Editorial
The importance of audiometric assessment in middle ear surgery

Roberto Albera[1]

[1]*Professor of Otorhinolaryngology, University of Turin, Italy*

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The assessment of hearing function currently uses various audiometric techniques, some of which are highly sophisticated. However, in middle ear pathology, the test from which it is essential to begin a process that leads to the correct diagnosis and to the surgical indication is pure tone audiometry (PTA). Through this test it is possible to define the audiometric threshold at different frequencies by differentiating the deficit component attributable to the functionality of the external and middle ear (conductive component of hearing loss) and the inner ear (sensorineural component of hearing loss).

The hearing loss degree is assessed in reference to the audiometric threshold determined by air conduction (AC) at different frequencies; this parameter expresses the impact of hearing loss on the patient's life.

The impact of hearing loss on the quality of life of the patient is related to hearing threshold, considering normal values within 20 dB. In this regard, the WHO divides the extent of hearing deficit into the following levels:

- mild: between 20 and 35 dB
- moderate: between 35 and 50 dB
- moderately severe: between 50 and 65 dB
- severe: between 65 and 80 dB
- profound: between 80 and 95 dB
- complete: greater than 95 dB.

The bone-conducted threshold (BC) describes the functional state of the inner ear while the difference between the AC and BC thresholds, defined as air-bone gap, expresses the extent of the functional defect in the transmission of sound due to suffering of the external-middle ear system. The definition of the air-bone gap is fundamental because it allows to define the extent of the possible improvement of the audiometric threshold after surgery.

Since the audiometric test is performed on a wide range of frequencies, one must ask on which of them the evaluation should be performed and whether it should refer to single frequencies or to the average of multiple frequencies.

The range of frequencies examined by the audiometric test is between 125/250 and 8000 Hz. However, the evaluation performed on all frequencies taken individually appears very complex because a large number of values is obtained and data are often not easy to be interpretated.

The most relevant element of the frequency-by-frequency evaluation on the basis of the air-bone gap is the location of the deficit at the various frequencies; since in presence of rigidity of the transmission system the deficit is more accentuated at low frequencies in otosclerosis there will be a more significant deficit in this part of the tonal range while in case of presence of hypertrophic lesions (granulations) the transmission deficit will be at all the frequencies or mainly at the higher ones (Ayerbe et al., 1999).

The most commonly method to define the extent of the hearing deficit, applicable to AC, BC and air-bone gap, is to consider an

average value on multiple frequencies. This technique allows to obtain an average value that expresses with a single number the functional situation. In this evaluation the frequencies considered are limited to the most central ones. In the larger number of papers, the mean value among 0.5-1-2-4 kHz is taken into consideration (Albera et al., 2022) while in Menière's disease the average of 0.5-1-2-3 kHz was proposed in relation to the fact that in this pathology the deficit secondary to hydrops is mainly located on the low tones, which therefore appear more relevant in the evaluation of the progression of the disease (Committee on Hearing and Equilibrium).

The evaluation on a frequency range between 500 and 4000 Hz allows to define both the transmission component, usually more accentuated on the low tones, and the disability resulting from hearing loss, for which the frequency of 4 kHz is also important.

If the interest of the Authors is the possible post-surgical cochlear suffering, the use of the average value at high frequencies (4-6-8 kHz) could also be evaluated (Committee on Hearing and Equilibrium).

The audiometric evaluation is performed in the pre-operative phase for diagnostic purposes and to indicate the intervention and in the post-operative phase to evaluate the result.

In the preoperative phase, the correct diagnosis must be reached not only by means of PTA but also anamnesis, otoscopy, vocal audiometry, impedance analysis, imaging and eventually other tests.

Once the diagnosis has been made, thanks to PTA it is possible to define the surgical indication. In fact it appears essential to define the hearing loss level and the amount of the deficit that can be corrected surgically.

To better understand these aspects, we will refer to two specific pathologies of the middle ear for which the surgical indication is predominantly functional, therefore based on PTA informations: tympanic perforation and otosclerosis. It was decided not to consider cholesteatoma as it is a pathology at risk of complications and the functional indication appears often secondary to the need to solve the inflammatory problem.

From an instrumental point of view, the pre-surgical evaluation must be supported by the evaluation of AC, BA and air-bone gap. Among these audiometric parameters the one that assumes greater importance for the surgical indication is the air-bone gap. This parameter accurately describes the role of middle ear pathology in the genesis of hearing loss and it is the one that allows us to predict the functional usefulness of the intervention.

In tympanic perforation in the absence of ossicular chain damage, a frequent event in this pathology, the transmission component of the hearing loss generally appears relatively modest (Albera et al., 2015) with an average air-bone gap that rarely exceeds 20 dB and the entity of air-bone gap is correlated with the size and the site of the perforation; the presence of a greater transmission deficit could be an indicator of ossicular chain damage or sclerosis of the tympanic remnants. This assessment is also very important in order to correctly inform the patient about the possible surgical variants to be performed (ossiculoplasty, complete replacement of the eardrum) and the probability of obtaining a good functional result.

The extent of the transmission component in myringoplasty is also fundamental in determining the risk of having a worsening of the post-operative audiometric threshold, a risk that is greater the more modest the air-bone gap. In the absence of recurrent inflammation and of water penetration in the external meatus or on the basis of patient's age, if the air-bone gap appears low, it may be useful to advise against myringoplasty (Albera et al., 2009).

In otosclerosis, whose surgical therapy is exclusively directed to hearing improvement and in the absence of risks of other complications, the audiometric assessment in fundamental in the determination of the disability determined by the hearing deficit and of the possible usefulness of surgical therapy.

As for tympanic perforation, the extent of the disability is assessed on the basis of the AC threshold. The air-bone gap appears to be a fundamental parameter for the surgical indication since in this pathology a reduced air-bone gap correlates with an increased risk of inner ear complications, with possible irreversible worsening of the hearing deficit, due

to a greater probability of mobilization of the stapes footplate (Albera et al., 2022).

Finally, the bone-conducted threshold appears to be fundamental for predicting the possible need, in the case of high threshold values of this parameter, for predicting the necessity of a hearing aid application despite a good surgical outcome; in this case, the prosthesis will be more effective thanks to the improvement of the AC threshold resulting from the reduction of the air-bone gap.

The post-operative audiometric evaluation must be performed quickly after surgery in case of doubt of cochlear impairment (presence of vertigo, very intense tinnitus or significant hearing deterioration). Conversely, the definitive evaluation of the outcome of the surgery should be performed when the situation can be considered stabilized; in myringoplasty, the definitive functional result can be evaluated when the inflammation of the drum has resolved, generally 1-6 months later in relation to the type of surgery performed (partial or total eardrum reconstruction); in stapes surgery the definitive result is achieved much more quickly than in myringoplasty, generally after one month, although with the teflon prosthesis the time necessary for the best adhesion to the incus could be longer, up to 3 months (Albera et al., 2022).

Even in post-surgical control, the evaluation of the outcome must be based on the evaluation of the AC, BC and air bone gap, both as an absolute value and as a comparison between the pre and post-operative situation.

The evaluation of the AC threshold is the one that best correlates with the patient's satisfaction. The evaluation of the BC threshold informs us about the functional state of the cochlea after surgery; in the large majority of cases BC threshold remains stable after surgery but its worsening, usually irreversible, is the principal risk in otosclerosis surgery. The air-bone gap is the parameter that better expresses the functional correction of the transmission system; it is therefore the most important parameter for defining the outcome of surgery. In presence of an improvement in the AC threshold, especially if significant, a stability of the bone-conducted threshold and a reduction of the air-bone gap are normally associated.

Conversely, in the presence of a lack of improvement or worsening of the AC threshold, in order to understand where the problem is located, it is necessary to evaluate the BC threshold and the air-bone gap, values that allow us to define whether the persistence of the hearing deficit is due to a defect in the transmission of sound, offering us a possibility of remediation through a second surgical look, or to cochlear suffering, prognostically more difficult to be cured.

In the case of post-surgical evaluation, even in the presence of a good functional result, the evaluation of the BC threshold at 3 and 4 kHz, and of the AC threshold at 6 and 8 kHz (frequencies not evaluated by means of bone stimulation) appears extremely important to search for any, and often modest, cochlear suffering at high frequencies, deficit often not perceived by patients (Albera et al., 2022).

Finally, in the case of otosclerosis surgery, it is possible to find an improvement of BC threshold at 2 kHz, resulting from an improvement in the fluid dynamics of the inner ear obtained thanks to the normalization of ossicular mobility.

In conclusion the auditory function evaluation between pre and post operative condition by means of PTA is still the best test to allow the outcome. The numeric data consent a clear and easy statistic evaluation of threshold modifications after surgery, evaluation always based on AC, BC and air bone gap; in this approach the following strategies can be followed if applied to casuistries:

- comparison of pre and post-operative threshold values each of the frequencies examined and statistical analysis of the differences by means of Student's t test for paired data;
- comparison of mean pre and post-operative threshold values at 0,5-4 kHz and statistical analysis of the differences by means of Student's t test for paired data;
- graphic representation of data by means of histograms;
- number and rates of cases who show improvement, no modification or worsening of threshold and statistical analysis by means of chi-square test (Albera et al., 2001);

- number and rates of cases on the basis of hearing threshold grouped in relation to its value (i.e. 0-10 dB, 11-20 dB and so on) (Albera et al., 2001);
- cumulative rates.

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