Common errors in Audiological measurements related to Hearing Aid fitting

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Abstract

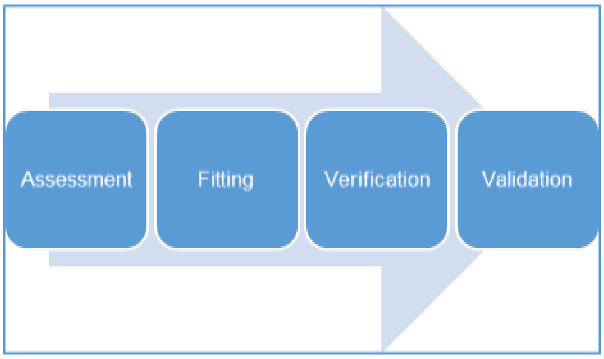
The Hearing Aid Fitting procedure contains a series of measurements during the Assessment and Verification steps. In order to validate the outcomes of the Hearing Instrument Fitting and to increase the level of confidence of the responsible Audiologist or Hearing Aid Professional the aforementioned phases have to be performed under a 'high accuracy' perspective. Corrections, conversions and calculations on different aspects of the sound signal as well as psychophysical, psychometric and Human Dynamics are in course of the study of the Hearing Instrument Fitting where complex audiometric diagnostic testing and electroacoustic measurements are implemented. The status of the instrumentation, the application of the accessories (transducers, microphones, etc.) and the condition of the examined individual can influence dramatically the results of hearing amplification. Several studies have examined the potential errors of these phases as separate entities but very few have targeted the overall procedure. The goal of this study is to bring in the foreground the possible errors in all stages of the Hearing Instrument Fitting procedure and raise awareness of those important factors that can influence the outcomes of fitting in terms of hearing amplification benefits and user satisfaction.

Keywords: Common Errors, Hearing Amplification, Assessment, Fitting, Verification, Validation

Introduction

Hearing Amplification via the natural orifice involves hearing aids, personal sound amplifiers and other similar technologies where the stages of assessment, fitting, verification and validation (picture 1) are the standard steps according to most of the clinicians (American Academy of Audiology 2006) (Valente, et al. 1998). In every of the above steps there are critical measurements which has to be done under Best Practice methodology to reliably lead in patient satisfaction through Hearing Amplification. Best Practice is established by Evidence Base approach which is the new tendency in Hearing Aid Fitting. An approach which does not reflect the values of the expert and standard styles to care, but gives priority to the results of original clinical research that actually measures treatment success on patients in the real world (R. Cox 2005).

Hearing aid fitting in Greece started almost 70 years ago. At the early stages, the fitting process was offered by companies trading different consumer or non-consumer products. Now according to the Greek Acousticians Society there are more than 130 dedicated retail shops fitting Hearing Aids with more than 200 Acousticians offering their services. The Acoustician or Hearing Aid practitioner's profession is not licensed in Greece and can be administered by any individual.



Picture 1 Hearing Aid Fitting Process

Method

In order to answer the question ''which are the common errors in Audiological measurements related to hearing aid fitting'', we asked 10 Greek experienced hearing aid practitioners to note the most important errors in the Best Practice fitting process of assessment, fitting, verification and validation according to their opinion. The professionals were chosen randomly. In order to avoid any biasing the question was administered straightforward without any comments other than the description of the four steps of the fitting process (Assessment, Fitting, Verification and Validation) by the staff of the study to the professionals in face to face interview type discussion.

Results

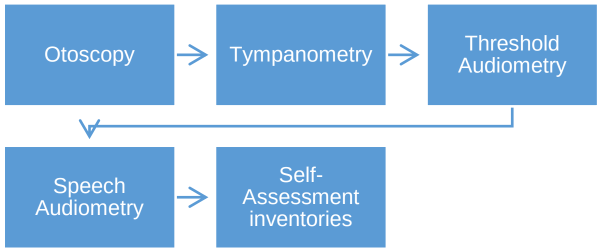
The Hearing Instrument practitioners noted 10 different causes of error in Audiological measurements related to hearing aid fitting process. The most popular cause of errors according to their opinion is the presence and management of cerumen in the ear canal. The second and third cause is audiometer calibration and air-bone gaps in threshold audiometry assessment. Different other causes were noted with seven out of ten practitioners not performing both Verification and Validation procedures at all.

PRACTITIONER	ERROR NOTED	
ACOUSTICIAN 1	Cerumen	Ambient noise
	Listener's cooperation	No verification - No validation
ACOUSTICIAN 2	Cerumen	Air-Bone Gaps
	Audiometer calibration	No verification - No validation
ACOUSTICIAN 3	Air-Bone Gaps	Listener's cooperation
	Cerumen	No verification - No validation
ACOUSTICIAN 4	Cerumen	Audiometer calibration
		Verification complexity
ACOUSTICIAN 5	Cerumen	No verification - No validation
	Live voice speech reliability	Audiometer calibration
ACOUSTICIAN 6	Air-Bone Gaps	Ambient noise
	Earphones placement	No verification - No validation
ACOUSTICIAN 7	Cerumen	Audiometer calibration
	Probe tube placement	Verification complexity
ACOUSTICIAN 8	Cerumen	Earphones placement
	Audiometer calibration	No verification - No validation
ACOUSTICIAN 9	Cerumen	Ambient noise
		No verification - No validation
ACOUSTICIAN 10	Air-Bone Gaps	Listener's cooperation
	Cerumen	Earphones placement
	Probe tube placement	Verification complexity

Taking into consideration the above realities, we studied the errors noted by the practitioners in detail for further discussion.

Assessment

The Assessment step includes all measurements needed for evaluation of the hearing function. Otoscopy, Tympanometry with reflex testing, Threshold Audiometry, Speech Audiometry, Otoacoustic emissions, pre-fitting supra threshold testing and Self-Assessment inventories complements the objective findings (picture 2). Can address as well Psychophysical (Summers, et al. 2003) and Psychometric (Crocker 2007) instrument tools in order to evaluate pre fitting and post fitting considerations on the hearing difficulty, communication needs and general candidacy in Hearing Amplification.



Picture 2. Basic steps of Hearing Assessment

Otoscopy

During the Audiological evaluation, in most cases, we follow the natural way of the traveling sound: Auricle – External Auditory Canal – Tympanic Membrane. The path, should always be open and clean. According to the Otolaryngology–Head and Neck Surgery Foundation in January's 2017 issue of Otolaryngology - Head and Neck Surgery updated practice guideline on evidence-based recommendations on diagnosis and treatment of earwax (cerumen impaction), excessive or impacted cerumen is present in 1 in 10 children, 1 in 20 adults, and more than one-third of the geriatric and developmentally delayed populations (American Academy of Otolaryngology — Head and Neck Surgery 2017). The wax is build up from cerumen, dead cells, sweat and is more common in elderly people and those who use Hearing Aids. According to Hydri et al. (Hydri and Siddiqui 2016), in a quasi-experimental double blind study the mean hearing loss in different grades of occlusion from wax varies from 8,7 – 9,5 ± 5,3 dB HL with maximum the 35 dB HL! It is of common sense that the inspection of the sound path should be the first step in every case we will proceed to an auditory evaluation. Searching for relevant articles in PubMed with the search terms ''common errors in otoscopy'' two search results were found not related to hearing aid fitting.

Tympanometry

In several guidelines of Hearing Aid Fitting (American Academy of Audiology 2006), (American Speech-Language-Hearing Association, the Department of Veterans Affairs, and the American Academy of Audiology 1999) in the Auditory Assessment and Diagnosis protocols, Tympanometry is a standard procedure in the auditory evaluation. Although is performed if there is abnormal appearance of the outer ear and/or the eardrum. In such case the patient should be referred to an ENT doctor or Audiologist for further evaluation (British Academy of Audiology 2016). Tympanometry and Reflex test errors are not in the scope of this paper but if the reader would like to enter in depth of this particular issue a well-defined presentation can be found in the AudiologyOnLine.com series of continue education videos under the title ''Common Errors in Aural Immittance Measurement: Tympanometry and Acoustic Reflexes by James W. Hall III, Ph.D. (Hall III 2017).

Threshold Audiometry

The next step has to do with the ear-specific and frequency-specific threshold estimates for air and bone conduction. The pure tone threshold audiometry is the standard procedure used for the prescription and fitting of hearing instruments. In this step, several errors can occurred from the user and from the equipment used. According to ISO 8253-1 second edition 2010-11-01 on Acoustics – Audiometric test methods, several aspects on Audiometric measurement are exhibited where common errors are very often claimed in research papers and scientific presentations (Champlin and Letowski 2014), (Franks 1998).

Not always, but in several cases, hearing aid fitting and audiometry assessment is conducted in a Hearing Instrument retail store or in a busy clinic where computers, VAC systems intermittent voices etc. are not providing a noise free condition and undoubtedly a situation not compliant with the ISO standard. Ambient SPL levels shall not mask the test tones used for the threshold estimation. We have to consider that for bone conduction audiometry for hearing threshold level measurements down to 0 dB the minimum acceptable environmental noise should be down to 8 dBA for the frequency of

500 Hz and 2 dBA for the frequency of 4000 Hz! For air conduction audiometry the corresponding values are 18 dBA for the frequency of 500 Hz and 36 dBA for the frequency of 4000 Hz. These values can be met, in most cases, where the assessment is done in a sound treated audiology booth or in a quiet room so long as the background noise is sufficiently controlled (Margolis and Madsen 2015).

In order to avoid minor errors of measuring the hearing acuity, the specialist it's better to use insert earphones which are offering additional attenuation compared to the supra-aural or circum-aural headphones (Killion 1985), better positioning to the ear (Paquier, Koehl and Jantzem 2012), headband tension free and improved performance in collapsing ear canals (Munro and Agnew 2009) (Barlow, et al. 2014). In our searching for relevant articles in PubMed with the search terms ''common errors in threshold audiometry'', four search results were found but only one related to hearing aid fitting. The results from the study of Schow RL and Goldbaum DE on collapsed ear canals found an overestimate hearing loss by 2-8 dB when collapsing ear canals are not considered (Schow and Goldbaum 1980).

It is noteworthy to mention that every type of headphone has different calibration related to the audiometric zero (0) expressed in dB HL. In the ISO 389 the Reference Equivalent Threshold Sound Pressure Level – RETSPL values are presented for all relevant headphones. In this respect, the headphones output of the Audiometer is calibrated to a certain type of headphones (Telephonics TDH series, 39, 49, 50, Etymotic EAR – 3A, etc.). It's a common error for the practitioner to unplug one type of earphone and plug in another. In some Hi-End Audiometers there are different outputs for different types of headphones to simplify this process.

In Hearing Aid Fitting process the type of headphones used for the assessment is also important for the verification procedures with Probe Microphone Measurement techniques. The target for the rational in use (DSL, NAL), is set by the threshold audiogram performed. Is self-evident that if the audiogram is wrong, the following procedures will be wrong as well. HL thresholds on the Audiogram are defined by the average data of otologically normal adult subjects. The SPL applied to the eardrum of an adult individual for a 65dBHL signal on the audiometer, is very different from the SPL applied to a baby's or child's eardrum. Even in adults, the 65dBHL of the audiometer screen (value) expressed in dBSPL in the eardrum it can be dramatically different from ear to ear because of different anatomical volumes. According to several studies (Wiley, et al. 1996) the Ear Canal Volume – ECV in adults can varies from 0,8 cc - 2,3 cc which has a big effect in HL Thresholds. A way to avoid this problem without calibrating the audiometer for each individual patient or perform a Real Ear to Dial Difference – REDD, is to convert dB HL thresholds to dB SPL at the eardrum with a Rael Ear to Coupler Difference - RECD technique.

Audiometers must be calibrated in order to produce reliable results. They have to be in accordance to the national standards and be calibrated in agreement with the relevant part of ISO 389 and complies with the requirements of IEC 60645-1. Apart of the routine check described in ISO 8253-1 second edition 2010-11-01 on Acoustics – Audiometric test methods, there are pitfalls, not described in routine checks, producing common errors related to the hearing assessment procedure linked to hearing aid fitting. An important concern is coming from the fact that the ISO specifications do not currently require accreditation in the calibration process. In this regard, every entity can provide calibration services without any certification. This lack of standardization has the potential for errors in the accuracy of the testing systems. The above issue can be more important where calibration procedures are done outside of the laboratory conditions. Another potential error may occur from the fact that in IEC 60645-1 (2012) an audiometer should work at range of atmospheric pressure between 98 kPa to 104 kPa, or in other words not in an altitude higher than 290 m. The variances in diverse altitudes could be as high as 3 dB SPL and a correction factor have to be implemented in order to have the proper calibration (Soares, Brasil and Fontes 2016).

Audiometry procedures used for the Hearing Aid Fitting are subjective and are related to listener's cooperation and general wellness, response procedure and users skills. Idiosyncratic effects and Psychophysical parameters have to be taken into account. Thresholds obtained using different psychophysical procedures for the same sound stimulus may differ by 5 dB or more (Hesse 1986). A reliability note (as an example: Poor, Fair, Good) should be included in every procedure so upon a reviewing of any study, the scientist in charge, has to take into account. We should not forget that in pure tone audiometry, threshold is the point at which a pure tone can just be heard 50%, half, of the time. The person who will perform the audiometry techniques has to be qualified, experienced and well trained. To achieve the best results possible has to instruct the patient well. The instructions has to be clear and brief, letting the patient know what to expect and how to respond. Due to the fact that most of the patients looking for hearing amplification solutions are elderly and have a hearing handicap, it is often useful to use gestures. If the instructions are not clear, false-positive or false-negative results can originate.

Masking techniques used very often in Audiometry and are necessary for establish a concrete threshold for air and bone procedures (DeRuiter and Ramachandran 2016), (M. Valente 2011). Under-masking or over-masking is one the most common errors in hearing assessment (Coles and Priede 1970). Masking is considered as the lower sound threshold made through the introduction of a noise to avoid contralateral hearing. It is used in tone, bone and speech audiometry and is adapted according to the question has to be answered. Maybe one of the most detailed and straightforward guide for masking is described in British Society of Audiology guide ''Recommended Procedure Pure-tone air-conduction and bone-conduction threshold audiometry with and without masking Date: 9th September 2011 Minor amendments: 6th February 2012''. Masking errors are very usual in establishing the air-bone gap which influence the hearing aid fitting rational. DSL adjusts the targets for conductive hearing loss by increasing predicted UCL values by 25% of the air-bone gap. This will result in a small increase of the target amplification. For a maximal air-bone gap, the correction adds 5 to 9 dB of gain and output to the aided speech targets, depending upon the hearing level (Scollie 2007). NAL-NL1 and NAL-NL2 applies the sensorineural loss formula to the sensorineural part of the loss (that is, that part reflected in the bone conduction thresholds) and then adds gain equal to 75% of the conductive part of the loss (Johnson 2013).

1.1.4 Speech Audiometry

Speech Audiometry is related to the speech recognition seeking every patient who is candidate for hearing aid fitting. Speech testing is existing since the very beginning of Audiology history as part of the hearing aid selection and fitting process (Carhart 1951). Speech Detection Threshold – SDT, Speech Recognition Threshold – SRT and Word Recognition Score – WRS in quiet and in noise are the most common speech tests. In order to reduce speaker variability, speaker loudness calibration issues, articulation errors and inaccuracies, the recommended standard of practice is to use recorded stimuli and not live voice testing (Mendel and Owen 2011). They are extensively used in English speaking countries, although there is no convincing review supporting or not supporting the use of speech audiometry as a predictor of a successful fitting (Taylor, Predicting Real World Hearing Aid Benefit with Speech Audiometry: An Evidence-Based Review. 2007). It is important to note that speech tests are done in a laboratory environment which does applies into real life conditions. A common error in Hearing Aid fitting procedure is coming from the fact that there are several logics like verification, validation, patient satisfaction or objective patient benefit in speech discrimination where they are producing results not necessary related to each other or even controversial. In other words we may achieve patient satisfaction without following a verification procedure, or we may have measure a positive patient benefit in speech discrimination in the laboratory but with negative validation outcome in a self-report measure (Williams, Johnson and Danhauer 2009). This can be happen with Speech Audiometry measurements. They can give important information to the practitioner but seems that there is not a significant correlation between self-reported satisfaction with hearing aids and pre-fitting speech measures (Killion and Gudmundsen 2005).

Fitting – Verification

Fitting and Verification stages includes the behavioral assessment and the electroacoustic measurements in the ear canal. In most cases we are considering these phases as a one-step procedure reflecting the tendency of the majority of the practitioners who are performing the Hearing Instrument fitting (Bentler, Mueller and Ricketts 2016). The behavior of people seeking for a solution in their hearing difficulties is challenging to be explained (R. Cox 2005) (Cox, Alexander and Gray, Who wants a hearing aid? Personality profiles of hearing aid seekers. 2005). Apart of a solution in their communication strain, cosmetic, physical comfort, cost - value, social pressure considerations have to be taken into account for a successful fitting (Blood 1997) (McCormack and Fortnum 2013). Several studies have been shown that Verification with Probe Microphone Measurements – PMM has the best results in audibility objective and patient satisfaction (Mueller 2005) (Taylor and Mueller 2016) (Jorgensen 2016). The NAL or DSL fitting rule on the HI software does not premise that the SPL results in the eardrum will be according to the prescriptive method. In (Sanders, et al. 2015), (Aazh H, et al. 2012) was clearly demonstrated that even when a manufacturer states that the DSL or NAL prescriptions have been implemented in their software, differences in the eardrum were still seen. And these differences can be more important when we are fitting babies or pediatric population. The most common error in this respect is that not all practitioners fitting hearing aids are following Best Practices, where PMM is an effective and evidence base procedure. According to (Kochkin 2011) only a small percentage of Hearing Healthcare Professionals in USA are using PMM for verification, in tune with our results from the Greek market. During the Verification procedure several actions and calculations are applied by the instruments in use. The practical application of this logic has several key elements where common errors occur. One of the objectives arisen from our research is probe tube placement. Real Ear Measurement is performed introducing a probe tube within 6 mm of the eardrum and 2 mm (Dillon and Storey 2001). An accurate placement of the probe tube is essential for accurate PMM measurements (Mueller, Hawkins and Northern 1992). A shallow probe tube placement can distort significantly the results of Real Ear Measurements procedures. This is happening because of the standing waves in the ear canal. The easiest way to ensure that the probe tube stays in place, is to monitor the output in the range above 6000 Hz where no notch is present. Also the practitioner has to take into account other factors like cerumen, ambient noise or anything else obstructs the sound access to the ear. Verification procedures in Real Ear or in Coupler are essential to the Hearing Aid fitting process, although objective measures do not assure patient satisfaction (Williams 2009).

Validation

Validation of Hearing Amplification intervention is a way to document patient's benefit or/and satisfaction after the Hearing Instrument fitting. In other words the practitioner has to determine with measurements in the laboratory what is the aided minus unaided performance, a relatively objective dimension, and satisfaction of the hearing amplification solution in real life conditions, a relatively subjective dimension (Ricketts, Bentler and Mueller 2018). Objective measurements are easily to be administered and comprehended but are restricted to a laboratory condition. Subjective measurements usually are made of selfreports targeting the domains of : use time, sound quality, loudness equalization, listening effort, speech understanding, quality of life, social interaction, reduced burden for the significant other etc.. Self-report methodology is the preferred technique of evaluation of the Hearing Instrument fitting because represents the outcomes in real life conditions (Mendel 2009). Several self-report questionaries' have been developed in English language but none is developed or translated in Greek language, so it is of noteworthy to say that in our research, Greek practitioners are not following any other procedure than the standard informal discussion between the patient and the professional related to the hearing amplification benefit. This kind of ''validation procedure'' is more a rehabilitative approach, has several pitfalls and definitely cannot be validated with norms.

Conclusion

In this study we examined the common errors in Audiological measurements related to Hearing Aid fitting from ten randomly chosen hearing aid Greek practitioners. The dominant cause of error according to their opinion is Cerumen presence which has to be administered before the practitioner proceed with any measurement. Other errors influencing the hearing aid fitting are audiometer calibration, ambient noise, air-bone gaps in threshold audiometry, listener's cooperation, earphones placement and live voice speech reliability. From the two practitioners who are using PMM in their fitting process, errors can generated from probe tube placement and verification complexity. The most important error revealed from the study though is that Verification procedures with PMM are not implemented in the battery of hearing aid fitting in Greece. This fact has to be taken into account from the Hearing Aid Acousticians Association as well as to proceed with the development or translation of well-designed self-report questionaries' for Validation of the Hearing Amplification techniques.

Hearing Aid Fitting in Greece is not driven by Best Practices as are described in literature. Although more than 16.000 Hearing Aids (Greek Acousticians Society est.) are fitted every year in Greece from more than 200 practitioners. These practitioners are facing less Audiological reliability pressure but the gravity of patient satisfaction object is the same all over the world.

Abbreviations:

PMM: Probe Microphone Measurements
NAL: National Acoustics Laboratory
DSL: Desired Sensation Level

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