditory** thresholds remain within normal limits. Cochlear synaptopathy is often called hidden hearing loss.

There are key studies that correlate the presence of tinnitus with cases of cochlear synaptopathy, and so electrocochleography (ECochG) can be an objective tool for investigating this pathology.

However, **studies are still scarce, and tinnitus (and hyperacusis) may be due to an unusual increase in the central gain of the auditory system** following some sort of disruption to peripheral signal input.

The central gain theory of tinnitus suggests that if there is a decrease in electrical activity in the cochlea, the central auditory pathway needs to compensate for this damage through an increase in the spontaneous firing rate and neuronal activity. The increase can occur in the cochlea itself, the cochlear nuclei, or the inferior colliculus, and this elevation of synaptic and neuronal activity is responsible for tinnitus.
If there is elevated neuronal activity, electrophysiological procedures might then be of an objective way of testing possible alterations in the auditory system.

This change, for example, might cause a change in the ECochG – more specifically, in the ratio between the summating potential and the action potential (the SP/AP ratio as shown in figure 1).

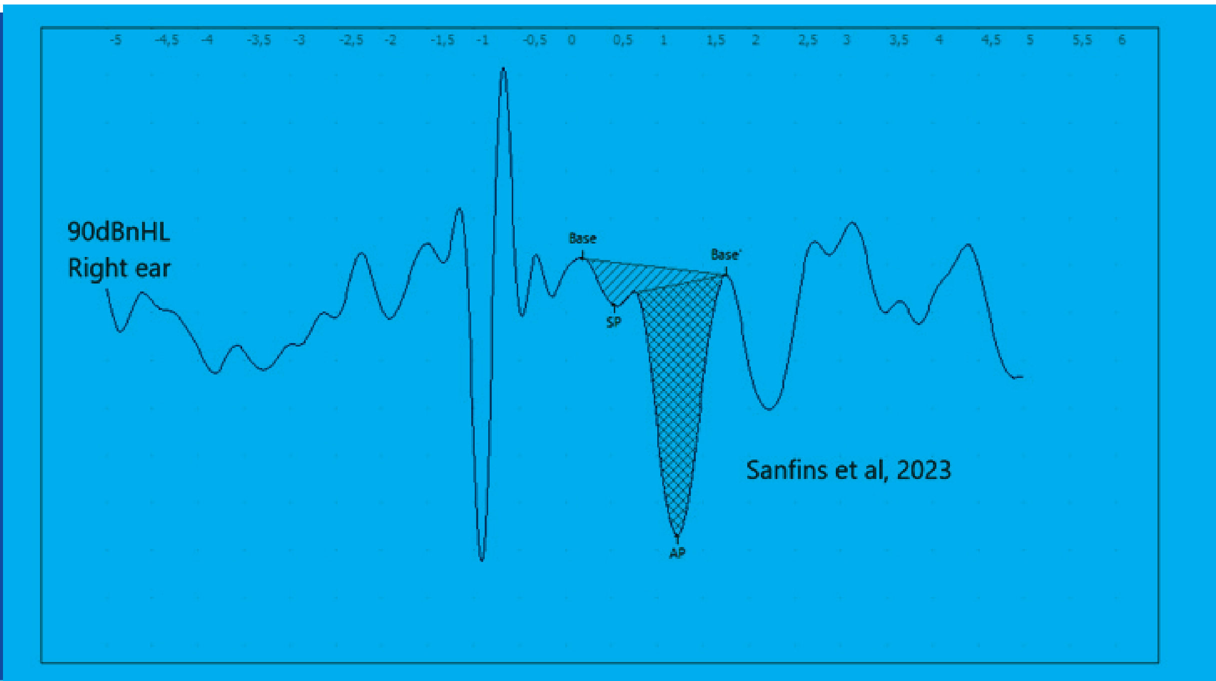


Figure 1: Example of an electrocochleography evaluation. A stimulus of 90 dBnHL was used together with a 10 mm Gold Tip Trode electrode. Equipment: Neuroaudio/ Neurosoft. Authors' own collection.

Using quantifiable immunocytochemical tests on animals, it is sometimes possible to measure changes in synapses.

Unfortunately, the same technique cannot be carried out in humans because it is invasive.

ULTIMATELY, HOWEVER, ELECTROPHYSIOLOGICAL ASSESSMENT BY ECOCHG COULD BECOME AN OBJECTIVE AND VIABLE TECHNIQUE.

Research has shown that there is a decrease in the amplitude of action potentials (APs) in individuals who have tinnitus but whose hearing is within normal limits.

However, it must be recognised that measuring the amplitude of the summating potential (SP) is difficult, so that this can produce appreciable error in deriving the SP/AP ratio.

Nevertheless, use of ECochG can help identify changes in neural firing in the hair cells and auditory nerve, and prompts further work on cochlear synaptopathy in patients who complain of buzzing in their ears.

Electrocochleography seems to be a promising tool to investigate tinnitus, especially in combination with new non-invasive techniques that allow testing to be noninvasive and not cause discomfort or inconvenience to the patient.

The use of special cables that allow connection to Gold Tip Trode electrodes can help in the investigation process (figure 2).

Figure 2: Cables for electrocochleography (left) using 10 mm Gold Tip Trode electrodes (right). Authors' personal collection.

BRAINSTEM AUDITORY EVOKED POTENTIALS (ABRS)

Although there is a range of articles on how ABR relates to tinnitus, it should be remembered that the parameters used in different studies are not exactly the same and so caution needs to be exercised in interpreting the results.

For a quick refresher on ABR waves, it may be helpful to read our previously published bulletins on the subject. Each wave in the ABR waveform has a different generating source, as listed in chart 2 and shown in figures 3 and 4.

WAVE	GENERATING SOURCE
I	Distal portion of auditory nerve
II	Proximal portion of auditory nerve
III	Cochlear nucleus
IV	Superior olive complex
V	Lateral lemniscus

Chart 2: ABR wave generator sources

Animal studies have shown that wave I of the ABR can be measured to give an indication of the effect of noise exposure.

Some studies have induced tinnitus in mice using two methods: a) exposure to noise and b) exposure to salicylate. In each case, the result was that the presence of tinnitus modified the ABR responses, generally by reducing the amplitude of wave I.

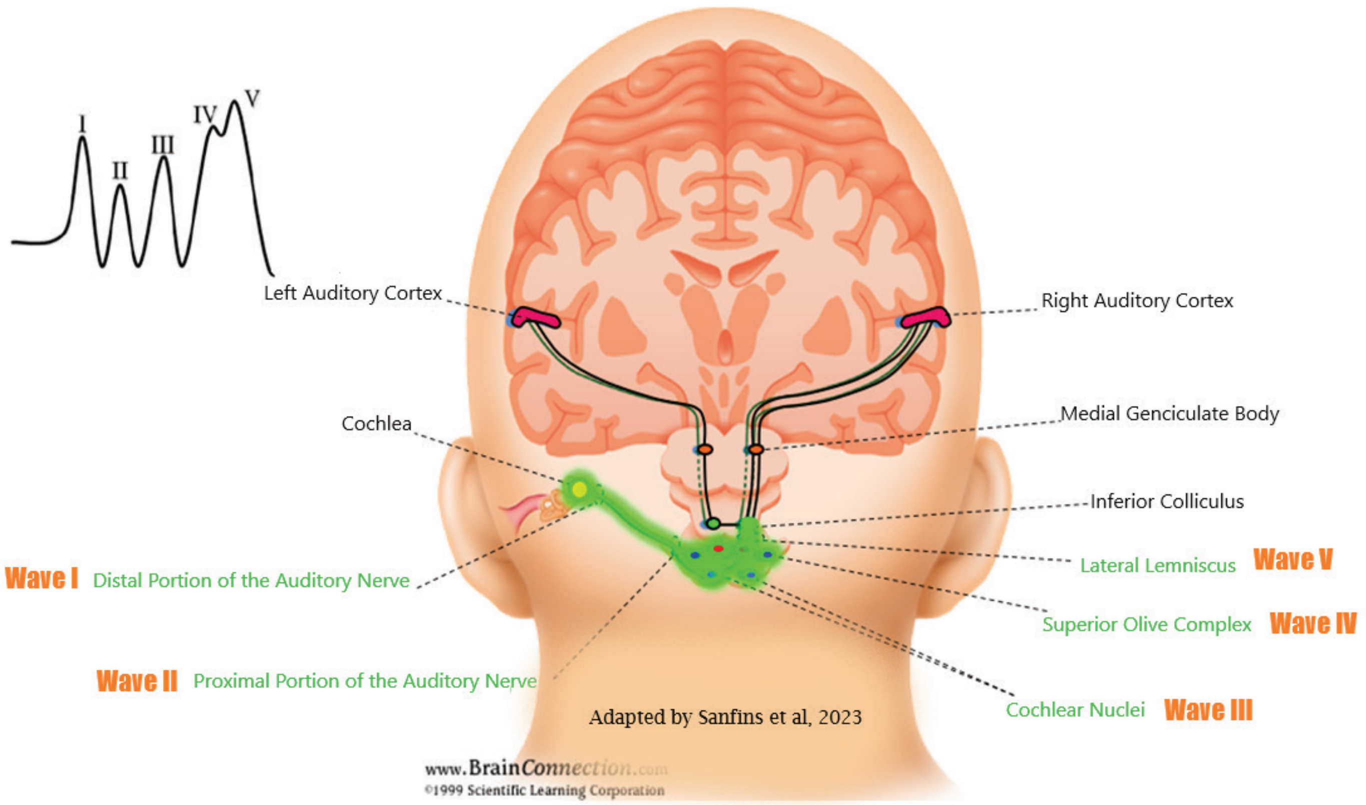


Figure 3: Auditory structures corresponding to the sources of ABR waves I to V.

Research has shown that if there is a reduction in the number of synapses in the region of the auditory nerve, there are changes in the ABR.

Studies on tinnitus patients have shown alterations in ABR wave I (a decreases in amplitude and a prolongation in latency).

The alterations which affect only wave I can be interpreted to mean that tinnitus initially affects the peripheral auditory system and then takes some time to reach higher levels. In the later stages of tinnitus, there may also be degeneration of the auditory nerve.

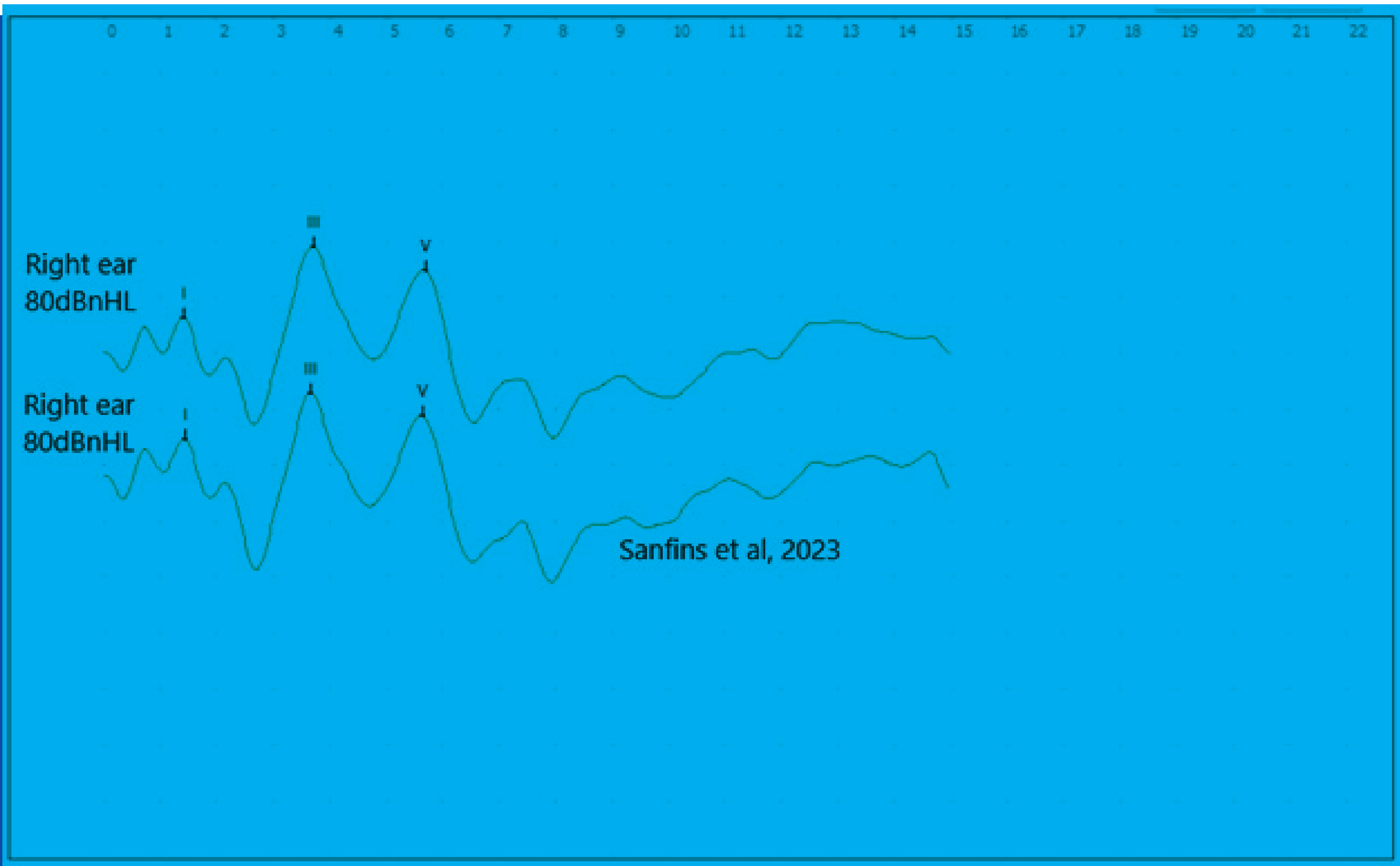


Figure 4: Chart of an ABR generated by a click of 80 dBnHL. Equipment: Neuroaudio/ Neurosoft. Authors' personal collection

When assessing ABRs in cases of patients with tinnitus, an analysis of the ratio between the amplitude of wave V and wave I is helpful. Studies have shown that the V/I amplitude ratio serves as a useful measure of tinnitus (figure 5), and this can help in monitoring neuroplastic changes in the auditory pathway. However, other studies point out that this relationship can only be observed in cases of chronic tinnitus.

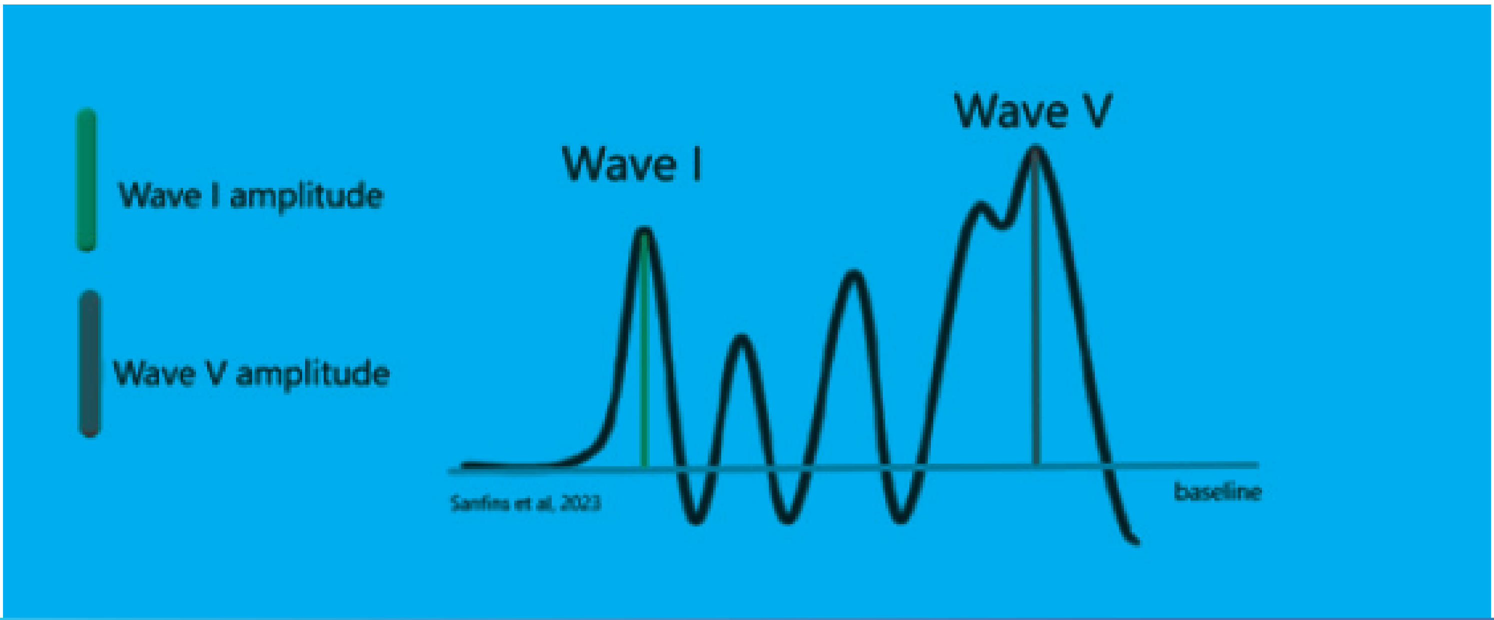


Figure 5: Measurement of the amplitude ratio of wave I to wave V. Authors' personal collection

Taken together, it should be emphasized that there is still no fully effective objective method of assessing patients with tinnitus. Moreover, the association between behavioral and electrophysiological methods is most helpful when attempting to make a diagnosis. In this case, use of a battery of investigation procedures for the entire vestibular system is highly recommended. A combination of test results can help choose the best intervention method and set a baseline for monitoring patients. We recommend the reader to a recent article by Prengel and colleagues (see reference 15). It is well written and provides clear and objective advice on tinnitus questionnaires, how to take a good anamnesis, and available diagnostic techniques.

Because there is an association between tinnitus and alterations in subcortical and cortical regions, our future bulletins will endeavor to discuss new methods of electrophysiological investigation in this area.

We invite you to follow new monthly newsletters! If you have any suggestions for topics that you would like us to cover, send an email to misanfins@gmail.com.

Until our next newsletter!

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