Recent Trends in Audiology: A Review

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Abstract: ***Audiology the science of Hearing is developing in a rapid pace. The Clinician and Audiologist have a number of modern Audiological tools at their service for easy diagnosis of Ear problems. This Article summarizes some of the relevant developments which will be useful for the Clinician and Scientist. Discussed topics include Otoreflectance Audiometry, Multi Frequency Tympanometry, Fast Spin Echo MRI, Cochlear Hydrops Analysis Masking Procedure and Vestibular Evoked Myogenic Potential***

Keywords: Audiology, Otology, Audiometry, CHAMP, VEMP

1. Introduction

The science of Audiology has progressed leaps and bounds in last few years. The objective of compilation is to introduce and sensitize the Clinicians, Scientists, Audiologists, and Post graduate students of Medicine and E.N.T surgery, the forthcoming and novel diagnostic modalities for detection and quantification of hearing impairment.

This compilation is by no means complete, those topics have chosen, which are believed to be the most useful very recent developments, (not given in textbooks) and put them together in one paper in simple words, for ease of quick perusal.

2. Otoreflectance Audiometry [1]

By Using Classical Impedance Audiometry we indirectly measure the Middle ear Compliance or Impedance using the following formula:

(Impedance) Compliance of Middle ear= Total Compliance - External Auditory canal Compliance.

There is no subtraction in Otoreflectance Audiometry hence it is useful in quick and accurate assessment of Middle and Inner ear status. It uses Acoustic pressure measurement in ear canal using a probe in frequency or time domain over a range of two or more stimulus.

In Otoreflectance Audiometry we simultaneously detect the Middle ear and Inner ear status. Linear Otoreflectance helps us in status of Middle ear. Non linear Otoreflectance uses diffuse High and Low excitation. Non Linear Otoreflectance determines the status of Inner ear. (Ref 1)

3. Multiple/ Multi Frequency Tympanometry [2]

Multi Frequency Tympanometry is essentially same as standard Tympanometry, the only difference is that it uses wide range of frequency that just 255 Hz for "Probe tone frequency" as in Standard Tympanometry. It is claimed to be more sensitive to Middle ear status/ disease in new born and Infants in whom a 225 Hz probe is said to produce erroneous results. Computer Software for analysis of MFT data are now under development.

4. Brain Stem Evoked Response Audiometry (BERA) [3]

Brain Stem Evoked Response Audiometry (BERA) or Auditory Brainstem Evoked Potentials (ABEP); is the measurement of the electrical activity of the Brain stem nucleus and complexes, in response to a sound. A wide band click is used to stimulate all the neural channels of cochlea. As a sound signal travels through the Brain stem and various nucleuses, it generates various waves in the tracing. Changes in the electrical activity of the brain in response to sound stimuli are called "Auditory Evoked Potentials". "Latency" of a wave refers to the time gap between giving the stimulus (Click or Tone burst) and recording of that wave. BERA is recording of the electrical waves currents for the first 10 milliseconds (1/1000 seconds) after stimulus, is called Short Latency Response. (S.L.R). [4]

Table 1: Generators of Waves in BERA) [3]

Wave Number	*Currently Understood Site Of Production*
I	Cochlea
II	Proximal auditory (hearing) nerve end activity
III	Superior olivary complex-Lower pons (Mid brain)
IV and V complex	Lateral lemniscus- Upper pons and junction of midbrain.

4.1 Type and Site of Hearing Loss Objectively Diagnosed [4, 6]

Type of hearing loss and site of lesion can also be detected by specific pattern in BERA. In Conductive hearing loss the Latency is shifted to right by an amount proportional to amount of Conductive hearing loss. In Cochlear High frequency Sensorineural hearing loss the wave V latency is elevated above the threshold of hearing. Retro-cochlear lesions manifest as prolonged Wave V latency and prolonged Inter-wave latency (I to V, I to III, or III to V). But, ABEP waves are normal in low frequency hearing losses.

4.2 Advantages and Disadvantages of BERA [3, 4, 5]

The main advantage of BERA is that it can used to detect hearing ability in newborn, persons in Coma, unconscious persons and Psychiatric patients. It can be used for Medico-

legal cases also, for instance in person claiming deafness for compensation. BERA does not give any frequency specific information. So an additional test called **Auditory Steady State Response ASSR** has been developed. ASSR provides frequency specific information on hearing ability and has all the advantages of BERA. ASSR uses an electrical voltage form called "40Hertz Steady state potential", which can be recorded as a continuous sinusoidal wave from, produced when person is provided sound 10-12dB sound above his hearing threshold. ASSR is recorded just like BERA but gives us more information on hearing defect.

5. Otoacoustic Emissions [3, 7, 8]

Organ of Corti is responsible for conversion of Sound into electrical impulses which are then fed into Brain, creating the sense of hearing. A remarkable property of the Organ of Corti is that it can also produce sound called Oto Acostic Emissions. OAE can be random and spontaneous or they can be in response to a sound, like an echo. Such an echo has been called "Cochlear or Kemp's Echo". Otoacoustic emission is the recording of this sound by a very sensitive microphone. The sound is produced by the Outer hair cells of Organ of Corti.

Presence of OAE indicates that the Organ of Corti is functioning normally. Absence of OAE may be due to noise in background, or simply, that it may be too faint for the microphone to detect or may reflect abnormality of Organ of Corti. Like BERA, patient's cooperation is not needed Portable and battery operated OAE machines are now available. These are now being used to check hearing of newborn children in peripheral and remote places.
There are three types of OAEs' in use [3]

5.1 Spontaneous OAE= this is spontaneous and random recording of OAE. They are recorded in less than 50% normal population, hence not reliable.

5.2. Transient Evoked OAE= TOAE is recorded when the ear is stimulated by a click or Tone burst sound. These are used in screening newborn children. TOAE does not provide any information on hearing threshold and frequency.

5.3. Distortion Product OAE= This method uses geometric mean of OAE Echo produced in response to two separate sounds. DPOAE gives frequency and threshold specific information on hearing ability of the child.

6. Screening for Vestibular Schwannoma

Two complimentary tests are developed recently for screening for Vestibular Schwannoma.

6.1 Fast Spin Echo (FSE) [9, 10]

Fast Spin Echo (FSE) technique is a recent advance in the imaging of vestibular Schwannoma. This uses the interval of time after first echo to receive the echo train. This is done by applying new 180 degree pulses to obtain a spin echo train. Within the lipid molecules, a spin- spin coupling occurs. FSE by rapid pulse disrupts this coupling of molecules and causes T2 weighed image to lengthen. Thus fat appears as higher signal in FSE than in standard echo. Vestibular Schwannoma appear hypo intense compared to CSF on T2-weighted FSE sequences. Intracanalicular tumor appears as a filling defect in the internal auditory canal. This can be rapidly done and does not need a gadolinium contrast. Further Contrast study may be needed only to confirm suspected tumors. FSE is very fast and is less affected by presence of external magnetic fields.

6.2 DIET – Delay Interval Echo Train [9, 10]

DIET sequence is used in FSE sequence to compensate the effect of fat on FSE images. In DIET FSE, Fat appears iso-intense and not bright as in FSE.

6.3 Stacked ABR Technique (Don's Test) [11]

In doing a Standard Auditory Brainstem Response a Wide band Click is used to elicit the amplitude of Electrical activity in the auditory pathway. A wide band click stimulates all the frequency region of cochlea. This signal is extracted by time locking phenomenon of the Electrical activity against electrical noise / interfering signal. "Time locking" phenomenon refer to the Electrical Action potential which occurs at a fixed time interval after the click, while noise can occur at any time. A Standard ABR thus measures only high frequency (fibers) responses of the pathway.

First, a standard BERA is taken and is a part of Stacked ABR/ BERA. Derived banding follows.

6.4 Derived Banding and Stacking [11, 12]

Stacking is the process of frequency wise isolation of neural responses recorded in BERA. Stacking is possible because the Cochlear nerve fibers are arranged in frequency wise bundles. This is called "Tonotopic" arrangement of the fibers of Cochlea nerve. (Greek Tono=sound, Topos= place).

Five different high frequency responses to obtain five Derived-band ABRs that reflect the neural contributions from five different frequency regions of the cochlea. This process is called Derived-band ABR Technique. The Stacking is done by first aligning wave V of the derived-band on time basis, then adding the amplitude of responses. This represents all the frequencies of cochlear. Any reduction in total amplitude is an indicator of pathology in that nerve fiber i.e. Non Conduction in that fiber leading to reduced total amplitude. The Stacked ABR has better sensitivity and specificity than the standard ABR for small size (< 1 cm) tumors. This technique can be used for screening for Vestibular Schwannoma. A Standard ABR / BERA are a part and parcel of Stacked ABR / BERA. So no separate BERA needs be ordered is an added advantage for the patients.

7. CHAMP - Cochlear Hydrops Analysis Masking Procedure (CHAMP) [12]

CHAMP is new investigation, in addition to standard Electrocochleography (ECochG) used to make a diagnosis of

Meniere's disease. A Summating Potential to Compound Action Potential ratio (SP/CAP Ratio) of more than 0.45 is considered diagnostic of Meniere's disease in Electrocochleogram. The result of ECochG is variable especially with the Ear Canal ECochG electrode placement. Trans-tympanic ECochG electrode is more sensitive but is invasive and may be painful. CHAMP overcomes these disadvantages of ECochG.

7.1 Under-masking – Phenomenon [12, 13]

Endolymphatic hydrops or Meniere's disease alters Basilar Membrane properties by stretching it. This stretched Basilar membrane alters the cochlear processing of auditory stimuli.

Low frequency noise can mask the ability to perceive high frequency sound in normal persons. An ABR/ BERA taken after this will show reduced amplitude of waves, especially the wave V.

In Endolymphatic Hydrops / Meniere's disease, this ability is lost and Low frequency noise cannot fully mask the High frequency sound. This is under masking.

A BERA taken in presence of Low frequency sound will still show BERA / ABR waves in Meniere's disease patient. This is in sense Cochlear Hydrops Analysis Masking Procedure or CHAMP.

8. Laser Stamp -Laser Stapedotomy minus Prosthesis [14]

Laser Stamp is a recent addition to procedures for Otosclerosis. It is a conservative procedure where Fissula ante fenestrum is alone involved. This involves doing an Anterior Crurotomy and partial excision of anterior one third of foot plate alone, the logic being that the Otosclerotic process usually only fixes the anterior one third of Foot plate. Hearing improvement with this technique is comparable as with Piston prosthesis. The specific advantage is that if the rest of the foot plate gets fixed, a full stapedectomy can also be done later. There are no the piston related problems like dislocation, perilymph "gusher etc, in addition refixation rates are also low.

9. High Frequency Audiometry [15]

High frequency Audiometry is nothing but Pure Tone Audiometry at Frequency ranges of 8,000 or 8 KHz and more, typically between 10 to 18 KHZ. Audiometry at this frequency is claimed to offer early and accurate detection of Noise induced and Drug induced Hearing losses in Patients.

10. LASER Doppler Vibrometry [16]

LDV is used to find displacement / velocity of a body. It employs two laser beams. The Doppler shift of the one laser beam to other is used to quantify the velocity of a body. It provides accurate measurement of movement of the body, without touching or loading the body. It is used to find a parameter called "Umbo Velocity" of the Tympanic membrane.

Umbo velocity tells us indirectly about the middle ear status just like a tympanometry i.e. ossicular discontinuity, Ossicular fixation, tympanosclerosis, Malleus head fixation etc. In addition, Umbo velocity can be found quickly and in a non invasive manner.

11. VEMP Vestibular Evoked Myogenic Potential [17, 18]

VEMP or Vestibular Evoked Myogenic Potential is a recent test to evaluate the integrity of Saccule. Saccule is sensitive to sound; it was used as a hearing apparatus in some distant evolutionary past. Saccule responds to linear acceleration but on exposure to sound (via Inferior Vestibular nerve) produces a Myogenic Potential is Sternomastoid muscle which can be picked up. So Saccular portion of the labyrinth can now be tested clinically.

11.1 Pathway for VEMP [19]

Sound→ Saccule →Inferior Vestibular nerve →Lateral Vestibular Nucleus →11th Nerve Nucleus→ Vestibulospinal tract →Sternomastoid Muscle→ Inhibition

The response consists of an initial positivity at 13 milliseconds called p13 followed by a more important, negative wave at 23 milliseconds called n23.The most important measure is the amplitude of the waves.

Low amplitude of n23 or higher threshold may be due to conductive hearing loss. Reduced amplitude indicates vestibular disturbances. Prolonged latency of p13 may be due to central causes. Conductive hearing loss obliterates VEMP; Sensorineural Hearing loss does not affect VEMP.

12. Some themes in Cochlear Implant [19, 20]

12.1 Hybrid Cochlear Implant and Hearing aid [19, 20]

Traditionally Cochlear Implantation is reserved for totally deaf patients with severe-to-profound hearing loss. There are a set of patients who have residual hearing especially at Lower frequency which would become redundant if the patient is implanted. For the benefit of such patients "Hybrid Cochlear Implant" has been developed. It is made up of a short "hybrid" electrode which does not extend into and disturb the apical cochlea, and hence preserves hearing at lower frequency. This type of Implant functions only to amplify High frequency sounds and speech.

12.2 Totally Implantable Cochlear Implant [19, 20]

In a traditional Cochlear Implant Sound is detected by an external microphone and directed to an external sound processor. This external speech processor looks like a Hearing aid which may be cosmetically unacceptable for the patient, especially females. To overcome this set back a Totally Implantable Cochlear Implant has been developed which has Speech Processor incorporated.

13. Conclusion

From dusty headphones and claustrophobic acoustic rooms, Audiology has thus advanced to the level where it is today possible to detect a person's hearing acuity; (with BERA and OAE) without even his or her cooperation. Our ability to diagnose Vestibular Schwannoma has also taken a leap with Stacked ABR and FSE MRI. New CHAMP and VEMP are for assessing the Meniere's disease and Saccule function. Hybrid Cochlear implants for partially deaf and Fully Implantable C.I are for the shy person who does not want to wear a visible speech processor.

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